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Chapter 1. Introduction

This chapter is informative except for the section on Normative Terminology.

This document, referred to as the "OpenXR Specification" or just the "Specification" hereafter, describes OpenXR: what it is, how it acts, and what is required to implement it. We assume that the reader has a basic understanding of computer graphics and the technologies involved in virtual and augmented reality. This means familiarity with the essentials of computer graphics algorithms and terminology, modern GPUs (Graphic Processing Units), tracking technologies, head mounted devices, and input modalities.

The canonical version of the Specification is available in the official OpenXR Registry, located at URL http://www.khronos.org/registry/openxr/

1.1. What is OpenXR?

OpenXR is an API (Application Programming Interface) for XR applications. XR refers to a continuum of real-and-virtual combined environments generated by computers through human-machine interaction and is inclusive of the technologies associated with virtual reality (VR), augmented reality (AR) and mixed reality (MR). OpenXR is the interface between an application and an in-process or out-of-process "XR runtime system", or just "runtime" hereafter. The runtime may handle such functionality as frame composition, peripheral management, and raw tracking information.

Optionally, a runtime may support device layer plugins which allow access to a variety of hardware across a commonly defined interface.

1.2. The Programmer’s View of OpenXR

To the application programmer, OpenXR is a set of functions that interface with a runtime to perform commonly required operations such as accessing controller/peripheral state, getting current and/or predicted tracking positions, and submitting rendered frames.

A typical OpenXR program begins with a call to create an instance which establishes a connection to a runtime. Then a call is made to create a system which selects for use a physical display and a subset of input, tracking, and graphics devices. Subsequently a call is made to create buffers into which the application will render one or more views using the appropriate graphics APIs for the platform. Finally calls are made to create a session and begin the application's XR rendering loop.

1.3. The Implementor’s View of OpenXR

To the runtime implementor, OpenXR is a set of functions that control the operation of the XR system and establishes the lifecycle of a XR application.
The implementor's task is to provide a software library on the host which implements the OpenXR API, while mapping the work for each OpenXR function to the graphics hardware as appropriate for the capabilities of the device.

### 1.4. Our View of OpenXR

We view OpenXR as a mechanism for interacting with VR/AR/MR systems in a platform-agnostic way.

We expect this model to result in a specification that satisfies the needs of both programmers and runtime implementors. It does not, however, necessarily provide a model for implementation. A runtime implementation **must** produce results conforming to those produced by the specified methods, but **may** carry out particular procedures in ways that are more efficient than the one specified.

### 1.5. Filing Bug Reports

Issues with and bug reports on the OpenXR Specification and the API Registry **can** be filed in the Khronos OpenXR GitHub repository, located at URL

[https://github.com/KhronosGroup/OpenXR-Docs](https://github.com/KhronosGroup/OpenXR-Docs)

Please tag issues with appropriate labels, such as “Specification”, “Ref Pages” or “Registry”, to help us triage and assign them appropriately. Unfortunately, GitHub does not currently let users who do not have write access to the repository set GitHub labels on issues. In the meantime, they **can** be added to the title line of the issue set in brackets, e.g. “[Specification]”.

### 1.6. Document Conventions

The OpenXR specification is intended for use by both implementors of the API and application developers seeking to make use of the API, forming a contract between these parties. Specification text may address either party; typically the intended audience can be inferred from context, though some sections are defined to address only one of these parties. (For example, Valid Usage sections only address application developers). Any requirements, prohibitions, recommendations or options defined by normative terminology are imposed only on the audience of that text.

#### 1.6.1. Normative Terminology

The key words **must**, **required**, **should**, **may**, and **optional** in this document, when denoted as above, are to be interpreted as described in RFC 2119:


**must**

When used alone, this word, or the term **required**, means that the definition is an absolute requirement of the specification. When followed by **not** (“must not”), the phrase means that the
definition is an absolute prohibition of the specification.

**should**

When used alone, this word means that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course. When followed by *not* ("**should** not"), the phrase means that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications **should** be understood and the case carefully weighed before implementing any behavior described with this label.

**may**

This word, or the adjective **optional**, means that an item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product while another vendor may omit the same item.

The additional terms **can** and **cannot** are to be interpreted as follows:

**can**

This word means that the particular behavior described is a valid choice for an application, and is never used to refer to runtime behavior.

**cannot**

This word means that the particular behavior described is not achievable by an application, for example, an entry point does not exist.

There is an important distinction between **cannot** and **must not**, as used in this Specification. **Cannot** means something the application literally is unable to express or accomplish through the API, while **must not** means something that the application is capable of expressing through the API, but that the consequences of doing so are undefined and potentially unrecoverable for the runtime.
Chapter 2. Fundamentals

2.1. API Version Numbers and Semantics

Multi-part version numbers are used in several places in the OpenXR API.

typedef uint64_t XrVersion;

In each such use, the API major version number, minor version number, and patch version number are packed into a 64-bit integer, referred to as XrVersion, as follows:

<table>
<thead>
<tr>
<th>Version Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The major version number is a 16-bit integer packed into bits 63-48.</td>
</tr>
<tr>
<td>• The minor version number is a 16-bit integer packed into bits 47-32.</td>
</tr>
<tr>
<td>• The patch version number is a 32-bit integer packed into bits 31-0.</td>
</tr>
</tbody>
</table>

Differences in any of the version numbers indicate a change to the API, with each part of the version number indicating a different scope of change, as follows.

Note

The rules below apply to OpenXR versions 1.0 or later. Prerelease versions of OpenXR may use different rules for versioning.

A difference in patch version numbers indicates that some usually small part of the specification or header has been modified, typically to fix a bug, and may have an impact on the behavior of existing functionality. Differences in the patch version number must affect neither full compatibility nor backwards compatibility between two versions, nor may it add additional interfaces to the API.

A difference in minor version numbers indicates that some amount of new functionality has been added. This will usually include new interfaces in the header, and may also include behavior changes and bug fixes. Functionality may be deprecated in a minor revision, but must not be removed. When a new minor version is introduced, the patch version is reset to 0, and each minor revision maintains its own set of patch versions. Differences in the minor version number should not affect backwards compatibility, but will affect full compatibility.

A difference in major version numbers indicates a large set of changes to the API, potentially including new functionality and header interfaces, behavioral changes, removal of deprecated features, modification or outright replacement of any feature, and is thus very likely to break compatibility.
Differences in the major version number will typically require significant modification to application code in order for it to function properly.

The following table attempts to detail the changes that may occur versus when they must not be updated (indicating the next version number must be updated instead) during an update to any of the major, minor, or patch version numbers:

Table 1. Scenarios Which May Cause a Version Change

<table>
<thead>
<tr>
<th>Reason</th>
<th>Major Version</th>
<th>Minor Version</th>
<th>Patch Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensions Added/Removed*</td>
<td>may</td>
<td>may</td>
<td>may</td>
</tr>
<tr>
<td>Spec-Optional Behavior Changed*</td>
<td>may</td>
<td>may</td>
<td>may</td>
</tr>
<tr>
<td>Spec Required Behavior Changed*</td>
<td>may</td>
<td>may</td>
<td>must not</td>
</tr>
<tr>
<td>Core Interfaces Added*</td>
<td>may</td>
<td>may</td>
<td>must not</td>
</tr>
<tr>
<td>Weak Deprecation*</td>
<td>may</td>
<td>may</td>
<td>must not</td>
</tr>
<tr>
<td>Strong Deprecation*</td>
<td>may</td>
<td>must not</td>
<td>must not</td>
</tr>
<tr>
<td>Core Interfaces Changed/Removed*</td>
<td>may</td>
<td>must not</td>
<td>must not</td>
</tr>
</tbody>
</table>

In the above table, the following identify the various cases in detail:

- **Extensions Added/Removed**
  An extension may be added or removed with a change at this patch level.

- **Specification-Optional Behavior Changed**
  Some optional behavior laid out in this specification has changed. Usually this will involve a change in behavior that is marked with the normatives `should` or `may`. For example, a runtime that previously did not validate a particular use case may now begin validating that use case.

- **Specification-Required Behavior Changed**
  A behavior of runtimes that is required by this specification `may` have changed. For example, a previously optional validation `may` now have become mandatory for runtimes.

- **Core Interfaces Added**
  New interfaces `may` have been added to this specification (and to the OpenXR header file) in revisions at this level.
Weak Deprecation

An interface may have been weakly deprecated at this level. This may happen if there is now a better way to accomplish the same thing. Applications making this call should behave the same as before the deprecation, but following the new path may be more performant, less latent, or otherwise yield better results. It is possible that some runtimes may choose to give run-time warnings that the feature has been weakly deprecated and will likely be strongly deprecated or removed in the future.

Strong Deprecation

An interface may have been strongly deprecated at this level. This means that the interface must still exist (so applications that are compiled against it will still run) but it may now be a no-op, or it may be that its behavior has been significantly changed. It may be that this functionality is no longer necessary, or that its functionality has been subsumed by another call. This should not break an application, but some behavior may be different or unanticipated.

Interfaces Changed/Removed

An interface may have been changed — with different parameters or return types — at this level. An interface or feature may also have been removed entirely. It is almost certain that rebuilding applications will be required.

2.2. String Encoding

This API uses strings as input and output for some functions. Unless otherwise specified, all such strings are NULL terminated UTF-8 encoded case-sensitive character arrays.

2.3. Threading Behavior

The OpenXR API is intended to provide scalable performance when used on multiple host threads. All functions must support being called concurrently from multiple threads, but certain parameters, or components of parameters are defined to be externally synchronized. This means that the caller must guarantee that no more than one thread is using such a parameter at a given time.

More precisely, functions use simple stores to update software structures representing objects. A parameter declared as externally synchronized may have its software structures updated at any time during the host execution of the function. If two functions operate on the same object and at least one of the functions declares the object to be externally synchronized, then the caller must guarantee not only that the functions do not execute simultaneously, but also that the two functions are separated by an appropriate memory barrier if needed.

For all functions which destroy an object handle, the application must externally synchronize the object handle parameter and any child handles.
Externally Synchronized Parameters

- The `instance` parameter, and any child handles, in `xrDestroyInstance`
- The `session` parameter, and any child handles, in `xrDestroySession`
- The `space` parameter, and any child handles, in `xrDestroySpace`
- The `swapchain` parameter, and any child handles, in `xrDestroySwapchain`
- The `actionSet` parameter, and any child handles, in `xrDestroyActionSet`
- The `action` parameter, and any child handles, in `xrDestroyAction`
- The `objectHandle` member of the `nameInfo` parameter in `xrSetDebugUtilsObjectNameEXT`
- The `instance` parameter, and any child handles, in `xrCreateDebugUtilsMessengerEXT`
- The `messenger` parameter in `xrDestroyDebugUtilsMessengerEXT`
- The `anchor` parameter, and any child handles, in `xrDestroySpatialAnchorMSFT`
- The `nodeBinding` parameter, and any child handles, in `xrDestroySpatialGraphNodeBindingMSFT`
- The `handTracker` parameter, and any child handles, in `xrDestroyHandTrackerEXT`
- The `sceneObserver` parameter, and any child handles, in `xrDestroySceneObserverMSFT`
- The `scene` parameter, and any child handles, in `xrDestroySceneMSFT`
- The `facialTracker` parameter, and any child handles, in `xrDestroyFacialTrackerHTC`
- The `profile` parameter, and any child handles, in `xrDestroyFoveationProfileFB`
- The `mesh` parameter, and any child handles, in `xrDestroyTriangleMeshFB`
- The `passthrough` parameter, and any child handles, in `xrDestroyPassthroughFB`
- The `layer` parameter, and any child handles, in `xrDestroyPassthroughLayerFB`
- The `instance` parameter, and any child handles, in `xrDestroyGeometryInstanceFB`
- The `spatialAnchorStore` parameter, and any child handles, in `xrDestroySpatialAnchorStoreConnectionMSFT`
Implicit Externally Synchronized Parameters

- The `session` parameter by any other `xrWaitFrame` call in `xrWaitFrame`
- The `session` parameter by any other `xrBeginFrame` or `xrEndFrame` call in `xrBeginFrame`
- The `session` parameter by any other `xrBeginFrame` or `xrEndFrame` call in `xrEndFrame`
- The `XrInstance` used to create `messenger`, and all of its child handles in `xrDestroyDebugUtilsMessengerEXT`
- The buffers returned from calls to `xrTriangleMeshGetVertexBufferFB` and `xrTriangleMeshGetIndexBufferFB` on `mesh` in `xrDestroyTriangleMeshFB`

2.4. Multiprocessing Behavior

The OpenXR API does not explicitly recognize nor require support for multiple processes using the runtime simultaneously, nor does it prevent a runtime from providing such support.

2.5. Runtime

An OpenXR runtime is software which implements the OpenXR API. There **may** be more than one OpenXR runtime installed on a system, but only one runtime can be active at any given time.

2.6. Extensions

OpenXR is an extensible API that **can** grow through the addition of new features. Similar to other Khronos APIs, extensions **can** be used to expose new OpenXR functions or modify the behavior of existing OpenXR functions. Extensions are optional and therefore **must** be enabled by the application before the extended functionality is made available. Because extensions are optional, they **may** be implemented only on a subset of runtimes, graphics platforms, or operating systems. Therefore, an application **should** first query which extensions are available before enabling.

The application queries the available list of extensions using the `xrEnumerateInstanceExtensionProperties` function. Once an application determines which target extensions are supported, it **can** enable some subset of them during the call to `xrCreateInstance`.

OpenXR extensions have unique names that convey information about what functionality is provided. The names have the following format:
Extension Name Formatting

• The prefix "XR_" to identify this as an OpenXR extension

• A string identifier for the vendor tag, which corresponds to the company or group exposing the extension. The vendor tag must use only uppercase letters and decimal digits. Some examples include:
  ◦ "KHR" for Khronos extensions, supported by multiple vendors.
  ◦ "EXT" for non-Khronos extensions supported by multiple vendors.

• An underscore "_".

• A string uniquely identifying the extension. The string is a compound of substrings which must use only lower case letters and decimal digits. The substrings are delimited with single underscores.

For example: XR_KHR_composition_layer_cube is an OpenXR extension created by the Khronos (KHR) OpenXR Working Group to support cube composition layers.

The public list of available extensions known at the time of this specification being generated appears in the List of Extensions appendix at the end of this document.

2.7. API Layers

OpenXR is designed to be a layered API, which means that a user or application may insert API layers between the application and the runtime implementation. These API layers provide additional functionality by intercepting OpenXR functions from the layer above and then performing different operations than would otherwise be performed without the layer. In the simplest cases, the layer simply calls the next layer down with the same arguments, but a more complex layer may implement API functionality that is not present in the layers or runtime below it. This mechanism is essentially an architected “function shimming” or "intercept" feature that is designed into OpenXR and meant to replace more informal methods of "hooking" API calls.

2.7.1. Examples of API Layers

Validation Layer

The layered API approach employed by OpenXR allows for the expensive validation of correct API usage to be implemented in a "validation" layer. This layer allows the application developer to develop their application with the validation layer active to ensure that the application is using the API correctly. The validation layer confirms that the application has set up object state correctly, has provided the required data for each function, ensures that required resources are available, etc. If the validation layer detects a problem, it issues an error message that can be logged or captured by the application via a callback. After the developer has determined that the application is correct, they turn off the validation layer to allow the application to run in a production environment without repeatedly
incurring the validation expense.

**API Logging Layer**

Another example of an API layer is an API logging layer that simply serializes all the API calls to an output sink in a text format, including printing out argument values and structure contents.

**API Trace Layer**

A related API trace layer produces a trace file that contains all the information provided to the API so that the trace file can be played back by a replay program.

### 2.7.2. Naming API Layers

To organize API layer names and prevent collisions in the API layer name namespace, API layers **must** be named using the following convention:

```
XR_API_LAYER_<VENDOR-TAG>_short_name
```

Vendors are responsible for registering a vendor tag with the OpenXR working group and just like for implementors, they must maintain their vendor namespace.

Example of an API layer name produced by the Acme company for the "check best practices" API layer:

```
XR_API_LAYER_ACME_check_best_practices
```

### 2.7.3. Activating API Layers

**Application Activation**

Applications **can** determine the API layers that are available to them by calling the `xrEnumerateApiLayerProperties` function to obtain a list of available API layers. Applications then **can** select the desired API layers from this list and provide them to the `xrCreateInstance` function when creating an instance.

**System Activation**

Application users or users performing roles such as system integrator or system administrator **may** configure a system to activate API layers without involvement from the applications. These platform-dependent steps **may** include the installation of API layer-related files, setting environment variables, or other platform-specific operations. The options that are available for configuring the API layers in this manner are also dependent on the platform and/or runtime.
2.7.4. API Layer Extensions

API layers **may** implement OpenXR functions that may or may not be supported by the underlying runtime. In order to expose these new features, the API layer must expose this functionality in the form of an OpenXR **extension**. It **must** not expose new OpenXR functions without an associated extension.

For example, an OpenXR API-logging API layer might expose an API function to allow the application to turn logging on for only a portion of its execution. Since new functions **must** be exposed through an extension, the vendor has created an extension called `XR_ACME_logging_on_off` to contain these new functions. The application **should** query if the API layer supports the extension and then, only if it exists, enable both the extension and the API layer by name during `xrCreateInstance`.

To find out what extensions an API layer supports, an application **must** first verify that the API layer exists on the current system by calling `xrEnumerateApiLayerProperties`. After verifying an API layer of interest exists, the application then **should** call `xrEnumerateInstanceExtensionProperties` and provide the API layer name as the first parameter. This will return the list of extensions implemented internally in that API layer.

2.7.5. Type Aliasing

Type aliasing refers to the situation in which the actual type of a element does not match the declared type. Some C and C++ compilers can be configured to assume that the actual type matches the declared type, and may be so configured by default at common optimization levels. Without this, otherwise undefined behavior may occur. This compiler feature is typically referred to as "strict aliasing," and it can usually be enabled or disabled via compiler options. The OpenXR specification does not support strict aliasing, as there are some cases in which an application intentionally provides a struct with a type that differs from the declared type. For example, `XrFrameEndInfo::layers` is an array of type `const XrCompositionLayerBaseHeader * const`. However, the array **must** be of one of the specific layer types, such as `XrCompositionLayerQuad`. Similarly, `xrEnumerateSwapchainImages` accepts an array of `XrSwapchainImageBaseHeader`, whereas the actual type passed **must** be an array of a type such as `XrSwapchainImageVulkanKHR`. For OpenXR to work correctly, the compiler **must** support the type aliasing described here.

```c
#if !defined(XR_MAY_ALIAS)
#if defined(__clang__) || (defined(__GNUC__) && (__GNUC__ > 4))
#define XR_MAY_ALIAS __attribute__((__may_alias__))
#else
#define XR_MAY_ALIAS
#endif
#endif
```

As a convenience, some types and pointers that are known at specification time to alias values of
different types have been annotated with the \texttt{XR\_MAY\_ALIAS} definition. If this macro is not defined before including OpenXR headers, and a new enough Clang or GCC compiler is used, it will be defined to the compiler-specific attribute annotation to inform these compilers that those pointers may alias. However, there is no guarantee that all aliasing types or pointers have been correctly marked with this macro, so thorough testing is still recommended if you choose (at your own risk) to permit your compiler to perform type-based aliasing analysis.

### 2.7.6. Valid Usage

Valid usage defines a set of conditions which \textbf{must} be met in order to achieve well-defined run-time behavior in an application. These conditions depend only on API state, and the parameters or objects whose usage is constrained by the condition.

Some valid usage conditions have dependencies on runtime limits or feature availability. It is possible to validate these conditions against the API's minimum or maximum supported values for these limits and features, or some subset of other known values.

Valid usage conditions \textbf{should} apply to a function or structure where complete information about the condition would be known during execution of an application. This is such that a validation API layer or linter \textbf{can} be written directly against these statements at the point they are specified.

### 2.7.7. Implicit Valid Usage

Some valid usage conditions apply to all functions and structures in the API, unless explicitly denoted otherwise for a specific function or structure. These conditions are considered implicit. Implicit valid usage conditions are described in detail below.

**Valid Usage for Object Handles**

Any input parameter to a function that is an object handle \textbf{must} be a valid object handle, unless otherwise specified. An object handle is valid if and only if:

<table>
<thead>
<tr>
<th>Object Handle Validity Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• it has been created or allocated by a previous, successful call to the API,</td>
</tr>
<tr>
<td>• it has not been destroyed by a previous call to the API, and</td>
</tr>
<tr>
<td>• its parent handle is also valid.</td>
</tr>
</tbody>
</table>

There are contexts in which an object handle is \textbf{optional} or otherwise unspecified. In those cases, the API uses \texttt{XR\_NULL\_HANDLE}, which has the integer value \texttt{0}.

**Valid Usage for Pointers**

Any parameter that is a pointer \textbf{must} be a valid pointer when the specification indicates that the
runtime uses the pointer. A pointer is valid if and only if it points at memory containing values of the number and type(s) expected by the function, and all fundamental types accessed through the pointer (e.g. as elements of an array or as members of a structure) satisfy the alignment requirements of the host processor.

**Valid Usage for Enumerated Types**

Any parameter of an enumerated type must be a valid enumerant for that type. An enumerant is valid if and only if the enumerant is defined as part of the enumerated type in question.

**Valid Usage for Flags**

A collection of flags is represented by a bitmask using the type XrFlags64:

```c
typedef uint64_t XrFlags64;
```

Bitmasks are passed to many functions and structures to compactly represent options and are stored in memory defined by the XrFlags64 type. But the API does not use the XrFlags64 type directly. Instead, a Xr*Flags type is used which is an alias of the XrFlags64 type. The API also defines a set of constant bit definitions used to set the bitmasks.

Any Xr*Flags member or parameter used in the API must be a valid combination of bit flags. A valid combination is either zero or the bitwise OR of valid bit flags. A bit flag is valid if and only if:

**Bit Flag Validity**

- The bit flag is one of the constant bit definitions defined by the same Xr*Flags type as the Xr*Flags member or parameter. Valid flag values may also be defined by extensions.
- The flag is allowed in the context in which it is being used. For example, in some cases, certain bit flags or combinations of bit flags are mutually exclusive.

**Valid Usage for Structure Types**

Any parameter that is a structure containing a type member must have a value of type which is a valid XrStructureType value matching the type of the structure. As a general rule, the name of this value is obtained by taking the structure name, stripping the leading Xr, prefixing each capital letter with an underscore, converting the entire resulting string to upper case, and prefixing it with XR_TYPE_.

The only exceptions to this rule are API and Operating System names which are converted in a way that produces a more readable value:
Structure Type Format Exceptions

- OpenGL ⇒ _OPENGL
- OpenGLES ⇒ _OPENGL_ES
- EGL ⇒ _EGL
- D3D ⇒ _D3D
- VULKAN ⇒ _VULKAN

Valid Usage for Structure Pointer Chains

Any structure containing a `void*` next member **must** have a value of next that is either `NULL`, or points to a valid structure that also contains type and next member values. The set of structures connected by next pointers is referred to as a next chain.

In order to use a structure type defined by an extension in a next chain, the proper extension **must** have been previously enabled during `xrCreateInstance`. A runtime **must** ignore all unrecognized structures in a next chain, including those associated with an extension that has not been enabled.

Some structures for use in a chain are described in the core OpenXR specification and are mentioned in the Member Descriptions. Any structure described in this document intended for use in a chain is mentioned in a "See also" list in the implicit valid usage of the structure they chain to. Most chained structures are associated with extensions, and are described in the base OpenXR Specification under the List of Extensions. Vendor-specific extensions **may** be found there as well, or **may** only be available from the vendor’s website or internal document repositories.

Unless otherwise specified: Chained structs which are output structs **may** be modified by the runtime with the exception of the type and next fields. Upon return from any function, all type and next fields in the chain **must** be unmodified.

Useful Base Structures

As a convenience to runtimes and layers needing to iterate through a structure pointer chain, the OpenXR API provides the following base structures:

The **XrBaseInStructure** structure is defined as:

```c
typedef struct XrBaseInStructure {
    XrStructureType type;
    const struct XrBaseInStructure* next;
} XrBaseInStructure;
```
Member Descriptions

- **type** is the XrStructureType of this structure. This base structure itself has no associated XrStructureType value.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

XrBaseInStructure can be used to facilitate iterating through a read-only structure pointer chain.

The XrBaseOutStructure structure is defined as:

```c
typedef struct XrBaseOutStructure {
    XrStructureType type;
    struct XrBaseOutStructure* next;
} XrBaseOutStructure;
```

Member Descriptions

- **type** is the XrStructureType of this structure. This base structure itself has no associated XrStructureType value.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

XrBaseOutStructure can be used to facilitate iterating through a structure pointer chain that returns data back to the application.

These structures allow for some type safety and can be used by OpenXR API functions that operate on generic inputs and outputs.

**Next Chain Structure Uniqueness**

Applications **should** ensure that they create and insert no more than one occurrence of each type of extension structure in a given next chain. Other components of OpenXR (such as the OpenXR loader or an API Layer) **may** insert duplicate structures into this chain. This provides those components the ability to update a structure that appears in the next chain by making a modified copy of that same structure and placing the new version at the beginning of the chain. The benefit of allowing this duplication is each component is no longer required to create a copy of the entire next chain just to update one structure. When duplication is present, all other OpenXR components **must** process only the first instance of a structure of a given type, and then ignore all instances of a structure of that same type.
If a component makes such a structure copy, and the original structure is also used to return content, then that component **must** copy the necessary content from the copied structure and into the original version of the structure upon completion of the function prior to proceeding back up the call stack. This is to ensure that OpenXR behavior is consistent whether or not that particular OpenXR component is present and/or enabled on the system.

**Valid Usage for Nested Structures**

The above conditions also apply recursively to members of structures provided as input to a function, either as a direct argument to the function, or themselves a member of another structure.

Specifics on valid usage of each function are covered in their individual sections.

### 2.8. Return Codes

While the core API is not designed to capture incorrect usage, some circumstances still require return codes. Functions in the API return their status via return codes that are in one of the two categories below.

**Return Code Categories**

- Successful completion codes are returned when a function needs to communicate success or status information. All successful completion codes are non-negative values.
- Run time error codes are returned when a function needs to communicate a failure that could only be detected at run time. All run time error codes are negative values.

```c
typedef enum XrResult {
    XR_SUCCESS = 0,
    XR_TIMEOUT_EXPIRED = 1,
    XR_SESSION_LOSS_PENDING = 3,
    XR_EVENT_UNAVAILABLE = 4,
    XR_SPACE_BOUNDS_UNAVAILABLE = 7,
    XR_SESSION_NOT_FOCUSED = 8,
    XR_FRAME_DISCARDED = 9,
    XR_ERROR_VALIDATION_FAILURE = -1,
    XR_ERROR_RUNTIME_FAILURE = -2,
    XR_ERROR_OUT_OF_MEMORY = -3,
    XR_ERROR_API_VERSION_UNSUPPORTED = -4,
    XR_ERROR_INITIALIZATION_FAILED = -6,
    XR_ERROR_FUNCTION_UNSUPPORTED = -7,
    XR_ERROR_FEATURE_UNSUPPORTED = -8,
    XR_ERROR_EXTENSION_NOT_PRESENT = -9,
};
```
XR_ERROR_LIMIT_REACHED = -10,
XR_ERROR_SIZE_INSUFFICIENT = -11,
XR_ERROR_HANDLE_INVALID = -12,
XR_ERROR_INSTANCE_LOST = -13,
XR_ERROR_SESSION_RUNNING = -14,
XR_ERROR_SESSION_NOT_RUNNING = -16,
XR_ERROR_SESSION_LOST = -17,
XR_ERROR_SYSTEM_INVALID = -18,
XR_ERROR_PATH_INVALID = -19,
XR_ERROR_PATH_COUNT_EXCEEDED = -20,
XR_ERROR_PATH_FORMAT_INVALID = -21,
XR_ERROR_PATH_UNSUPPORTED = -22,
XR_ERROR_LAYER_INVALID = -23,
XR_ERROR_LAYER_LIMIT_EXCEEDED = -24,
XR_ERROR_SWAPCHAIN_RECT_INVALID = -25,
XR_ERROR_SWAPCHAIN_FORMAT_UNSUPPORTED = -26,
XR_ERROR_ACTION_TYPE_MISMATCH = -27,
XR_ERROR_SESSION_NOT_READY = -28,
XR_ERROR_SESSION_NOT_STOPPING = -29,
XR_ERROR_TIME_INVALID = -30,
XR_ERROR_REFERENCE_SPACE_UNSUPPORTED = -31,
XR_ERROR_FILE_ACCESS_ERROR = -32,
XR_ERROR_FILE_CONTENTS_INVALID = -33,
XR_ERROR_FORM_FACTOR_UNSUPPORTED = -34,
XR_ERROR_FORM_FACTOR_UNAVAILABLE = -35,
XR_ERROR_API_LAYER_NOT_PRESENT = -36,
XR_ERROR_CALL_ORDER_INVALID = -37,
XR_ERROR_GRAPHICS_DEVICE_INVALID = -38,
XR_ERROR_POSE_INVALID = -39,
XR_ERROR_INDEX_OUT_OF_RANGE = -40,
XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED = -41,
XR_ERROR_EMAIL_BEACON_UNSUPPORTED = -42,
XR_ERROR_NAME_DUPLICATED = -44,
XR_ERROR_NAME_INVALID = -45,
XR_ERROR_ACTIONSET_NOT_ATTACHED = -46,
XR_ERROR_ACTIONSETS_ALREADY_ATTACHED = -47,
XR_ERROR_LOCALIZED_NAME_DUPLICATED = -48,
XR_ERROR_LOCALIZED_NAME_INVALID = -49,
XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING = -50,
XR_ERROR_RUNTIME_UNAVAILABLE = -51,
XR_ERROR_ANDROID_THREAD_SETTINGS_ID_INVALID_KHR = -1000003000,
XR_ERROR_ANDROID_THREAD_SETTINGS_FAILURE_KHR = -100003001,
XR_ERROR_CREATE_SPATIAL_ANCHOR_FAILED_MSFT = -1000003001,
XR_ERROR_SECONDARY_VIEW_CONFIGURATION_TYPE_NOT_ENABLED_MSFT = -1000053000,
XR_ERROR_CONTROLLER_MODEL_KEY_INVALID_MSFT = -1000055000,
XR_ERROR_REPROJECTION_MODE_UNSUPPORTED_MSFT = -1000066000,
XR_ERROR_COMPUTE_NEW_SCENE_NOT_COMPLETED_MSFT = -1000097000,
XR_ERROR_SCENE_COMPONENT_ID_INVALID_MSFT = -1000097001,
All return codes in the API are reported via XrResult return values.

Some common suffixes shared across many of the return codes are defined below:

- **_INVALID**: The specified handle, atom or value is formatted incorrectly, or the specified handle was never created or has been destroyed.

- **_UNSUPPORTED**: The specified handle, atom, enumerant or value is formatted correctly but cannot be used for the lifetime of this function’s parent handle.

- **_UNAVAILABLE**: The specified handle, atom, enumerant or value is supported by this function’s parent handle but not at this moment.

### Success Codes

<table>
<thead>
<tr>
<th>Enum</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_SUCCESS</td>
<td>Function successfully completed.</td>
</tr>
<tr>
<td>XR_TIMEOUT_EXPIRED</td>
<td>The specified timeout time occurred before the operation could complete.</td>
</tr>
<tr>
<td>XR_SESSION_LOSS_PENDING</td>
<td>The session will be lost soon.</td>
</tr>
<tr>
<td>XR_EVENT_UNAVAILABLE</td>
<td>No event was available.</td>
</tr>
<tr>
<td>Enum</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_SPACE_BOUNDS_UNAVAILABLE</td>
<td>The space’s bounds are not known at the moment.</td>
</tr>
<tr>
<td>XR_SESSION_NOT_FOCUSED</td>
<td>The session is not in the focused state.</td>
</tr>
<tr>
<td>XR_FRAME_DISCARDED</td>
<td>A frame has been discarded from composition.</td>
</tr>
<tr>
<td>XR_RENDER_MODEL_UNAVAILABLE_FB</td>
<td>The model is unavailable. (Added by the XR_FB_render_model extension)</td>
</tr>
</tbody>
</table>

**Error Codes**

<table>
<thead>
<tr>
<th>Enum</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_ERROR_VALIDATION_FAILURE</td>
<td>The function usage was invalid in some way.</td>
</tr>
<tr>
<td>XR_ERROR_RUNTIME_FAILURE</td>
<td>The runtime failed to handle the function in an unexpected way that is not covered by another error result.</td>
</tr>
<tr>
<td>XR_ERROR_OUT_OF_MEMORY</td>
<td>A memory allocation has failed.</td>
</tr>
<tr>
<td>XR_ERROR_API_VERSION_UNSUPPORTED</td>
<td>The runtime does not support the requested API version.</td>
</tr>
<tr>
<td>XR_ERROR_INITIALIZATION_FAILED</td>
<td>Initialization of object could not be completed.</td>
</tr>
<tr>
<td>XR_ERROR_FUNCTION_UNSUPPORTED</td>
<td>The requested function was not found or is otherwise unsupported.</td>
</tr>
<tr>
<td>XR_ERROR_FEATURE_UNSUPPORTED</td>
<td>The requested feature is not supported.</td>
</tr>
<tr>
<td>XR_ERROR_EXTENSION_NOT_PRESENT</td>
<td>A requested extension is not supported.</td>
</tr>
<tr>
<td>XR_ERROR_LIMIT_REACHED</td>
<td>The runtime supports no more of the requested resource.</td>
</tr>
<tr>
<td>XR_ERROR_SIZE_INSUFFICIENT</td>
<td>The supplied size was smaller than required.</td>
</tr>
<tr>
<td>XR_ERROR_HANDLE_INVALID</td>
<td>A supplied object handle was invalid.</td>
</tr>
<tr>
<td>XR_ERROR_INSTANCE_LOST</td>
<td>The XrInstance was lost or could not be found. It will need to be destroyed and optionally recreated.</td>
</tr>
<tr>
<td>XR_ERROR_SESSION_RUNNING</td>
<td>The session is already running.</td>
</tr>
<tr>
<td>XR_ERROR_SESSION_NOT_RUNNING</td>
<td>The session is not yet running.</td>
</tr>
<tr>
<td>XR_ERROR_SESSION_LOST</td>
<td>The XrSession was lost. It will need to be destroyed and optionally recreated.</td>
</tr>
<tr>
<td>XR_ERROR_SYSTEM_INVALID</td>
<td>The provided XrSystemId was invalid.</td>
</tr>
<tr>
<td>XR_ERROR_PATH_INVALID</td>
<td>The provided XrPath was not valid.</td>
</tr>
<tr>
<td>Enum</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_ERROR_PATH_COUNT_EXCEEDED</td>
<td>The maximum number of supported semantic paths has been reached.</td>
</tr>
<tr>
<td>XR_ERROR_PATH_FORMAT_INVALID</td>
<td>The semantic path character format is invalid.</td>
</tr>
<tr>
<td>XR_ERROR_PATH_UNSUPPORTED</td>
<td>The semantic path is unsupported.</td>
</tr>
<tr>
<td>XR_ERROR_LAYER_INVALID</td>
<td>The layer was NULL or otherwise invalid.</td>
</tr>
<tr>
<td>XR_ERROR_LAYER_LIMIT_EXCEEDED</td>
<td>The number of specified layers is greater than the supported number.</td>
</tr>
<tr>
<td>XR_ERROR_SWAPCHAIN_RECT_INVALID</td>
<td>The image rect was negatively sized or otherwise invalid.</td>
</tr>
<tr>
<td>XR_ERROR_SWAPCHAIN_FORMAT_UNSUPPORTED</td>
<td>The image format is not supported by the runtime or platform.</td>
</tr>
<tr>
<td>XR_ERROR_ACTION_TYPE_MISMATCH</td>
<td>The API used to retrieve an action’s state does not match the action’s type.</td>
</tr>
<tr>
<td>XR_ERROR_SESSION_NOT_READY</td>
<td>The session is not in the ready state.</td>
</tr>
<tr>
<td>XR_ERROR_SESSION_NOT_STOPPING</td>
<td>The session is not in the stopping state.</td>
</tr>
<tr>
<td>XR_ERROR_TIME_INVALID</td>
<td>The provided XrTime was zero, negative, or out of range.</td>
</tr>
<tr>
<td>XR_ERROR_REFERENCE_SPACE_UNSUPPORTED</td>
<td>The specified reference space is not supported by the runtime or system.</td>
</tr>
<tr>
<td>XR_ERROR_FILE_ACCESS_ERROR</td>
<td>The file could not be accessed.</td>
</tr>
<tr>
<td>XR_ERROR_FILE_CONTENTS_INVALID</td>
<td>The file’s contents were invalid.</td>
</tr>
<tr>
<td>XR_ERROR_FORM_FACTOR_UNSUPPORTED</td>
<td>The specified form factor is not supported by the current runtime or platform.</td>
</tr>
<tr>
<td>XR_ERROR_FORM_FACTOR_UNAVAILABLE</td>
<td>The specified form factor is supported, but the device is currently not available, e.g. not plugged in or powered off.</td>
</tr>
<tr>
<td>XR_ERROR_API_LAYER_NOT_PRESENT</td>
<td>A requested API layer is not present or could not be loaded.</td>
</tr>
<tr>
<td>XR_ERROR_CALL_ORDER_INVALID</td>
<td>The call was made without having made a previously required call.</td>
</tr>
<tr>
<td>XR_ERROR_GRAPHICS_DEVICE_INVALID</td>
<td>The given graphics device is not in a valid state. The graphics device could be lost or initialized without meeting graphics requirements.</td>
</tr>
<tr>
<td>XR_ERROR_POSE_INVALID</td>
<td>The supplied pose was invalid with respect to the requirements.</td>
</tr>
<tr>
<td>Enum</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_ERROR_INDEX_OUT_OF_RANGE</td>
<td>The supplied index was outside the range of valid indices.</td>
</tr>
<tr>
<td>XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED</td>
<td>The specified view configuration type is not supported by the runtime or platform.</td>
</tr>
<tr>
<td>XR_ERROR_ENVIRONMENT_BLEND_MODE_UNSUPPORTED</td>
<td>The specified environment blend mode is not supported by the runtime or platform.</td>
</tr>
<tr>
<td>XR_ERROR_NAME_DUPLICATED</td>
<td>The name provided was a duplicate of an already-existing resource.</td>
</tr>
<tr>
<td>XR_ERROR_NAME_INVALID</td>
<td>The name provided was invalid.</td>
</tr>
<tr>
<td>XR_ERROR_ACTIONSET_NOT_ATTACHED</td>
<td>A referenced action set is not attached to the session.</td>
</tr>
<tr>
<td>XR_ERROR_ACTIONSETS_ALREADY_ATTACHED</td>
<td>The session already has attached action sets.</td>
</tr>
<tr>
<td>XR_ERROR_LOCALIZED_NAME_DUPLICATED</td>
<td>The localized name provided was a duplicate of an already-existing resource.</td>
</tr>
<tr>
<td>XR_ERROR_LOCALIZED_NAME_INVALID</td>
<td>The localized name provided was invalid.</td>
</tr>
<tr>
<td>XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING</td>
<td>The <code>xrGetGraphicsRequirements</code> call was not made before calling <code>xrCreateSession</code>.</td>
</tr>
<tr>
<td>XR_ERROR_RUNTIME_UNAVAILABLE</td>
<td>The loader was unable to find or load a runtime.</td>
</tr>
<tr>
<td>XR_ERROR_ANDROID_THREAD_SETTINGS_ID_INVALID_KHR</td>
<td><code>xrSetAndroidApplicationThreadKHR</code> failed as thread id is invalid. (Added by the <code>XR_KHR_android_thread_settings</code> extension)</td>
</tr>
<tr>
<td>XR_ERROR_ANDROID_THREAD_SETTINGS_FAILURE_KHR</td>
<td><code>xrSetAndroidApplicationThreadKHR</code> failed setting the thread attributes/priority. (Added by the <code>XR_KHR_android_thread_settings</code> extension)</td>
</tr>
<tr>
<td>XR_ERROR_CREATE_SPATIAL_ANCHOR_FAILED_MSFT</td>
<td>Spatial anchor could not be created at that location. (Added by the <code>XR_MSFT_spatial_anchor</code> extension)</td>
</tr>
<tr>
<td>XR_ERROR_SECONDARY_VIEW_CONFIGURATION_TYPE_NOT_ENABLED_MSFT</td>
<td>The secondary view configuration was not enabled when creating the session. (Added by the <code>XR_MSFT_secondary_view_configuration</code> extension)</td>
</tr>
<tr>
<td>XR_ERROR_CONTROLLER_MODEL_KEY_INVALID_MSFT</td>
<td>The controller model key is invalid. (Added by the <code>XR_MSFT_controller_model</code> extension)</td>
</tr>
<tr>
<td>XR_ERROR_REPROJECTION_MODE_UNSUPPORTED_MSFT</td>
<td>The reprojection mode is not supported. (Added by the <code>XR_MSFT_composition_layer_reprojection</code> extension)</td>
</tr>
<tr>
<td>Enum</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_ERROR_COMPUTE_NEW_SCENE_NOT_COMPLETED_MSFT</td>
<td>Compute new scene not completed. (Added by the XR_MSFT_scene_understanding extension)</td>
</tr>
<tr>
<td>XR_ERROR_SCENE_COMPONENT_ID_INVALID_MSFT</td>
<td>Scene component id invalid. (Added by the XR_MSFT_scene_understanding extension)</td>
</tr>
<tr>
<td>XR_ERROR_SCENE_COMPONENT_TYPE_MISMATCH_MSFT</td>
<td>Scene component type mismatch. (Added by the XR_MSFT_scene_understanding extension)</td>
</tr>
<tr>
<td>XR_ERROR_SCENE_MESH_BUFFER_ID_INVALID_MSFT</td>
<td>Scene mesh buffer id invalid. (Added by the XR_MSFT_scene_understanding extension)</td>
</tr>
<tr>
<td>XR_ERROR_SCENE_COMPUTE_FEATURE_INCOMPATIBLE_MSFT</td>
<td>Scene compute feature incompatible. (Added by the XR_MSFT_scene_understanding extension)</td>
</tr>
<tr>
<td>XR_ERROR_SCENE_COMPUTE_CONSISTENCY_MISMATCH_MSFT</td>
<td>Scene compute consistency mismatch. (Added by the XR_MSFT_scene_understanding extension)</td>
</tr>
<tr>
<td>XR_ERROR_DISPLAY_REFRESH_RATE_UNSUPPORTED_FB</td>
<td>The display refresh rate is not supported by the platform. (Added by the XR_FB_display_refresh_rate extension)</td>
</tr>
<tr>
<td>XR_ERROR_COLOR_SPACE_UNSUPPORTED_FB</td>
<td>The color space is not supported by the runtime. (Added by the XR_FB_color_space extension)</td>
</tr>
<tr>
<td>XR_ERROR_SPACE_COMPONENT_NOT_SUPPORTED_FB</td>
<td>The component type is not supported for this space. (Added by the XR_FB_spatial_entity extension)</td>
</tr>
<tr>
<td>XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB</td>
<td>The required component is not enabled for this space. (Added by the XR_FB_spatial_entity extension)</td>
</tr>
<tr>
<td>XR_ERROR_SPACE_COMPONENT_STATUS_PENDING_FB</td>
<td>A request to set the component's status is currently pending. (Added by the XR_FB_spatial_entity extension)</td>
</tr>
<tr>
<td>XR_ERROR_SPACE_COMPONENT_STATUS_ALREADY_SET_FB</td>
<td>The component is already set to the requested value. (Added by the XR_FB_spatial_entity extension)</td>
</tr>
<tr>
<td>XR_ERROR_UNEXPECTED_STATE_PASSTHROUGH_FB</td>
<td>The object state is unexpected for the issued command. (Added by the XR_FB_passthrough extension)</td>
</tr>
<tr>
<td>XR_ERROR_FEATURE_ALREADY_CREATED_PASSTHROUGH_FB</td>
<td>Trying to create an MR feature when one was already created and only one instance is allowed. (Added by the XR_FB_passthrough extension)</td>
</tr>
<tr>
<td>Enum</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_ERROR_FEATURE_REQUIRED_PASSTHROUGH_FB</td>
<td>Requested functionality requires a feature to be created first. (Added by the XR_FB_passthrough extension)</td>
</tr>
<tr>
<td>XR_ERROR_NOT_PERMITTED_PASSTHROUGH_FB</td>
<td>Requested functionality is not permitted - application is not allowed to perform the requested operation. (Added by the XR_FB_passthrough extension)</td>
</tr>
<tr>
<td>XR_ERROR_INSUFFICIENT_RESOURCES_PASSTHROUGH_FB</td>
<td>There weren’t sufficient resources available to perform an operation. (Added by the XR_FB_passthrough extension)</td>
</tr>
<tr>
<td>XR_ERROR_UNKNOWN_PASSTHROUGH_FB</td>
<td>Unknown Passthrough error (no further details provided). (Added by the XR_FB_passthrough extension)</td>
</tr>
<tr>
<td>XR_ERROR_RENDER_MODEL_KEY_INVALID_FB</td>
<td>The model key is invalid. (Added by the XR_FB_render_model extension)</td>
</tr>
<tr>
<td>XR_ERROR_MARKER_NOT_TRACKED_VARJO</td>
<td>Marker tracking is disabled or the specified marker is not currently tracked. (Added by the XR_VARJO_marker_tracking extension)</td>
</tr>
<tr>
<td>XR_ERROR_MARKER_ID_INVALID_VARJO</td>
<td>The specified marker ID is not valid. (Added by the XR_VARJO_marker_tracking extension)</td>
</tr>
<tr>
<td>XR_ERROR_SPATIAL_ANCHOR_NAME_NOT_FOUND_MSFT</td>
<td>A spatial anchor was not found associated with the spatial anchor name provided (Added by the XR_MSFT_spatial_anchor_persistence extension)</td>
</tr>
<tr>
<td>XR_ERROR_SPATIAL_ANCHOR_NAME_INVALID_MSFT</td>
<td>The spatial anchor name provided was not valid (Added by the XR_MSFT_spatial_anchor_persistence extension)</td>
</tr>
</tbody>
</table>

### 2.8.1. Convenience Macros

```c
#define XR_SUCCEEDED(result) ((result) >= 0)
```

A convenience macro that can be used to test if a function succeeded. This may be a qualified success such as XR_FRAME_DISCARDED.
A convenience macro that can be used to test if a function has failed in some way.

A convenience macro that can be used to test a function’s failure. The XR_UNQUALIFIED_SUCCESS macro is a convenience macro which may be used to compare an XrResult to 0 (XR_SUCCESS) exclusively.

2.8.2. Validation

Except as noted below or in individual API specifications, valid API usage may be required by the runtime. Runtimes may choose to validate some API usage and return an appropriate error code.

Application developers should use validation layers to catch and eliminate errors during development. Once validated, applications should not enable validation layers by default.

If a function returns a run time error, unless otherwise specified any output parameters will have undefined contents, except that if the output parameter is a structure with type and next fields, those fields will be unmodified. Any output structures chained from next will also have undefined contents, except that the type and next will be unmodified.

Unless otherwise specified, errors do not affect existing OpenXR objects. Objects that have already been successfully created may still be used by the application.

XrResult code returns may be added to a given function in future versions of the specification. Runtimes must return only XrResult codes from the set documented for the given application API version.

Runtimes must ensure that incorrect usage by an application does not affect the integrity of the operating system, the API implementation, or other API client applications in the system, and does not allow one application to access data belonging to another application.

2.9. Handles

Objects which are allocated by the runtime on behalf of applications are represented by handles. Handles are opaque identifiers for objects whose lifetime is controlled by applications via the create and destroy functions. Example handle types include XrInstance, XrSession, and XrSwapchain. Handles which have not been destroyed are unique for a given application process, but may be reused after being destroyed. Unless otherwise specified, a successful handle creation function call returns a new unique handle. Unless otherwise specified, handles are implicitly destroyed when their parent handle is destroyed. Applications may destroy handles explicitly before the parent handle is destroyed,
and **should** do so if no longer needed, in order to conserve resources. Runtimes **may** detect `XR_NULL_HANDLE` and other invalid handles passed where a valid handle is required and return `XR_ERROR_HANDLE_INVALID`. However, runtimes are not required to do so unless otherwise specified, and so use of any invalid handle **may** result in undefined behavior. When a function has an optional handle parameter, `XR_NULL_HANDLE` **must** be used unless passing a valid handle.

All functions that take a handle parameter **may** return `XR_ERROR_HANDLE_INVALID`.

Handles form a hierarchy in which child handles fall under the validity and lifetime of parent handles. For example, to create an `XrSwapchain` handle, applications must call `xrCreateSwapchain` and pass an `XrSession` handle. Thus `XrSwapchain` is a child handle to `XrSession`.

### 2.10. Object Handle Types

The type of an object handle used in a function is usually determined by the specification of that function, as discussed in **Valid Usage for Object Handles**. However, some functions accept or return object handle parameters where the type of the object handle is unknown at execution time and is not specified in the description of the function itself. For these functions, the `XrObjectType` **may** be used to explicitly specify the type of a handle.

For example, an information-gathering or debugging mechanism implemented in a runtime extension or API layer extension **may** return a list of object handles that are generated by the mechanism's operation. The same mechanism **may** also return a parallel list of object handle types that allow the recipient of this information to easily determine the types of the handles.

In general, anywhere an object handle of more than one type can occur, the object handle type **may** be provided to indicate its type.
typedef enum XrObjectType {
    XR_OBJECT_TYPE_UNKNOWN = 0,
    XR_OBJECT_TYPE_INSTANCE = 1,
    XR_OBJECT_TYPE_SESSION = 2,
    XR_OBJECT_TYPE_SWAPCHAIN = 3,
    XR_OBJECT_TYPE_SPACE = 4,
    XR_OBJECT_TYPE_ACTION_SET = 5,
    XR_OBJECT_TYPE_ACTION = 6,
    XR_OBJECT_TYPE_DEBUG_UTILS_MESSENGER_EXT = 1000019000,
    XR_OBJECT_TYPE_SPATIAL_ANCHOR_MSFT = 1000039000,
    XR_OBJECT_TYPE_SPATIAL_GRAPH_NODE_BINDING_MSFT = 1000049000,
    XR_OBJECT_TYPE_HAND_TRACKER_EXT = 1000051000,
    XR_OBJECT_TYPE_SCENE_OBSERVER_MSFT = 1000097000,
    XR_OBJECT_TYPE_SCENE_MSFT = 1000097001,
    XR_OBJECT_TYPE_FACIAL_TRACKER_HTC = 1000104000,
    XR_OBJECT_TYPE_FOVEATION_PROFILE_FB = 1000114000,
    XR_OBJECT_TYPE_TRIANGLE_MESH_FB = 1000117000,
    XR_OBJECT_TYPE_PASSTHROUGH_FB = 1000118000,
    XR_OBJECT_TYPE_PASSTHROUGH_LAYER_FB = 1000118002,
    XR_OBJECT_TYPE_GEOMETRY_INSTANCE_FB = 1000118004,
    XR_OBJECT_TYPE_SPATIAL_ANCHOR_STORE_CONNECTION_MSFT = 1000142000,
    XR_OBJECT_TYPE_MAX_ENUM = 0x7FFFFFFF
} XrObjectType;

The XrObjectType enumeration defines values, each of which corresponds to a specific OpenXR handle type. These values can be used to associate debug information with a particular type of object through one or more extensions.

The following table defines XrObjectType and OpenXR Handle relationships:

<table>
<thead>
<tr>
<th>XrObjectType</th>
<th>OpenXR Handle Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_OBJECT_TYPE_UNKNOWN</td>
<td>Unknown/Undefined Handle</td>
</tr>
<tr>
<td>XR_OBJECT_TYPE_INSTANCE</td>
<td>XrInstance</td>
</tr>
<tr>
<td>XR_OBJECT_TYPE_SESSION</td>
<td>XrSession</td>
</tr>
<tr>
<td>XR_OBJECT_TYPE_SWAPCHAIN</td>
<td>XrSwapchain</td>
</tr>
<tr>
<td>XR_OBJECT_TYPE_SPACE</td>
<td>XrSpace</td>
</tr>
<tr>
<td>XR_OBJECT_TYPE_ACTION_SET</td>
<td>XrActionSet</td>
</tr>
<tr>
<td>XR_OBJECT_TYPE_ACTION</td>
<td>XrAction</td>
</tr>
</tbody>
</table>

2.11. Buffer Size Parameters

Functions with input/output buffer parameters take on either parameter form or struct form, looking
like one of the following examples, with the element type being float in this case:

Parameter form:

```c
XrResult xrFunction(uint32_t elementCapacityInput, uint32_t* elementCountOutput, float* elements);
```

Struct form:

```c
XrResult xrFunction(XrBuffer* buffer);

struct XrBuffer {
    uint32_t elementCapacityInput;
    uint32_t elementCountOutput;
    float* elements;
};
```

A two-call idiom may be employed, first calling `xrFunction` (with a valid `elementCountOutput` pointer if in parameter form), but passing `NULL` as `elements` and 0 as `elementCapacityInput`, to retrieve the required buffer size as number of elements (number of floats in this example). After allocating a buffer at least as large as `elementCountOutput` (in a struct) or the value pointed to by `elementCountOutput` (as parameters), a pointer to the allocated buffer should be passed as `elements`, along with the buffer's length in `elementCapacityInput`, to a second call to `xrFunction` to perform the retrieval of the data. In case that `elements` is a struct with type and next fields, the application must set the type to the correct value as well as next either to NULL or a struct with extension related data in which type and next also need to be well defined.

In the following discussion, "set `elementCountOutput" should be interpreted as "set the value pointed to by `elementCountOutput" in parameter form and "set the value of `elementCountOutput" in struct form. These functions have the below-listed behavior with respect to the buffer size parameters:
Buffer Size Parameter Behavior

- The element capacity and count arguments precede the array to which they refer, in argument order.
- `elementCapacityInput` specifies the capacity in number of elements of the buffer to be written, or 0 to indicate a request for the required buffer size.
- Independent of `elementCapacityInput` or `elements` parameters, the function sets `elementCountOutput`. `elementCountOutput` must be a valid pointer if the function uses parameter form.
- Where the `elementCapacityInput` is 0, the function sets `elementCountOutput` to the required size in number of elements and must return XR_SUCCESS. `elements` is ignored.
- Where the `elementCapacityInput` is non-zero but less than required, the function sets `elementCountOutput` to the required capacity, and must return XR_ERROR_SIZE_INSUFFICIENT. The data in `elements` is undefined.
- Where the `elementCapacityInput` is non-zero and the function returned successfully, the function sets `elementCountOutput` to the count of the elements that have been written to `elements`.
- Upon a failure for reasons unrelated to the element array capacity, the contents of `elementCountOutput` and `elements` are undefined.
- In the case that the element array refers to a string (is of type `char*`), `elementCapacityInput` and `elementCountOutput` refer to the string `strlen` plus 1 for a NULL terminator.

Some functions fill multiple buffers in one call. For these functions, the `elementCapacityInput`, `elementCountOutput` and `elements` parameters or fields are repeated, once per buffer, with different prefixes. In that case, the semantics above still apply, with the additional behavior that if any `elementCapacityInput` parameter or field is set to 0 by the application, the runtime must treat all `elementCapacityInput` values as if they were set to 0. If any `elementCapacityInput` value is too small to fit all elements of the buffer, XR_ERROR_SIZE_INSUFFICIENT must be returned, and the data in all buffers is undefined.

2.12. Time

Time is represented by a 64-bit signed integer representing nanoseconds (`XrTime`). The passage of time must be monotonic and not real-time (i.e. wall clock time). Thus the time is always increasing at a constant rate and is unaffected by clock changes, time zones, daylight savings, etc.

2.12.1. XrTime
typedef int64_t XrTime;

XrTime is a base value type that represents time as a signed 64-bit integer, representing the monotonically-increasing count of nanoseconds that have elapsed since a runtime-chosen epoch. XrTime always represents the time elapsed since that constant epoch, rather than a duration or a time point relative to some moving epoch such as vsync time, etc. Durations are instead represented by XrDuration.

A single runtime must use the same epoch for all simultaneous applications. Time must be represented the same regardless of multiple processors or threads present in the system.

The period precision of time reported by the runtime is runtime-dependent, and may change. One nanosecond is the finest possible period precision. A runtime may, for example, report time progression with only microsecond-level granularity.

Time must not be assumed to correspond to a system clock time.

Unless specified otherwise, zero or a negative value is not a valid XrTime, and related functions must return error XR_ERROR_TIME_INVALID. Applications must not initialize such XrTime fields to a zero value. Instead, applications should always assign XrTime fields to the meaningful point in time they are choosing to reason about, such as a frame's predicted display time, or an action's last change time.

The behavior of a runtime is undefined when time overflows beyond the maximum positive value that can be represented by an XrTime. Runtimes should choose an epoch that minimizes the chance of overflow. Runtimes should also choose an epoch that minimizes the chance of underflow below 0 for applications performing a reasonable amount of historical pose lookback. For example, if the runtime chooses an epoch relative to its startup time, it should push the epoch into the past by enough time to avoid applications performing reasonable pose lookback from reaching a negative XrTime value.

An application cannot assume that the system's clock and the runtime's clock will maintain a constant relationship across frames and should avoid storing such an offset, as this may cause time drift. Applications should instead always use time interop functions to convert a relevant time point across the system's clock and the runtime's clock using extensions, for example, XR_KHR_win32_convert_performance_counter_time or XR_KHR_convert_timespec_time.

2.13. Duration

Duration refers to an elapsed period of time, as opposed to an absolute timepoint.

2.13.1. XrDuration
typedef int64_t XrDuration;

The difference between two timepoints is a duration, and thus the difference between two XrTime values is an XrDuration value.

Functions that refer to durations use XrDuration as opposed to XrTime.

#define XR_NO_DURATION 0

For the case of timeout durations, XR_NO_DURATION may be used to indicate that the timeout is immediate.

#define XR_INFINITE_DURATION 0x7fffffffffffffffLL

XR_INFINITE_DURATION is a special value that may be used to indicate that the timeout never occurs. A timeout with a duration that refers to the past has the same effect as a timeout of XR_NO_DURATION.

2.14. Prediction Time Limits

Some functions involve prediction. For example, xrLocateViews accepts a display time for which to return the resulting data. Prediction times provided by applications may refer to time in the past or the future. Times in the past may be interpolated historical data. Runtimes have different practical limits with respect to how far forward or backward prediction times can be accurate. There is no prescribed forward limit the application can successfully request predictions for, though predictions may become less accurate as they get farther into the future. With respect to backward prediction, the application can pass a prediction time equivalent to the timestamp of the most recently received pose plus as much as 50 milliseconds in the past to retrieve accurate historical data. Requested times predating this time window, or requested times predating the earliest received pose, may result in a best effort data whose accuracy reduced or unspecified.

2.15. Colors

The XrColor4f structure is defined as:
typedef struct XrColor4f {
    float r;
    float g;
    float b;
    float a;
} XrColor4f;

**Member Descriptions**

- $r$ is the red component of the color.
- $g$ is the green component of the color.
- $b$ is the blue component of the color.
- $a$ is the alpha component of the color.

Unless otherwise specified, colors are encoded as linear (not with sRGB nor other gamma compression) values with individual components being in the range of 0.0 through 1.0, and without the RGB components being premultiplied by the alpha component.

If color encoding is specified as being premultiplied by the alpha component, the RGB components are set to zero if the alpha component is zero.

### 2.16. Coordinate System

This API uses a Cartesian right-handed coordinate system.

![Figure 1. Right Handed Coordinate System](image)

The conventions for mapping coordinate axes of any particular space to meaningful directions depend on and are documented with the description of the space.

The API uses 2D, 3D, and 4D floating-point vectors to describe points and directions in a space.

A two-dimensional vector is defined by the `XrVector2f` structure:
typedef struct XrVector2f {
  float    x;
  float    y;
} XrVector2f;

**Member Descriptions**

- `x` is the x coordinate of the vector.
- `y` is the y coordinate of the vector.

If used to represent physical distances (rather than e.g. normalized direction) and not otherwise specified, values **must** be in meters.

A three-dimensional vector is defined by the `XrVector3f` structure:

typedef struct XrVector3f {
  float    x;
  float    y;
  float    z;
} XrVector3f;

**Member Descriptions**

- `x` is the x coordinate of the vector.
- `y` is the y coordinate of the vector.
- `z` is the z coordinate of the vector.

If used to represent physical distances (rather than e.g. velocity or angular velocity) and not otherwise specified, values **must** be in meters.

A four-dimensional or homogeneous vector is defined by the `XrVector4f` structure:
typedef struct XrVector4f {
    float x;
    float y;
    float z;
    float w;
} XrVector4f;

**Member Descriptions**

- **x** is the x coordinate of the vector.
- **y** is the y coordinate of the vector.
- **z** is the z coordinate of the vector.
- **w** is the w coordinate of the vector.

If used to represent physical distances, **x**, **y**, and **z** values **must** be in meters.

Rotation is represented by a unit quaternion defined by the `XrQuaternionf` structure:

typedef struct XrQuaternionf {
    float x;
    float y;
    float z;
    float w;
} XrQuaternionf;

**Member Descriptions**

- **x** is the x coordinate of the quaternion.
- **y** is the y coordinate of the quaternion.
- **z** is the z coordinate of the quaternion.
- **w** is the w coordinate of the quaternion.

A pose is defined by the `XrPosef` structure:
typedef struct XrPosef {
    XrQuaternionf orientation;
    XrVector3f position;
} XrPosef;

Member Descriptions

• orientation is an XrQuaternionf representing the orientation within a space.
• position is an XrVector3f representing position within a space.

A construct representing a position and orientation within a space, with position expressed in meters, and orientation represented as a unit quaternion. When using XrPosef the rotation described by orientation is always applied before the translation described by position.

A runtime must return XR_ERROR_POSE_INVALID if the orientation norm deviates by more than 1% from unit length.

2.17. Common Object Types

Some types of OpenXR objects are used in multiple structures. Those include the XrVector*f and types specified above but also the following structures: offset, extents and rectangle.

Offsets are used to describe the magnitude of an offset in two dimensions.

A floating-point offset is defined by the structure:

typedef struct XrOffset2Df {
    float x;
    float y;
} XrOffset2Df;

Member Descriptions

• x the floating-point offset in the x direction.
• y the floating-point offset in the y direction.

This structure is used for component values that may be fractional (floating-point). If used to represent physical distances, values must be in meters.
An integer offset is defined by the structure:

```c
typedef struct XrOffset2Di {
    int32_t    x;
    int32_t    y;
} XrOffset2Di;
```

### Member Descriptions

- **x** the integer offset in the x direction.
- **y** the integer offset in the y direction.

This variant is for representing discrete values such as texels. For representing physical distances, the floating-point variant **must** be used instead.

Extents are used to describe the size of a rectangular region in two dimensions.

A two-dimensional floating-point extent is defined by the structure:

```c
typedef struct XrExtent2Df {
    float    width;
    float    height;
} XrExtent2Df;
```

### Member Descriptions

- **width** the floating-point width of the extent.
- **height** the floating-point height of the extent.

This structure is used for component values that may be fractional (floating-point). If used to represent physical distances, values **must** be in meters.

The **width** and **height** value **must** be non-negative.

A two-dimensional integer extent is defined by the structure:
typedef struct XrExtent2Di {
    int32_t   width;
    int32_t   height;
} XrExtent2Di;

**Member Descriptions**

- **width** the integer width of the extent.
- **height** the integer height of the extent.

This variant is for representing discrete values such as texels. For representing physical distances, the floating-point variant **must** be used instead.

The **width** and **height** value **must** be non-negative.

Rectangles are used to describe a specific rectangular region in two dimensions. Rectangles **must** include both an offset and an extent defined in the same units. For instance, if a rectangle is in meters, both offset and extent **must** be in meters.

A rectangle with floating-point values is defined by the structure:

typedef struct XrRect2Df {
    XrOffset2Df   offset;
    XrExtent2Df   extent;
} XrRect2Df;

**Member Descriptions**

- **offset** is the **XrOffset2Df** specifying the rectangle offset.
- **extent** is the **XrExtent2Df** specifying the rectangle extent.

This structure is used for component values that may be fractional (floating-point).

A rectangle with integer values is defined by the structure:
typedef struct XrRect2Di {
    XrOffset2Di    offset;
    XrExtent2Di    extent;
} XrRect2Di;

**Member Descriptions**

- **offset** is the `XrOffset2Di` specifying the integer rectangle offset.
- **extent** is the `XrExtent2Di` specifying the integer rectangle extent.

This variant is for representing discrete values such as texels. For representing physical distances, the floating-point variant **must** be used instead.

### 2.18. Angles

Where a value is provided as a function parameter or as a structure member and will be interpreted as an angle, the value is defined to be in radians.

Field of view (FoV) is defined by the structure:

typedef struct XrFovf {
    float    angleLeft;
    float    angleRight;
    float    angleUp;
    float    angleDown;
} XrFovf;

**Member Descriptions**

- **angleLeft** is the angle of the left side of the field of view. For a symmetric field of view this value is negative.
- **angleRight** is the angle of the right side of the field of view.
- **angleUp** is the angle of the top part of the field of view.
- **angleDown** is the angle of the bottom part of the field of view. For a symmetric field of view this value is negative.

Angles to the right of the center and upwards from the center are positive, and angles to the left of the
center and down from the center are negative. The total horizontal field of view is $\text{angleRight}$ minus $\text{angleLeft}$, and the total vertical field of view is $\text{angleUp}$ minus $\text{angleDown}$. For a symmetric FoV, $\text{angleRight}$ and $\text{angleUp}$ will have positive values, $\text{angleLeft}$ will be $-\text{angleRight}$, and $\text{angleDown}$ will be $-\text{angleUp}$.

The angles must be specified in radians, and must be between $-\pi/2$ and $\pi/2$ exclusively.

When $\text{angleLeft} > \text{angleRight}$, the content of the view must be flipped horizontally. When $\text{angleDown} > \text{angleUp}$, the content of the view must be flipped vertically.

### 2.19. Boolean Values

```c
typedef uint32_t XrBool32;
```

Boolean values used by OpenXR are of type `XrBool32` and are 32-bits wide as suggested by the name. The only valid values are the following:

<table>
<thead>
<tr>
<th>Enumerant Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• XR_TRUE represents a true value.</td>
</tr>
<tr>
<td>• XR_FALSE represents a false value.</td>
</tr>
</tbody>
</table>

### 2.20. Events

Events are messages sent from the runtime to the application.

#### 2.20.1. Event Polling

These events are placed in a queue and the application must read from the queue with regularity. Events are read from the queue one at a time via `xrPollEvent`. Every event is identified by an individual struct, with each struct beginning with an `XrEventDataBaseHeader`. 
Example 1. Proper Method for Receiving OpenXR Event Data

```c
XrInstance instance; // previously initialized

// Initialize an event buffer to hold the output.
XrEventDataBuffer event;
// Only the header needs to be initialized.
event.type = XR_TYPE_EVENT_DATA_BUFFER;
event.next = nullptr;
XrResult result = xrPollEvent(instance, &event);
if (result == XR_SUCCESS) {
    switch (event.type) {
        case XR_TYPE_EVENT_DATA_SESSION_STATE_CHANGED: {
            const XrEventDataSessionStateChanged& session_state_changed_event =
                *reinterpret_cast<XrEventDataSessionStateChanged*>(&event);
            // ...
            break;
        }
        case XR_TYPE_EVENT_DATA_INSTANCE_LOSS_PENDING: {
            const XrEventDataInstanceLossPending& instance_loss_pending_event =
                *reinterpret_cast<XrEventDataInstanceLossPending*>(&event);
            // ...
            break;
        }
    }
}
```

xrPollEvent

```c
XrResult xrPollEvent(
    XrInstance instance,
    XrEventDataBuffer* eventData);
```

xrPollEvent polls for the next event and returns an event if one is available. xrPollEvent returns immediately regardless of whether an event was available. The event (if present) is unilaterally removed from the queue if a valid XrInstance is provided. On return the eventData parameter is filled with the event's data and the type field is changed to the event's type. Runtimes may create valid next chains depending on enabled extensions, but they must guarantee that any such chains point only to objects which fit completely within the original XrEventDataBuffer pointed to by eventData.
Parameter Descriptions

- `instance` is a valid `XrInstance`.
- `eventData` is a pointer to a valid `XrEventDataBuffer`.

Valid Usage (Implicit)

- `instance` **must** be a valid `XrInstance` handle
- `eventData` **must** be a pointer to an `XrEventDataBuffer` structure

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_EVENT_UNAVAILABLE`

**Failure**

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`

The runtime **must** discard queued events which contain destroyed or otherwise invalid handles.

Table 2. Event Descriptions

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>XrEventDataEventsLost</code></td>
<td>event queue has overflowed and some events were lost</td>
</tr>
<tr>
<td><code>XrEventDataInstanceLossPending</code></td>
<td>application is about to lose the instance</td>
</tr>
<tr>
<td><code>XrEventDataInteractionProfileChanged</code></td>
<td>active input form factor for one or more top level user paths has changed</td>
</tr>
<tr>
<td><code>XrEventDataReferenceSpaceChangePending</code></td>
<td>runtime will begin operating with updated space bounds</td>
</tr>
<tr>
<td><code>XrEventDataSessionStateChanged</code></td>
<td>application has changed lifecycle state</td>
</tr>
</tbody>
</table>

The `XrEventDataBaseHeader` structure is defined as:
typedef struct XrEventDataBaseHeader {
    XrStructureType type;
    const void* next;
} XrEventDataBaseHeader;

Parameter Descriptions

• **type** is the XrStructureType of this structure. This base structure itself has no associated XrStructureType value.

• **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

The **XrEventDataBaseHeader** is a generic structure used to identify the common event data elements.

Upon receipt, the **XrEventDataBaseHeader** pointer should be type-cast to a pointer of the appropriate event data based on the **type** parameter.

Valid Usage (Implicit)

• **type** must be one of the following XrStructureType values:
  - XR_TYPE_EVENT_DATA_DISPLAY_REFRESH_RATE_CHANGED_FB,
  - XR_TYPE_EVENT_DATA_EVENTS_LOST,
  - XR_TYPE_EVENT_DATA_INSTANCE_LOSS_PENDING,
  - XR_TYPE_EVENT_DATA_INTERACTION_PROFILE_CHANGED,
  - XR_TYPE_EVENT_DATA_MAIN_SESSION_VISIBILITY_CHANGED_EXTX,
  - XR_TYPE_EVENT_DATA_MARKER_TRACKING_UPDATE_VARJO,
  - XR_TYPE_EVENT_DATA_PERF_SETTINGS_EXT,
  - XR_TYPE_EVENT_DATA_REFERENCE_SPACE_CHANGE_PENDING,
  - XR_TYPE_EVENT_DATA_SESSION_STATE_CHANGED,
  - XR_TYPE_EVENT_DATA_SPACE_ERASE_COMPLETE_FB,
  - XR_TYPE_EVENT_DATA_SPACE_QUERY_COMPLETE_FB,
  - XR_TYPE_EVENT_DATA_SPACE_QUERY_RESULTS_AVAILABLE_FB,
  - XR_TYPE_EVENT_DATA_SPACE_SET_STATUS_COMPLETE_FB,
  - XR_TYPE_EVENT_DATA_SPATIAL_ANCHOR_CREATE_COMPLETE_FB,
  - XR_TYPE_EVENT_DATA_VISIBILITY_MASK_CHANGED_KHR,
  - XR_TYPE_EVENT_DATA_VIVE_TRACKER_CONNECTED_HTCX

• **next** must be NULL or a valid pointer to the next structure in a structure chain

The **XrEventDataBuffer** is a structure passed to **xrPollEvent** large enough to contain any returned event data element. The maximum size is specified by XR_MAX_EVENT_DATA_SIZE.

It is sufficient to clear the **type** and **next** parameters of an **XrEventDataBuffer** when passing it as an input to **xrPollEvent**.
An `XrEventDataBuffer` may be type-cast to an `XrEventDataBaseHeader` pointer or a pointer to any other appropriate event data based on the `type` parameter.

```c
typedef struct XrEventDataBuffer {
    XrStructureType    type;
    const void*        next;
    uint8_t            varying[4000];
} XrEventDataBuffer;
```

### Parameter Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **varying** is a fixed sized output buffer big enough to hold returned data elements for all specified event data types.

### Valid Usage (Implicit)

- **type** must be `XR_TYPE_EVENT_DATA_BUFFER`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

`XR_MAX_EVENT_DATA_SIZE` is the maximum size of an `XrEventDataBuffer`.

```c
#define XR_MAX_EVENT_DATA_SIZE sizeof(XrEventDataBuffer)
```

### XrEventDataEventsLost

The `XrEventDataEventsLost` structure is defined as:

The `XrEventDataEventsLost` structure is defined as:
typedef struct XrEventDataEventsLost {
    XrStructureType    type;
    const void*        next;
    uint32_t           lostEventCount;
} XrEventDataEventsLost;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **lostEventCount** is the number of events which have overflowed since the last call to xrPollEvent.

Receiving the XrEventDataEventsLost event structure indicates that the event queue overflowed and some events were removed at the position within the queue at which this event was found.

**Valid Usage (Implicit)**

- **type** must be XR_TYPE_EVENT_DATA_EVENTS_LOST
- **next** must be NULL or a valid pointer to the next structure in a structure chain

Other event structures are defined in later chapters in the context where their definition is most relevant.

2.21. System resource lifetime

The creator of an underlying system resource is responsible for ensuring the resource’s lifetime matches the lifetime of the associated OpenXR handle.

Resources passed as inputs from the application to the runtime when creating an OpenXR handle should not be freed while that handle is valid. A runtime must not free resources passed as inputs or decrease their reference counts (if applicable) from the initial value. For example, the graphics device handle (or pointer) passed in to xrCreateSession in XrGraphicsBinding* structure should be kept alive when the corresponding XrSession handle is valid, and should be freed by the application after the XrSession handle is destroyed.

Resources created by the runtime should not be freed by the application, and the application should maintain the same reference count (if applicable) at the destruction of the OpenXR handle as it had at its creation. For example, the ID3D*Texture2D objects in the XrSwapchainImageD3D* are created by the runtime and associated with the lifetime of the XrSwapchain handle. The application should not keep
additional reference counts on any ID3D*Texture2D objects past the lifetime of the XrSwapchain handle, or make extra reference count decrease after destroying the XrSwapchain handle.
Chapter 3. API Initialization

Before using an OpenXR runtime, an application must initialize it by creating an XrInstance object. The following functions are useful for gathering information about the API layers and extensions installed on the system and creating the instance.

### Instance Creation Functions

- xrEnumerateApiLayerProperties
- xrEnumerateInstanceExtensionProperties
- xrCreateInstance

xrEnumerateApiLayerProperties and xrEnumerateInstanceExtensionProperties can be called before calling xrCreateInstance.

### 3.1. Exported Functions

A dynamically linked library (.dll or .so) that implements the API loader must export all core OpenXR API functions. However, the application can gain access to extension functions by obtaining pointers to these functions through the use of xrGetInstanceProcAddr.

### 3.2. Function Pointers

Function pointers for all OpenXR functions can be obtained with the function xrGetInstanceProcAddr.

```c
XrResult xrGetInstanceProcAddr(
    XrInstance instance,
    const char* name,
    PFN_xrVoidFunction* function);
```

**Parameter Descriptions**

- **instance** is the instance that the function pointer will be compatible with, or NULL for functions not dependent on any instance.
- **name** is the name of the function to obtain.
- **function** is the address of the function pointer to get.
xrGetInstanceProcAddr itself is obtained in a platform- and loader-specific manner. Typically, the loader library will export this function as a function symbol, so applications can link against the loader library, or load it dynamically and look up the symbol using platform-specific APIs. Loaders must export function symbols for all core OpenXR functions. Because of this, applications that use only the core OpenXR functions have no need to use xrGetInstanceProcAddr.

Because an application can call xrGetInstanceProcAddr before creating an instance, xrGetInstanceProcAddr returns a valid function pointer when the instance parameter is XR_NULL_HANDLE and the name parameter is one of the following strings:

- xrEnumerateInstanceExtensionProperties
- xrEnumerateApiLayerProperties
- xrCreateInstance

xrGetInstanceProcAddr must return XR_ERROR_HANDLE_INVALID if name is not one of the above strings and instance is XR_NULL_HANDLE. xrGetInstanceProcAddr may return XR_ERROR_HANDLE_INVALID if name is not one of the above strings and instance is invalid but not XR_NULL_HANDLE.

If name is the name of an extension function, then the result returned by xrGetInstanceProcAddr will depend upon how the instance was created. If instance was created with the related extension's name appearing in the XrInstanceCreateInfo::enabledExtensionNames array, then xrGetInstanceProcAddr returns a valid function pointer. If the related extension's name did not appear in the XrInstanceCreateInfo::enabledExtensionNames array during the creation of instance, then xrGetInstanceProcAddr returns XR_ERROR_FUNCTION_UNSUPPORTED. Because of this, function pointers returned by xrGetInstanceProcAddr using one XrInstance may not be valid when used with objects related to a different XrInstance.

The returned function pointer is of type PFN_xrVoidFunction, and must be cast to the type of the function being queried.

The table below defines the various use cases for xrGetInstanceProcAddr and return value (“fp” is “function pointer”) for each case.

Table 3. xrGetInstanceProcAddr behavior

<table>
<thead>
<tr>
<th>instance parameter</th>
<th>name parameter</th>
<th>return value</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>NULL</td>
<td>undefined</td>
</tr>
<tr>
<td>invalid instance</td>
<td>*</td>
<td>undefined</td>
</tr>
<tr>
<td>instance parameter</td>
<td>name parameter</td>
<td>return value</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>NULL</td>
<td>xrEnumerateInstanceExtensionProperties</td>
<td>fp</td>
</tr>
<tr>
<td>NULL</td>
<td>xrEnumerateApiLayerProperties</td>
<td>fp</td>
</tr>
<tr>
<td>NULL</td>
<td>xrCreateInstance</td>
<td>fp</td>
</tr>
<tr>
<td>NULL</td>
<td>* (any name not covered above)</td>
<td>NULL</td>
</tr>
<tr>
<td>instance</td>
<td>core OpenXR function</td>
<td>fp</td>
</tr>
<tr>
<td>instance</td>
<td>enabled extension function for instance</td>
<td>fp</td>
</tr>
<tr>
<td>instance</td>
<td>* (any name not covered above)</td>
<td>NULL</td>
</tr>
</tbody>
</table>

1

The returned function pointer **must** only be called with a handle (the first parameter) that is `instance` or a child of `instance`.

### Valid Usage (Implicit)

- **If instance** is not `XR_NULL_HANDLE`, `instance` **must** be a valid `XrInstance` handle
- **name** **must** be a null-terminated UTF-8 string
- **function** **must** be a pointer to a `PFN_xrVoidFunction` value

### Return Codes

#### Success

- `XR_SUCCESS`

#### Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
typedef void (XRAPI_PTR *PFN_xrVoidFunction)(void);

Parameter Descriptions

- no parameters.

PFN_xrVoidFunction is a generic function pointer type returned by queries, specifically those to xrGetInstanceProcAddr.
Chapter 4. Instance

An OpenXR instance is an object that allows an OpenXR application to communicate with an OpenXR runtime. The application accomplishes this communication by calling `xrCreateInstance` and receiving a handle to the resulting `XrInstance` object.

The `XrInstance` object stores and tracks OpenXR-related application state, without storing any such state in the application’s global address space. This allows the application to create multiple instances as well as safely encapsulate the application’s OpenXR state since this object is opaque to the application. OpenXR runtimes may limit the number of simultaneous `XrInstance` objects that may be created and used, but they must support the creation and usage of at least one `XrInstance` object per process.

Physically, this state may be stored in any of the OpenXR loader, OpenXR API layers or the OpenXR runtime components. The exact storage and distribution of this saved state is implementation-dependent, except where indicated by this specification.

The tracking of OpenXR state in the instance allows the streamlining of the API, where the intended instance is inferred from the highest ascendant of an OpenXR function’s target object. For example, in:

```c
myResult = xrEndFrame(mySession, &myEndFrameDescription);
```

the `XrSession` object was created from an `XrInstance` object. The OpenXR loader typically keeps track of the `XrInstance` that is the parent of the `XrSession` object in this example and directs the function to the runtime associated with that instance. This tracking of OpenXR objects eliminates the need to specify an `XrInstance` in every OpenXR function.

4.1. API Layers and Extensions

Additional functionality may be provided by API layers or extensions. An API layer must not add or modify the definition of OpenXR functions, while an extension may do so.

The set of API layers to enable is specified when creating an instance, and those API layers are able to intercept any functions dispatched to that instance or any of its child objects.

Example API layers may include (but are not limited to):

- an API layer to dump out OpenXR API calls
- an API layer to perform OpenXR validation
To determine what set of API layers are available, OpenXR provides the `xrEnumerateApiLayerProperties` function:

```c
XrResult xrEnumerateApiLayerProperties(
    uint32_t propertyCapacityInput,
    uint32_t* propertyCountOutput,
    XrApiLayerProperties* properties);
```

**Parameter Descriptions**

- `propertyCapacityInput` is the capacity of the properties array, or 0 to indicate a request to retrieve the required capacity.
- `propertyCountOutput` is a pointer to the count of properties written, or a pointer to the required capacity in the case that `propertyCapacityInput` is insufficient.
- `properties` is a pointer to an array of `XrApiLayerProperties` structures, but can be `NULL` if `propertyCapacityInput` is 0.
- See the Buffer Size Parameters section for a detailed description of retrieving the required `properties` size.

The list of available layers may change at any time due to actions outside of the OpenXR runtime, so two calls to `xrEnumerateApiLayerProperties` with the same parameters may return different results, or retrieve different `propertyCountOutput` values or `properties` contents.

Once an instance has been created, the layers enabled for that instance will continue to be enabled and valid for the lifetime of that instance, even if some of them become unavailable for future instances.

**Valid Usage (Implicit)**

- `propertyCountOutput` must be a pointer to a `uint32_t` value
- If `propertyCapacityInput` is not 0, `properties` must be a pointer to an array of `propertyCapacityInput XrApiLayerProperties` structures
Return Codes

Success

- XR_SUCCESS

Failure

- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_SIZE_INSUFFICIENT

The `XrApiLayerProperties` structure is defined as:

```c
typedef struct XrApiLayerProperties {
    XrStructureType type;
    void* next;
    char layerName[XR_MAX_API_LAYER_NAME_SIZE];
    XrVersion specVersion;
    uint32_t layerVersion;
    char description[XR_MAX_API_LAYER_DESCRIPTION_SIZE];
} XrApiLayerProperties;
```

Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **layerName** is a string specifying the name of the API layer. Use this name in the `XrInstanceCreateInfo::enabledApiLayerNames` array to enable this API layer for an instance.
- **specVersion** is the API version the API layer was written to, encoded as described in the API Version Numbers and Semantics section.
- **layerVersion** is the version of this API layer. It is an integer, increasing with backward compatible changes.
- **description** is a string providing additional details that can be used by the application to identify the API layer.
Valid Usage (Implicit)

- **type** must be `XR_TYPE_API_LAYER_PROPERTIES`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

To enable a layer, the name of the layer **should** be added to the `enabledApiLayerNames` member of `XrInstanceCreateInfo` when creating an `XrInstance`.

Loader implementations **may** provide mechanisms outside this API for enabling specific API layers. API layers enabled through such a mechanism are implicitly enabled, while API layers enabled by including the API layer name in `XrInstanceCreateInfo::enabledApiLayerNames` are explicitly enabled. Except where otherwise specified, implicitly enabled and explicitly enabled API layers differ only in the way they are enabled. Explicitly enabling an API layer that is implicitly enabled has no additional effect.

Instance extensions are able to affect the operation of the instance and any of its child objects. As stated earlier, extensions can expand the OpenXR API and provide new functions or augment behavior.

Examples of extensions **may be** (but are not limited to):

Extension Examples

- an extension to include OpenXR functions to work with a new graphics API
- an extension to expose debug information via a callback

The application can determine the available instance extensions by calling `xrEnumerateInstanceExtensionProperties`:

```c
XrResult xrEnumerateInstanceExtensionProperties(
    const char* layerName,
    uint32_t propertyCapacityInput,
    uint32_t* propertyCountOutput,
    XrExtensionProperties* properties);
```
Parameter Descriptions

- **layerName** is either **NULL** or a pointer to a string naming the API layer to retrieve extensions from, as returned by `xrEnumerateApiLayerProperties`.

- **propertyCapacityInput** is the capacity of the properties array, or 0 to indicate a request to retrieve the required capacity.

- **propertyCountOutput** is a pointer to the count of properties written, or a pointer to the required capacity in the case that **propertyCapacityInput** is insufficient.

- **properties** is a pointer to an array of `XrExtensionProperties` structures, but can be **NULL** if **propertyCapacityInput** is 0.

- See the **Buffer Size Parameters** section for a detailed description of retrieving the required properties size.

If **properties** is **NULL**, then the number of extensions properties available is returned in **propertyCountOutput**. Otherwise, **propertyCountInput** must point to a variable set by the user to the number of elements in the **properties** array. If **propertyCountInput** is less than the number of extension properties available, the contents of **properties** will be undefined. If **propertyCountInput** is smaller than the number of extensions available, the runtime must return the failure code **XR_ERROR_SIZE_INSUFFICIENT** and the contents of **properties** are undefined.

Because the list of available layers may change externally between calls to `xrEnumerateInstanceExtensionProperties`, two calls may retrieve different results if a **layerName** is available in one call but not in another. The extensions supported by a layer may also change between two calls, e.g. if the layer implementation is replaced by a different version between those calls.

Valid Usage (Implicit)

- If **layerName** is not **NULL**, **layerName** must be a null-terminated UTF-8 string

- **propertyCountOutput** must be a pointer to a `uint32_t` value

- If **propertyCapacityInput** is not 0, **properties** must be a pointer to an array of `propertyCapacityInput` `XrExtensionProperties` structures
Return Codes

Success
• XR_SUCCESS

Failure
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_SIZE_INSUFFICIENT
• XR_ERROR_RUNTIME_UNAVAILABLE
• XR_ERROR_API_LAYER_NOT_PRESENT

The XrExtensionProperties structure is defined as:

typedef struct XrExtensionProperties {
    XrStructureType    type;
    void*              next;
    char               extensionName[XR_MAX_EXTENSION_NAME_SIZE];
    uint32_t           extensionVersion;
} XrExtensionProperties;

Member Descriptions

• type is the XrStructureType of this structure.
• next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
• extensionName is a NULL terminated string specifying the name of the extension.
• extensionVersion is the version of this extension. It is an integer, incremented with backward compatible changes.

Valid Usage (Implicit)

• type must be XR_TYPE_EXTENSION_PROPERTIES
• next must be NULL or a valid pointer to the next structure in a structure chain
4.2. Instance Lifecycle

The `xrCreateInstance` function is defined as:

```c
XrResult xrCreateInstance(
    const XrInstanceCreateInfo* createInfo,
    XrInstance* instance);
```

Parameter Descriptions

- `createInfo` points to an instance of `XrInstanceCreateInfo` controlling creation of the instance.
- `instance` points to an `XrInstance` handle in which the resulting instance is returned.

`xrCreateInstance` creates the `XrInstance`, then enables and initializes global API layers and extensions requested by the application. If an extension is provided by an API layer, both the API layer and extension must be specified at `xrCreateInstance` time. If a specified API layer cannot be found, no `XrInstance` will be created and the function will return `XR_ERROR_API_LAYER_NOT_PRESENT`. Likewise, if a specified extension cannot be found, the call must return `XR_ERROR_EXTENSION_NOT_PRESENT` and no `XrInstance` will be created. Additionally, some runtimes may limit the number of concurrent instances that may be in use. If the application attempts to create more instances than a runtime can simultaneously support, `xrCreateInstance` may return `XR_ERROR_LIMIT_REACHED`.

If the `XrApplicationInfo::applicationName` is the empty string the runtime must return `XR_ERROR_NAME_INVALID`.

If the `XrInstanceCreateInfo` structure contains a platform-specific extension for a platform other than the target platform, `XR_ERROR_INITIALIZATION_FAILED` may be returned. If a mandatory platform-specific extension is defined for the target platform but no matching extension struct is provided in `XrInstanceCreateInfo` the runtime must return `XR_ERROR_INITIALIZATION_FAILED`.

Valid Usage (Implicit)

- `createInfo` must be a pointer to a valid `XrInstanceCreateInfo` structure
- `instance` must be a pointer to an `XrInstance` handle
Return Codes

Success

- XR_SUCCESS

Failure

- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_RUNTIME_UNAVAILABLE
- XR_ERROR_NAME_INVALID
- XR_ERROR_INITIALIZATION_FAILED
- XR_ERROR_EXTENSION_NOT_PRESENT
- XR_ERROR_API_VERSION_UNSUPPORTED
- XR_ERROR_API_LAYER_NOT_PRESENT

The `XrInstanceCreateInfo` structure is defined as:

```c
typedef struct XrInstanceCreateInfo {
    XrStructureType          type;
    const void*              next;
    XrInstanceCreateFlags    createFlags;
    XrApplicationInfo        applicationInfo;
    uint32_t                 enabledApiLayerCount;
    const char* const*       enabledApiLayerNames;
    uint32_t                 enabledExtensionCount;
    const char* const*       enabledExtensionNames;
} XrInstanceCreateInfo;
```
Member Descriptions

- **type** is the **XrStructureType** of this structure.
- **next** is **NULL** or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **createFlags** is a bitmask of **XrInstanceCreateFlags** that identifies options that apply to the creation.
- **applicationInfo** is an instance of **XrApplicationInfo**. This information helps runtimes recognize behavior inherent to classes of applications. **XrApplicationInfo** is defined in detail below.
- **enabledApiLayerCount** is the number of global API layers to enable.
- **enabledApiLayerNames** is a pointer to an array of **enabledApiLayerCount** strings containing the names of API layers to enable for the created instance. See the API Layers And Extensions section for further details.
- **enabledExtensionCount** is the number of global extensions to enable.
- **enabledExtensionNames** is a pointer to an array of **enabledExtensionCount** strings containing the names of extensions to enable.

Valid Usage (Implicit)

- **type** must be **XR_TYPE_INSTANCE_CREATE_INFO**
- **next** must be **NULL** or a valid pointer to the next structure in a structure chain. See also: **XrDebugUtilsMessengerCreateInfoEXT, XrInstanceCreateInfoAndroidKHR**
- **createFlags** must be **0**
- **applicationInfo** must be a valid **XrApplicationInfo** structure
- If **enabledApiLayerCount** is not **0**, **enabledApiLayerNames** must be a pointer to an array of **enabledApiLayerCount** null-terminated UTF-8 strings
- If **enabledExtensionCount** is not **0**, **enabledExtensionNames** must be a pointer to an array of **enabledExtensionCount** null-terminated UTF-8 strings

The **XrInstanceCreateFlags** include:

```c
// Flag bits for XrInstanceCreateFlags
```

There are currently no instance creation flags. This is reserved for future use.
The `XrApplicationInfo` structure is defined as:

```c
typedef struct XrApplicationInfo {
    char         applicationName[XR_MAX_APPLICATION_NAME_SIZE];
    uint32_t     applicationVersion;
    char         engineName[XR_MAX_ENGINE_NAME_SIZE];
    uint32_t     engineVersion;
    XrVersion    apiVersion;
} XrApplicationInfo;
```

### Member Descriptions

- **applicationName** is a non-empty string containing the name of the application.
- **applicationVersion** is an unsigned integer variable containing the developer-supplied version number of the application.
- **engineName** is a string containing the name of the engine (if any) used to create the application. It may be empty to indicate no specified engine.
- **engineVersion** is an unsigned integer variable containing the developer-supplied version number of the engine used to create the application. May be zero to indicate no specified engine.
- **apiVersion** is the version of this API against which the application will run, encoded as described in the API Version Numbers and Semantics section. If the runtime does not support the requested `apiVersion` it **must** return `XR_ERROR_API_VERSION_UNSUPPORTED`.

### Valid Usage (Implicit)

- `applicationName` **must** be a null-terminated UTF-8 string whose length is less than or equal to `XR_MAX_APPLICATION_NAME_SIZE`
- `engineName` **must** be a null-terminated UTF-8 string whose length is less than or equal to `XR_MAX_ENGINE_NAME_SIZE`
When using the OpenXR API to implement a reusable engine that will be used by many applications, **engineName** should be set to a unique string that identifies the engine, and **engineVersion** should encode a representation of the engine’s version. This way, all applications that share this engine version will provide the same **engineName** and **engineVersion** to the runtime. The engine should then enable individual applications to choose their specific **applicationName** and **applicationVersion**, enabling one application to be distinguished from another application.

When using the OpenXR API to implement an individual application without a shared engine, the input **engineName** should be left empty and **engineVersion** should be set to 0. The **applicationName** should then be filled in with a unique string that identifies the app and the **applicationVersion** should encode a representation of the application’s version.

The `xrDestroyInstance` function is defined as:

```c
XrResult xrDestroyInstance(
    XrInstance instance);
```

The `xrDestroyInstance` function is used to destroy an `XrInstance`.

### Parameter Descriptions

- **instance** is the handle to the instance to destroy.

`XrInstance` handles are destroyed using `xrDestroyInstance`. When an `XrInstance` is destroyed, all handles that are children of that `XrInstance` are also destroyed.

### Valid Usage (Implicit)

- **instance** must be a valid `XrInstance` handle

### Thread Safety

- Access to **instance**, and any child handles, must be externally synchronized
Return Codes

**Success**
- XR_SUCCESS

**Failure**
- XR_ERROR_HANDLE_INVALID

4.3. Instance Information

The `xrGetInstanceProperties` function provides information about the instance and the associated runtime.

```c
XrResult xrGetInstanceProperties(
    XrInstance instance,
    XrInstanceProperties* instanceProperties);
```

### Parameter Descriptions

- `instance` is a handle to an `XrInstance` previously created with `xrCreateInstance`.
- `instanceProperties` points to an `XrInstanceProperties` which describes the `instance`.

The `instanceProperties` parameter must be filled out by the runtime in response to this call, with information as defined in `XrInstanceProperties`.

### Valid Usage (Implicit)

- `instance` must be a valid `XrInstance` handle
- `instanceProperties` must be a pointer to an `XrInstanceProperties` structure
Return Codes

Success

- XR_SUCCESS

Failure

- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST

The XrInstanceProperties structure is defined as:

typedef struct XrInstanceProperties {
    XrStructureType    type;
    void*              next;
    XrVersion          runtimeVersion;
    char               runtimeName[XR_MAX_RUNTIME_NAME_SIZE];
} XrInstanceProperties;

Member Descriptions

- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- runtimeVersion is the runtime's version (not necessarily related to an OpenXR API version), expressed in the format of XR_MAKE_VERSION.
- runtimeName is the name of the runtime.

Valid Usage (Implicit)

- type must be XR_TYPE_INSTANCE_PROPERTIES
- next must be NULL or a valid pointer to the next structure in a structure chain
4.4. Platform-Specific Instance Creation

Some amount of data required for instance creation is exposed through chained structures defined in extensions. These structures may be optional or even required for instance creation on specific platforms, but not on other platforms. Separating off platform-specific functionality into extension structures prevents the primary XrInstanceCreateInfo structure from becoming too bloated with unnecessary information.

See the List of Extensions appendix for the list of available extensions and their related structures. These structures expand the XrInstanceCreateInfo parent struct using the XrInstanceCreateInfo::next member. The specific list of structures that may be used for extending XrInstanceCreateInfo::next can be found in the "Valid Usage (Implicit)” block immediately following the definition of the structure.

4.4.1. The Instance Lost Error

The XR_ERROR_INSTANCE_LOST error indicates that the XrInstance has become unusable. This can happen if a critical runtime process aborts, if the connection to the runtime is otherwise no longer available, or if the runtime encounters an error during any function execution which prevents it from being able to support further function execution. Once XR_ERROR_INSTANCE_LOST is first returned, it must henceforth be returned by all non-destroy functions that involve an XrInstance or child handle type until the instance is destroyed. Applications must destroy the XrInstance. Applications may then attempt to continue by recreating all relevant OpenXR objects, starting with a new XrInstance. A runtime may generate an XrEventDataInstanceLossPending event when instance loss is detected.

4.4.2. XrEventDataInstanceLossPending

typedef struct XrEventDataInstanceLossPending {
    XrStructureType    type;
    const void*        next;
    XrTime             lossTime;
} XrEventDataInstanceLossPending;

Receiving the XrEventDataInstanceLossPending event structure indicates that the application is about to lose the indicated XrInstance at the indicated lossTime in the future. The application should call xrDestroyInstance and relinquish any instance-specific resources. This typically occurs to make way for a replacement of the underlying runtime, such as via a software update.

After the application has destroyed all of its instances and their children and waited past the specified time, it may then re-try xrCreateInstance in a loop waiting for whatever maintenance the runtime is performing to complete. The runtime will return XR_ERROR_RUNTIME_UNAVAILABLE from xrCreateInstance as long as it is unable to create the instance. Once the runtime has returned and is able to continue, it must resume returning XR_SUCCESS from xrCreateInstance if valid data is passed in.
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **lossTime** is the absolute time at which the indicated instance will be considered lost and become unusable.

Valid Usage (Implicit)

- **type** **must** be XR_TYPE_EVENT_DATA_INSTANCE_LOSS_PENDING
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain

4.5. Instance Enumerated Type String Functions

Applications often want to turn certain enum values from the runtime into strings for use in log messages, to be localized in UI, or for various other reasons. OpenXR provides functions that turn common enum types into UTF-8 strings for use in applications.

```c
XrResult xrResultToString(
    XrInstance instance,
    XrResult value,
    char buffer[XR_MAX_RESULT_STRING_SIZE]);
```

Parameter Descriptions

- **instance** is the handle of the instance to ask for the string.
- **value** is the XrResult value to turn into a string.
- **buffer** is the buffer that will be used to return the string in.

Returns the text version of the provided XrResult value as a UTF-8 string.

In all cases the returned string must be one of:
Result String Return Values

- The literal string defined for the provide numeric value in the core spec or extension. (e.g. the value 0 results in the string XR_SUCCESS)
- XR_UNKNOWN_SUCCESS concatenated with the positive result number expressed as a decimal number.
- XR_UNKNOWN_FAILURE concatenated with the negative result number expressed as a decimal number.

Valid Usage (Implicit)

- instance must be a valid XrInstance handle
- value must be a valid XrResult value
- buffer must be a character array of length XR_MAX_RESULT_STRING_SIZE

Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST

The xrStructureTypeToString function is defined as:

XRResult xrStructureTypeToString(
    XrInstance instance,
    XrStructureType value,
    char buffer[XR_MAX_STRUCTURE_NAME_SIZE]);
Parameter Descriptions

- **instance** is the handle of the instance to ask for the string.
- **value** is the XrStructureType value to turn into a string.
- **buffer** is the buffer that will be used to return the string in.

Returns the text version of the provided XrStructureType value as a UTF-8 string.

In all cases the returned string **must** be one of:

### Structure Type String Return Values

- The literal string defined for the provide numeric value in the core spec or extension. (e.g. the value of XR_TYPE_INSTANCE_CREATE_INFO results in the string XR_TYPE_INSTANCE_CREATE_INFO)
- XR_UNKNOWN_STRUCTURE_TYPE_ concatenated with the structure type number expressed as a decimal number.

### Valid Usage (Implicit)

- **instance** **must** be a valid XrInstance handle
- **value** **must** be a valid XrStructureType value
- **buffer** **must** be a character array of length XR_MAX_STRUCTURE_NAME_SIZE

### Return Codes

**Success**
- XR_SUCCESS

**Failure**
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
Chapter 5. System

This API separates the concept of physical systems of XR devices from the logical objects that applications interact with directly. A system represents a collection of related devices in the runtime, often made up of several individual hardware components working together to enable XR experiences. An XrSystemId is returned by xrGetSystem representing the system of devices the runtime will use to support a given form factor. Each system may include: a VR/AR display, various forms of input (gamepad, touchpad, motion controller), and other trackable objects.

The application uses the system to create a session, which can then be used to accept input from the user and output rendered frames. The application also provides a default set of bindings from its actions to any number of input sources. The runtime may use this action information to activate only a subset of devices and avoid wasting resources on devices that are not in use. Exactly which devices are active once an XR system is selected will depend on the features provided by the runtime, and may vary from runtime to runtime. For example, a runtime that is capable of mapping from one tracking system's space to another’s may support devices from multiple tracking systems simultaneously.

5.1. Form Factors

The first step in selecting a system is for the application to request its desired form factor. The form factor defines how the display(s) moves in the environment relative to the user’s head and how the user will interact with the XR experience. A runtime may support multiple form factors, such as on a mobile phone that supports both slide-in VR headset experiences and handheld AR experiences.

While an application’s core XR rendering may span across form factors, its user interface will often be written to target a particular form factor, requiring explicit tailoring to function well on other form factors. For example, screen-space UI designed for a handheld phone will produce an uncomfortable experience for users if presented in screen-space on an AR headset.

```c
typedef enum XrFormFactor {
    XR_FORM_FACTOR_HEAD_MOUNTED_DISPLAY = 1,
    XR_FORM_FACTOR_HANDHELD_DISPLAY = 2,
    XR_FORM_FACTOR_MAX_ENUM = 0x7FFFFFFF
} XrFormFactor;
```

The predefined form factors which may be supported by OpenXR runtimes are:
Enumerant Descriptions

- **XR_FORM_FACTOR_HEAD_MOUNTED_DISPLAY.** The tracked display is attached to the user’s head. The user cannot touch the display itself. A VR headset would be an example of this form factor.

- **XR_FORM_FACTOR_HANDHELD_DISPLAY.** The tracked display is held in the user’s hand, independent from the user’s head. The user *may* be able to touch the display, allowing for screen-space UI. A mobile phone running an AR experience using pass-through video would be an example of this form factor.

### 5.2. Getting the XrSystemId

**XR_DEFINE_ATOM(XrSystemId)**

An XrSystemId is an opaque atom used by the runtime to identify a system. The value **XR_NULL_SYSTEM_ID** is considered an invalid system.

```c
#define XR_NULL_SYSTEM_ID 0
```

The only XrSystemId value defined to be constant across all instances is the invalid system **XR_NULL_SYSTEM_ID**. No supported system is associated with **XR_NULL_SYSTEM_ID**. Unless explicitly permitted, it **should** not be passed to API calls or used as a structure attribute when a valid XrSystemId is required.

The **xrGetSystem** function is defined as:

```c
XrResult xrGetSystem(
    XrInstance                                  instance,
    const XrSystemGetInfo*                      getInfo,
    XrSystemId*                                 systemId);
```
**Parameter Descriptions**

- `instance` is the handle of the instance from which to get the information.
- `getInfo` is a pointer to an `XrSystemGetInfo` structure containing the application’s requests for a system.
- `systemId` is the returned `XrSystemId`.

To get an `XrSystemId`, an application specifies its desired form factor to `xrGetSystem` and gets the runtime's `XrSystemId` associated with that configuration.

If the form factor is supported but temporarily unavailable, `xrGetSystem` must return `XR_ERROR/Form_FACTOR_UNAVAILABLE`. A runtime may return `XR_SUCCESS` on a subsequent call for a form factor it previously returned `XR_ERROR/Form_FACTOR_UNAVAILABLE`. For example, connecting or warming up hardware might cause an unavailable form factor to become available.

**Valid Usage (Implicit)**

- `instance` must be a valid `XrInstance` handle
- `getInfo` must be a pointer to a valid `XrSystemGetInfo` structure
- `systemId` must be a pointer to an `XrSystemId` value

**Return Codes**

**Success**
- `XR_SUCCESS`

**Failure**
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_FORM_FACTOR_UNSUPPORTED`
- `XR_ERROR_FORM_FACTOR_UNAVAILABLE`

The `XrSystemGetInfo` structure is defined as:

---

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typedef struct XrSystemGetInfo {
    XrStructureType    type;
    const void*        next;
    XrFormFactor       formFactor;
} XrSystemGetInfo;

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **formFactor** is the `XrFormFactor` requested by the application.

The `XrSystemGetInfo` structure specifies attributes about a system as desired by an application.

**Valid Usage (Implicit)**

- **type** must be `XR_TYPE_SYSTEM_GET_INFO`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- **formFactor** must be a valid `XrFormFactor` value
XrInstance instance; // previously initialized

XrSystemGetInfo system_get_info;
memset(&system_get_info, 0, sizeof(system_get_info));
system_get_info.type = XR_TYPE_SYSTEM_GET_INFO;
system_get_info.formFactor = XR_FORM_FACTOR_HEAD_MOUNTED_DISPLAY;

XrSystemId systemId;
CHK_XR(xrGetSystem(instance, &system_get_info, &systemId));

// create session
// create swapchains
// begin session

// main loop

// end session
// destroy session

// no access to hardware after this point

5.3. System Properties

The **xrGetSystemProperties** function is defined as:

```c
XrResult xrGetSystemProperties(
    XrInstance instance,  
    XrSystemId systemId,  
    XrSystemProperties* properties);
```

**Parameter Descriptions**

- **instance** is the instance from which **systemId** was retrieved.
- **systemId** is the **XrSystemId** whose properties will be queried.
- **properties** points to an instance of the **XrSystemProperties** structure, that will be filled with returned information.

An application **can** call **xrGetSystemProperties** to retrieve information about the system such as vendor ID, system name, and graphics and tracking properties.
Valid Usage (Implicit)

- instance must be a valid XrInstance handle
- properties must be a pointer to an XrSystemProperties structure

Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_SYSTEM_INVALID

The XrSystemProperties structure is defined as:

typedef struct XrSystemProperties {
    XrStructureType type;
    void* next;
    XrSystemId systemId;
    uint32_t vendorId;
    char systemName[XR_MAX_SYSTEM_NAME_SIZE];
    XrSystemGraphicsProperties graphicsProperties;
    XrSystemTrackingProperties trackingProperties;
} XrSystemProperties;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **vendorId** is a unique identifier for the vendor of the system.
- **systemId** is the `XrSystemId` identifying the system.
- **systemName** is a string containing the name of the system.
- **graphicsProperties** is an `XrSystemGraphicsProperties` structure specifying the system graphics properties.
- **trackingProperties** is an `XrSystemTrackingProperties` structure specifying system tracking properties.

Valid Usage (Implicit)

- **type** must be `XR_TYPE_SYSTEM_PROPERTIES`  
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrRenderModelCapabilitiesRequestFB`, `XrSystemColorSpacePropertiesFB`, `XrSystemEyeGazeInteractionPropertiesEXT`, `XrSystemFacialTrackingPropertiesHTC`, `XrSystemFoveatedRenderingPropertiesVARJO`, `XrSystemHandTrackingMeshPropertiesMSFT`, `XrSystemHandTrackingPropertiesEXT`, `XrSystemKeyboardTrackingPropertiesFB`, `XrSystemMarkerTrackingPropertiesVARJO`, `XrSystemPassthroughPropertiesFB`, `XrSystemRenderModelPropertiesFB`, `XrSystemSpaceWarpPropertiesFB`, `XrSystemSpatialEntityPropertiesFB`  

The `XrSystemGraphicsProperties` structure is defined as:

```c
typedef struct XrSystemGraphicsProperties {
    uint32_t maxSwapchainImageHeight;
    uint32_t maxSwapchainImageWidth;
    uint32_t maxLayerCount;
} XrSystemGraphicsProperties;
```
Member Descriptions

- `maxSwapchainImageHeight` is the maximum swapchain image pixel height supported by this system.
- `maxSwapchainImageWidth` is the maximum swapchain image pixel width supported by this system.
- `maxLayerCount` is the maximum number of composition layers supported by this system. The runtime **must** support at least `XR_MIN_COMPOSITION_LAYERS_SUPPORTED` layers.

```
#define XR_MIN_COMPOSITION_LAYERS_SUPPORTED 16
```

`XR_MIN_COMPOSITION_LAYERS_SUPPORTED` defines the minimum number of composition layers that a conformant runtime must support. A runtime **must** return the `XrSystemGraphicsProperties::maxLayerCount` at least the value of `XR_MIN_COMPOSITION_LAYERS_SUPPORTED`.

The `XrSystemTrackingProperties` structure is defined as:

```
typedef struct XrSystemTrackingProperties {
    XrBool32  orientationTracking;
    XrBool32  positionTracking;
} XrSystemTrackingProperties;
```

Member Descriptions

- `orientationTracking` is set to `XR_TRUE` to indicate the system supports orientational tracking of the view pose(s), `XR_FALSE` otherwise.
- `positionTracking` is set to `XR_TRUE` to indicate the system supports positional tracking of the view pose(s), `XR_FALSE` otherwise.
Chapter 6. Path Tree and Semantic Paths

OpenXR incorporates an internal semantic path tree model, also known as the path tree, with entities associated with nodes organized in a logical tree and referenced by path name strings structured like a filesystem path or URL. The path tree unifies a number of concepts used in this specification and a runtime may add additional nodes as implementation details. As a general design principle, the most application-facing paths should have semantic and hierarchical meaning in their name. Thus, these paths are often referred to as semantic paths. However, path names in the path tree model may not all have the same level or kind of semantic meaning.

In regular use in an application, path name strings are converted to instance-specific XrPath values which are used in place of path strings. The mapping between XrPath values and their corresponding path name strings may be considered to be tracked by the runtime in a one-to-one mapping in addition to the natural tree structure of the referenced entities. Runtimes may use any internal implementation that satisfies the requirements.

Formally, the runtime maintains an instance-specific bijective mapping between well-formed path name strings and valid XrPath (uintptr_t) values. These XrPath values are only valid within a single XrInstance, and applications must not share these values between instances. Applications must instead use the string representation of a path in their code and configuration, and obtain the correct corresponding XrPath at runtime in each XrInstance. The term path or semantic path may refer interchangeably to either the path name string or its associated XrPath value within an instance when context makes it clear which type is being discussed.

Given that path trees are a unifying model in this specification, the entities referenced by paths can be of diverse types. For example, they may be used to represent physical device or sensor components, which may be of various component types. They may also be used to represent frames of reference that are understood by the application and the runtime, as defined by an XrSpace. Additionally, to permit runtime re-configuration and support hardware-independent development, any syntactically-valid path string may be used to retrieve a corresponding XrPath without error given sufficient resources, even if no logical or hardware entity currently corresponds to that path at the time of the call. Later retrieval of the associated path string of such an XrPath using xrPathToString should succeed if the other requirements of that call are met. However, using such an XrPath in a later call to any other API function may result in an error if no entity of the type required by the call is available at the path at that later time. A runtime should permit the entity referenced by a path to vary over time to naturally reflect varying system configuration and hardware availability.

6.1. Path Atom Type

XR_DEFINE_ATOM(XrPath)
The \texttt{XrPath} is an atom that connects an application with a single path, within the context of a single instance. There is a bijective mapping between well-formed path strings and atoms in use. This atom is used—in place of the path name string it corresponds to—to retrieve state and perform other operations.

As an \texttt{XrPath} is only shorthand for a well-formed path string, they have no explicit life cycle.

Lifetime is implicitly managed by the \texttt{XrInstance}. An \texttt{XrPath} must not be used unless it is received at execution time from the runtime in the context of a particular \texttt{XrInstance}. Therefore, with the exception of \texttt{XR_NULL_PATH}, \texttt{XrPath} values must not be specified as constant values in applications: the corresponding path string should be used instead. During the lifetime of a given \texttt{XrInstance}, the \texttt{XrPath} associated with that instance with any given well-formed path must not vary, and similarly the well-formed path string that corresponds to a given \texttt{XrPath} in that instance must not vary. An \texttt{XrPath} that is received from one \texttt{XrInstance} may not be used with another. Such an invalid use may be detected and result in an error being returned, or it may result in undefined behavior.

Well-written applications should typically use a small, bounded set of paths in practice. However, the runtime should support looking up the \texttt{XrPath} for a large number of path strings for maximum compatibility. Runtime implementers should keep in mind that applications supporting diverse systems may look up path strings in a quantity exceeding the number of non-empty entities predicted or provided by any one runtime's own path tree model, and this is not inherently an error. However, system resources are finite and thus runtimes may signal exhaustion of resources dedicated to these associations under certain conditions.

When discussing the behavior of runtimes at these limits, a new \texttt{XrPath} refers to an \texttt{XrPath} value that, as of some point in time, has neither been received by the application nor tracked internally by the runtime. In this case, since an application has not yet received the value of such an \texttt{XrPath}, the runtime has not yet made any assertions about its association with any path string. In this context, new only refers to the fact that the mapping has not necessarily been made constant for a given value/path string pair for the remaining life of the associated instance by being revealed to the application. It does not necessarily imply creation of the entity, if any, referred to by such a path. Similarly, it does not imply the absence of such an entity prior to that point. Entities in the path tree have varied lifetime that is independent from the duration of the mapping from path string to \texttt{XrPath}.

For flexibility, the runtime may internally track or otherwise make constant, in instance or larger scope, any mapping of a path string to an \texttt{XrPath} value even before an application would otherwise receive that value, thus making it no longer new by the above definition.

When the runtime's resources to track the path string-\texttt{XrPath} mapping are exhausted, and the application makes an API call that would have otherwise retrieved a new \texttt{XrPath} as defined above, the runtime must return \texttt{XR_ERROR_PATH_COUNT_EXCEEDED}. This includes both explicit calls to \texttt{xrStringToPath} as well as other calls that retrieve an \texttt{XrPath} in any other way.

The runtime should support creating as many paths as memory will allow and must return \texttt{XR_ERROR_PATH_COUNT_EXCEEDED} from relevant functions when no more can be created.
The only XrPath value defined to be constant across all instances is the invalid path XR_NULL_PATH. No well-formed path string is associated with XR_NULL_PATH. Unless explicitly permitted, it should not be passed to API calls or used as a structure attribute when a valid XrPath is required.

6.2. Well-Formed Path Strings

Even though they look similar, semantic paths are not file paths. To avoid confusion with file path directory traversal conventions, many file path conventions are explicitly disallowed from well-formed path name strings.

A well-formed path name string must conform to the following rules:

- Path name strings must be constructed entirely from characters on the following list.
  - Lower case ASCII letters: a-z
  - Numeric digits: 0-9
  - Dash: -
  - Underscore: _
  - Period: .
  - Forward Slash: /
- Path name strings must start with a single forward slash character.
- Path name strings must not end with a forward slash character.
- Path name strings must not contain two or more adjacent forward slash characters.
- Path name strings must not contain two forward slash characters that are separated by only period characters.
- Path name strings must not contain only period characters following the final forward slash character in the string.
- The maximum string length for a path name string, including the terminating \0 character, is defined by XR_MAX_PATH_LENGTH.

6.2.1. xrStringToPath

The xrStringToPath function is defined as:
XrResult xrStringToPath(
    XrInstance instance,
    const char* pathString,
    XrPath* path);

Parameter Descriptions

- **instance** is an instance previously created.
- **pathString** is the path name string to retrieve the associated XrPath for.
- **path** is the output parameter, which must point to an XrPath. Given a well-formed path name string, this will be populated with an opaque value that is constant for that path string during the lifetime of that instance.

xrStringToPath retrieves the XrPath value for a well-formed path string. If such a value had not yet been assigned by the runtime to the provided path string in this XrInstance, one must be assigned at this point. All calls to this function with the same XrInstance and path string must retrieve the same XrPath value. Upon failure, xrStringToPath must return an appropriate XrResult, and may set the output parameter to XR_NULL_PATH. See Path Atom Type for the conditions under which an error may be returned when this function is given a valid XrInstance and a well-formed path string.

If the runtime’s resources are exhausted and it cannot create the path, a return value of XR_ERROR_PATH_COUNT_EXCEEDED must be returned. If the application specifies a string that is not a well-formed path string, XR_ERROR_PATH_FORMAT_INVALID must be returned.

A return value of XR_SUCCESS from xrStringToPath may not necessarily imply that the runtime has a component or other source of data that will be accessible through that semantic path. It only means that the path string supplied was well-formed and that the retrieved XrPath maps to the given path string within and during the lifetime of the XrInstance given.

Valid Usage (Implicit)

- **instance** must be a valid XrInstance handle
- **pathString** must be a null-terminated UTF-8 string
- **path** must be a pointer to an XrPath value
Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_PATH_FORMAT_INVALID
- XR_ERROR_PATH_COUNT_EXCEEDED

6.2.2. xrPathToString

```c
XrResult xrPathToString(
    XrInstance                                  instance,
    XrPath                                      path,
    uint32_t                                    bufferCapacityInput,
    uint32_t*                                   bufferCountOutput,
    char*                                       buffer);
```

Parameter Descriptions

- `instance` is an instance previously created.
- `path` is the valid XrPath value to retrieve the path string for.
- `bufferCapacityInput` is the capacity of the buffer, or 0 to indicate a request to retrieve the required capacity.
- `bufferCountOutput` is a pointer to the count of characters written (including the terminating \0), or a pointer to the required capacity in the case that `bufferCapacityInput` is insufficient.
- `buffer` is a pointer to an application-allocated buffer that will be filled with the semantic path string. It can be NULL if `bufferCapacityInput` is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required buffer size.

xrPathToString retrieves the path name string associated with an XrPath, in the context of a given
XrInstance, in the form of a NULL terminated string placed into a caller-allocated buffer. Since the mapping between a well-formed path name string and an XrPath is bijective, there will always be exactly one string for each valid XrPath value. This can be useful if the calling application receives an XrPath value that they had not previously retrieved via xrStringToPath. During the lifetime of the given XrInstance, the path name string retrieved by this function for a given valid XrPath will not change. For invalid paths, including XR_NULL_PATH, XR_ERROR_PATH_INVALID must be returned.

### Valid Usage (Implicit)
- **instance** must be a valid XrInstance handle
- **bufferCountOutput** must be a pointer to a uint32_t value
- If **bufferCapacityInput** is not 0, **buffer** must be a pointer to an array of bufferCapacityInput char values

### Return Codes

**Success**
- XR_SUCCESS

**Failure**
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_PATH_INVALID

### 6.3. Reserved Paths

In order for some uses of semantic paths to work consistently across runtimes, it is necessary to standardize several paths and require each runtime to use the same paths or patterns of paths for certain classes of usage. Those paths are as follows.

#### 6.3.1. /user paths

Some paths are used to refer to entities that are filling semantic roles in the system. These paths are all under the /user subtree.

The reserved user paths are:
Reserved Semantic Paths

- `/user/hand/left` represents the user’s left hand. It might be tracked using a controller or other device in the user’s left hand, or tracked without the user holding anything, e.g. using computer vision.
- `/user/hand/right` represents the user’s right hand in analog to the left hand.
- `/user/head` represents inputs on the user’s head, often from a device such as a head-mounted display. To reason about the user’s head, see the `XR_REFERENCE_SPACE_TYPE_VIEW` reference space.
- `/user/gamepad` is a two-handed gamepad device held by the user.
- `/user/treadmill` is a treadmill or other locomotion-targeted input device.

Runtimes are not required to provide interaction at all of these paths. For instance, in a system with no hand tracking, only `/user/head` would be active for interaction. In a system with only one controller, the runtime may provide access to that controller via either `/user/hand/left` or `/user/hand/right` as it deems appropriate.

The runtime may change the devices referred to by `/user/hand/left` and `/user/hand/right` at any time.

If more than two hand-held controllers or devices are active, the runtime must determine which two are accessible as `/user/hand/left` and `/user/hand/right`.

6.3.2. Input subpaths

Devices on the source side of the input system need to define paths for each component that can be bound to an action. This section describes the naming conventions for those input components. Runtimes must ignore input source paths that use identifiers and component names that do not appear in this specification or otherwise do not follow the pattern specified below.

Each input source path must match the following pattern:

- `.../input/<identifier>[_<location>][/<component>]`

Identifiers are often the label on the component or related to the type and location of the component.

When specifying a suggested binding there are several cases where the component part of the path can be determined automatically. See Suggested Bindings for more details.

See Interaction Profiles for examples of input subpaths.

Standard identifiers

- trackpad - A 2D input source that usually includes click and touch component.
- thumbstick - A small 2D joystick that is meant to be used with the user’s thumb. These sometimes
include click and/or touch components.

- joystick - A 2D joystick that is meant to be used with the user’s entire hand, such as a flight stick. These generally do not have click component, but might have touch components.

- trigger - A 1D analog input component that returns to a rest state when the user stops interacting with it. These sometime include touch and/or click components.

- throttle - A 1D analog input component that remains in position when the user stops interacting with it.

- trackball - A 2D relative input source. These sometimes include click components.

- pedal - A 1D analog input component that is similar to a trigger but meant to be operated by a foot

- system - A button with the specialised meaning that it enables the user to access system-level functions and UI. Input data from system buttons is generally used internally by runtimes and may not be available to applications.

- dpad_up, dpad_down, dpad_left, and dpad_right - A set of buttons arranged in a plus shape.

- diamond_up, diamond_down, diamond_left, and diamond_right - Gamepads often have a set of four buttons arranged in a diamond shape. The labels on those buttons vary from gamepad to gamepad, but their arrangement is consistent. These names are used for the A/B/X/Y buttons on a Xbox controller, and the square/cross/circle/triangle button on a PlayStation controller.

- a, b, x, y, start, home, end, select - Standalone buttons are named for their physical labels. These are the standard identifiers for such buttons. Extensions may add new identifiers as detailed in the next section. Groups of four buttons in a diamond shape should use the diamond-prefix names above instead of using the labels on the buttons themselves.

- volume_up, volume_down, mute_mic, play_pause, menu, view, back - Some other standard controls are often identified by icons. These are their standard names.

- thumbrest - Some controllers have a place for the user to rest their thumb.

- shoulder - A button that is usually pressed with the index finger and is often positioned above a trigger.

- squeeze - An input source that indicates that the user is squeezing their fist closed. This could be a simple button or act more like a trigger. Sources with this identifier should either follow button or trigger conventions for their components.

- wheel - A steering wheel.

**Standard pose identifiers**

Input sources whose orientation and/or position are tracked also expose pose identifiers.

Standard pose identifiers for tracked hands or motion controllers as represented by /user/hand/left and /user/hand/right are:
• grip - A pose that allows applications to reliably render a virtual object held in the user's hand, whether it is tracked directly or by a motion controller. The grip pose is defined as follows:

  ◦ The grip position:
    ▪ For tracked hands: The user's palm centroid when closing the fist, at the surface of the palm.
    ▪ For handheld motion controllers: A fixed position within the controller that generally lines up with the palm centroid when held by a hand in a neutral position. This position should be adjusted left or right to center the position within the controller's grip.

  ◦ The grip orientation's +X axis: When you completely open your hand to form a flat 5-finger pose, the ray that is normal to the user's palm (away from the palm in the left hand, into the palm in the right hand).

  ◦ The grip orientation's -Z axis: When you close your hand partially (as if holding the controller), the ray that goes through the center of the tube formed by your non-thumb fingers, in the direction of little finger to thumb.

  ◦ The grip orientation's +Y axis: orthogonal to +Z and +X using the right-hand rule.

• aim - A pose that allows applications to point in the world using the input source, according to the platform’s conventions for aiming with that kind of source. The aim pose is defined as follows:

  ◦ For tracked hands: The ray that follows platform conventions for how the user aims at objects in the world with their entire hand, with +Y up, +X to the right, and -Z forward. The ray chosen will be runtime-dependent, for example, a ray emerging from the palm parallel to the forearm.

  ◦ For handheld motion controllers: The ray that follows platform conventions for how the user targets objects in the world with the motion controller, with +Y up, +X to the right, and -Z
forward. This is usually for applications that are rendering a model matching the physical controller, as an application rendering a virtual object in the user's hand likely prefers to point based on the geometry of that virtual object. The ray chosen will be runtime-dependent, although this will often emerge from the frontmost tip of a motion controller.

**Note**

When the `XR_EXT_palm_pose` extension is available and enabled, an additional "palm_ext" standard pose identifier is available, and a path is added to all interaction profiles valid for `/user/hand/left` or `/user/hand/right`. This includes interaction profiles defined in the core spec and in extensions. See the extension for details.

**Standard locations**

When a single device contains multiple input sources that use the same identifier, a location suffix is added to create a unique identifier for that input source.

Standard locations are:

- left
- right
- left_upper
- left_lower
- right_upper
- right_lower
- upper
- lower

**Standard components**

Components are named for the specific boolean, scalar, or other value of the input source. Standard components are:

- **click** - A physical switch has been pressed by the user. This is valid for all buttons, and is common for trackpads, thumbsticks, triggers, and dpads. "click" components are always boolean.

- **touch** - The user has touched the input source. This is valid for all trackpads, and **may** be present for any other kind of input source if the device includes the necessary sensor. "touch" components are always boolean.

- **force** - A 1D scalar value that represents the user applying force to the input. It varies from 0 to 1, with 0 being the rest state. This is present for any input source with a force sensor.

- **value** - A 1D scalar value that varies from 0 to 1, with 0 being the rest state. This is present for...
triggers, throttles, and pedals. It may also be present for squeeze or other components.

- x, y - scalar components of 2D values. These vary in value from -1 to 1. These represent the 2D position of the input source with 0 being the rest state on each axis. -1 means all the way left for x axis or all the way down for y axis. +1 means all the way right for x axis or all the way up for y axis. x and y components are present for trackpads, thumbsticks, and joysticks.

- twist - Some sources, such as flight sticks, have a sensor that allows the user to twist the input left or right. For this component -1 means all the way left and 1 means all the way right.

- pose - The orientation and/or position of this input source. This component may exist for dedicated pose identifiers like grip and aim, or may be defined on other identifiers such as trackpad to let applications reason about the surface of that part.

**Output paths**

Many devices also have subpaths for output features such as haptics. The runtime must ignore output component paths that do not follow the pattern:

- `.../output/<output_identifier>[_<location>]`

Standard output identifiers are:

- haptic - A haptic element like an LRA (Linear Resonant Actuator) or vibration motor

Devices which contain multiple haptic elements with the same output identifier must use a location suffix as specified above.

### 6.3.3. Adding input sources via extensions

Extensions may enable input source path identifiers, output source path identifiers, and component names that are not included in the core specification, subject to the following conditions:

- EXT extensions must include the _ext suffix on any identifier or component name. E.g. `.../input/newidentifier_ext/newcomponent_ext`

- Vendor extensions must include the vendor’s tag as a suffix on any identifier or component name. E.g. `.../input/newidentifier_vendor/newcomponent_vendor` (where "vendor" is replaced with the vendor’s actual extension tag.)

- Khronos (KHR) extensions may add undecorated identifier or component names.

These rules are in place to prevent extensions from adding first class undecorated names that become defacto standards. Runtimes must ignore input source paths that do not follow the restrictions above.

Extensions may also add new location suffixes, and may do so by adding a new identifier and location combination using the appropriate suffix. E.g. `.../input/newidentifier_newlocation_ext`
6.4. Interaction Profile Paths

An interaction profile path identifies a collection of buttons and other input sources in a physical arrangement to allow applications and runtimes to coordinate action bindings.

Interaction profile paths are of the form:

- /interaction_profiles/<vendor_name>/<type_name>

Note

When the XR_EXT_palm_pose extension is available and enabled, an additional input component path is added to all core interaction profiles valid for /user/hand/left or /user/hand/right. See the extension for more details.

6.4.1. Khronos Simple Controller Profile

Path: /interaction_profiles/khr/simple_controller

Valid for user paths:

- /user/hand/left
- /user/hand/right

This interaction profile provides basic pose, button, and haptic support for applications with simple input needs. There is no hardware associated with the profile, and runtimes which support this profile should map the input paths provided to whatever the appropriate paths are on the actual hardware.

Supported component paths:

- ../input/select/click
- ../input/menu/click
- ../input/grip/pose
- ../input/aim/pose
- ../output/haptic

6.4.2. Google Daydream Controller Profile

Path: /interaction_profiles/google/daydream_controller

Valid for user paths:

- /user/hand/left
• /user/hand/right

This interaction profile represents the input sources on the Google Daydream Controller.

Supported component paths:

• .../input/select/click
• .../input/trackpad/x
• .../input/trackpad/y
• .../input/trackpad/click
• .../input/trackpad/touch
• .../input/grip/pose
• .../input/aim/pose

6.4.3. HTC Vive Controller Profile

Path: /interaction_profiles/htc/vive_controller

Valid for user paths:

• /user/hand/left
• /user/hand/right

This interaction profile represents the input sources and haptics on the Vive Controller.

Supported component paths:

• .../input/system/click (may not be available for application use)
• .../input/squeeze/click
• .../input/menu/click
• .../input/trigger/click
• .../input/trigger/value
• .../input/trackpad/x
• .../input/trackpad/y
• .../input/trackpad/click
• .../input/trackpad/touch
• .../input/grip/pose
• .../input/aim/pose
• .../output/haptic
6.4.4. HTC Vive Pro Profile

Path: /interaction_profiles/htc/vive_pro

Valid for user paths:

- /user/head

This interaction profile represents the input sources on the Vive Pro headset.

Supported component paths:

- .../input/system/click (may not be available for application use)
- .../input/volume_up/click
- .../input/volume_down/click
- .../input/mute_mic/click

6.4.5. Microsoft Mixed Reality Motion Controller Profile

Path: /interaction_profiles/microsoft/motion_controller

Valid for user paths:

- /user/hand/left
- /user/hand/right

This interaction profile represents the input sources and haptics on the Microsoft Mixed Reality Controller.

Supported component paths:

- .../input/menu/click
- .../input/squeeze/click
- .../input/trigger/value
- .../input/thumbstick/x
- .../input/thumbstick/y
- .../input/thumbstick/click
- .../input/trackpad/x
- .../input/trackpad/y
- .../input/trackpad/click
- .../input/trackpad/touch
- .../input/grip/pose
• .../input/aim/pose
• .../output/haptic

6.4.6. Microsoft Xbox Controller Profile

Path: /interaction_profiles/microsoft/xbox_controller

Valid for user paths:
• /user/gamepad

This interaction profile represents the input sources and haptics on the Microsoft Xbox Controller.

Supported component paths:
• .../input/menu/click
• .../input/view/click
• .../input/a/click
• .../input/b/click
• .../input/x/click
• .../input/y/click
• .../input/dpad_down/click
• .../input/dpad_right/click
• .../input/dpad_up/click
• .../input/dpad_left/click
• .../input/shoulder_left/click
• .../input/shoulder_right/click
• .../input/thumbstick_left/click
• .../input/thumbstick_right/click
• .../input/trigger_left/value
• .../input/trigger_right/value
• .../input/thumbstick_left/x
• .../input/thumbstick_left/y
• .../input/thumbstick_right/x
• .../input/thumbstick_right/y
• .../output/haptic_left
• .../output/haptic_right
• \texttt{/output/haptic\_left\_trigger}

• \texttt{/output/haptic\_right\_trigger}

6.4.7. Oculus Go Controller Profile

Path: \texttt{/interaction\_profiles/oculus/go\_controller}

Valid for user paths:

• \texttt{/user/hand/left}

• \texttt{/user/hand/right}

This interaction profile represents the input sources on the Oculus Go controller.

Supported component paths:

• \texttt{.../input/system/click} (may not be available for application use)

• \texttt{.../input/trigger/click}

• \texttt{.../input/back/click}

• \texttt{.../input/trackpad/x}

• \texttt{.../input/trackpad/y}

• \texttt{.../input/trackpad/click}

• \texttt{.../input/trackpad/touch}

• \texttt{.../input/grip/pose}

• \texttt{.../input/aim/pose}

6.4.8. Oculus Touch Controller Profile

Path: \texttt{/interaction\_profiles/oculus/touch\_controller}

Valid for user paths:

• \texttt{/user/hand/left}

• \texttt{/user/hand/right}

This interaction profile represents the input sources and haptics on the Oculus Touch controller.

Supported component paths:

• On \texttt{/user/hand/left} only:
  
  • \texttt{.../input/x/click}

  • \texttt{.../input/x/touch}

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.../input/y/click
.../input/y/touch
.../input/menu/click

• On /user/hand/right only:
  ◦ .../input/a/click
  ◦ .../input/a/touch
  ◦ .../input/b/click
  ◦ .../input/b/touch
  ◦ .../input/system/click *(may not be available for application use)*

• .../input/squeeze/value
• .../input/trigger/value
• .../input/trigger/touch
• .../input/thumbstick/x
• .../input/thumbstick/y
• .../input/thumbstick/click
• .../input/thumbstick/touch
• .../input/thumbrest/touch
• .../input/grip/pose
• .../input/aim/pose
• .../output/haptic

### 6.4.9. Valve Index Controller Profile

Path: /interaction_profiles/valve/index_controller

Valid for user paths:

• /user/hand/left
• /user/hand/right

This interaction profile represents the input sources and haptics on the Valve Index controller.

Supported component paths:

• .../input/system/click *(may not be available for application use)*
• .../input/system/touch *(may not be available for application use)*
• .../input/a/click
• .../input/a/touch
• .../input/b/click
• .../input/b/touch
• .../input/squeeze/value
• .../input/squeeze/force
• .../input/trigger/click
• .../input/trigger/value
• .../input/trigger/touch
• .../input/thumbstick/x
• .../input/thumbstick/y
• .../input/thumbstick/click
• .../input/thumbstick/touch
• .../input/trackpad/x
• .../input/trackpad/y
• .../input/trackpad/force
• .../input/trackpad/touch
• .../input/grip/pose
• .../input/aim/pose
• .../output/haptic
Chapter 7. Spaces

Across both virtual reality and augmented reality, XR applications have a core need to map the location of virtual objects to the corresponding real-world locations where they will be rendered. **Spaces** allow applications to explicitly create and specify the frames of reference in which they choose to track the real world, and then determine how those frames of reference move relative to one another over time.

**XR_DEFINE_HANDLE(XrSpace)**

Spaces are represented by **XrSpace** handles, which the application creates and then uses in API calls. Whenever an application calls a function that returns coordinates, it provides an **XrSpace** to specify the frame of reference in which those coordinates will be expressed. Similarly, when providing coordinates to a function, the application specifies which **XrSpace** the runtime should use to interpret those coordinates.

OpenXR defines a set of well-known **reference spaces** that applications use to bootstrap their spatial reasoning. These reference spaces are: **VIEW**, **LOCAL** and **STAGE**. Each reference space has a well-defined meaning, which establishes where its origin is positioned and how its axes are oriented.

Runtimes whose tracking systems improve their understanding of the world over time may track spaces independently. For example, even though a **LOCAL** space and a **STAGE** space each map their origin to a static position in the world, a runtime with an inside-out tracking system may introduce slight adjustments to the origin of each space on a continuous basis to keep each origin in place.

Beyond well-known reference spaces, runtimes expose other independently-tracked spaces, such as a pose action space that tracks the pose of a motion controller over time.

When one or both spaces are tracking a dynamic object, passing in an updated time to **xrLocateSpace** each frame will result in an updated relative pose. For example, the location of the left hand’s pose action space in the **STAGE** reference space will change each frame as the user’s hand moves relative to the stage’s predefined origin on the floor. In other XR APIs, it is common to report the "pose" of an object relative to some presumed underlying global space. This API is careful to not explicitly define such an underlying global space, because it does not apply to all systems. Some systems will support no **STAGE** space, while others may support a **STAGE** space that switches between various physical stages with dynamic availability. To satisfy this wide variability, "poses" are always described as the relationship between two spaces.

Some devices improve their understanding of the world as the device is used. The location returned by **xrLocateSpace** in later frames may change over time, even for spaces that track static objects, as either the target space or base space adjusts its origin.

Composition layers submitted by the application include an **XrSpace** for the runtime to use to position that layer over time. Composition layers whose **XrSpace** is relative to the **VIEW** reference space are
implicitly "head-locked", even if they may not be "display-locked" for non-head-mounted form factors.

7.1. Reference Spaces

An XrSpace handle for a reference space is created using xrCreateReferenceSpace, by specifying the chosen reference space type and a pose within the natural reference frame defined for that reference space type.

Runtimes implement well-known reference spaces from XrReferenceSpaceType if they support tracking of that kind:

```c
typedef enum XrReferenceSpaceType {
    XR_REFERENCE_SPACE_TYPE_VIEW = 1,
    XR_REFERENCE_SPACE_TYPE_LOCAL = 2,
    XR_REFERENCE_SPACE_TYPE_STAGE = 3,
    XR_REFERENCE_SPACE_TYPE_UNBOUNDDED_MSFT = 100038000,
    XR_REFERENCE_SPACE_TYPE_COMBINED_EYE_VARJO = 1000121000,
    XR_REFERENCE_SPACE_TYPE_MAX_ENUM = 0x7FFFFFFF
} XrReferenceSpaceType;
```

Available reference space types are indicated by xrEnumerateReferenceSpaces. Note that other spaces can be created as well, such as pose action spaces created by xrCreateActionSpace, which are not enumerated by that API.
Enumerant Descriptions

- **XR_REFERENCE_SPACE_TYPE_VIEW.** The VIEW space tracks the view origin used to generate view transforms for the primary viewer (or centroid of view origins if stereo), with \(+Y\) up, \(+X\) to the right, and \(-Z\) forward. This space points in the forward direction for the viewer without incorporating the user's eye orientation, and is not gravity-aligned.

  VIEW space is primarily useful when projecting from the user’s perspective into another space to obtain a targeting ray, or when rendering small head-locked content such as a reticle. Content rendered in VIEW space will stay at a fixed point on head-mounted displays and may be uncomfortable to view if too large. To obtain the ideal view and projection transforms to use each frame for rendering world content, applications should call `xrLocateViews` instead of using this space.

  Runtimes **must** support this reference space.

- **XR_REFERENCE_SPACE_TYPE_LOCAL.** The LOCAL reference space establishes a world-locked origin, gravity-aligned to exclude pitch and roll, with \(+Y\) up, \(+X\) to the right, and \(-Z\) forward. This space locks in both its initial position and orientation, which the runtime **may** define to be either the initial position at application launch or some other calibrated zero position.

  LOCAL space is useful when an application needs to render seated-scale content that is not positioned relative to the physical floor.

  When a user needs to recenter LOCAL space, a runtime **may** offer some system-level recentering interaction that is transparent to the application, but which causes the current leveled head space to become the new LOCAL space. When such a recentering occurs, the runtime **must** queue the `XrEventDataReferenceSpaceChangePending` event, with the recentered LOCAL space origin only taking effect for `xrLocateSpace` or `xrLocateViews` calls whose `XrTime` parameter is greater than or equal to the `changeTime` provided in that event.

  When views, controllers or other spaces experience tracking loss relative to the LOCAL space, runtimes **should** continue to provide inferred or last-known position and orientation values. These inferred poses can, for example, be based on neck model updates, inertial dead reckoning, or a last-known position, so long as it is still reasonable for the application to use that pose. While a runtime is providing position data, it **must** continue to set `XR_SPACE_LOCATION_POSITION_VALID_BIT` and `XR_VIEW_STATE_POSITION_VALID_BIT` but it **can** clear `XR_SPACE_LOCATION_POSITION_TRACKED_BIT` and `XR_VIEW_STATE_POSITION_TRACKED_BIT` to indicate that the position is inferred or last-known in this way.

  When tracking is recovered, runtimes **should** snap the pose of other spaces back into position relative to the LOCAL space's original origin.

  Runtimes **must** support this reference space.

- **XR_REFERENCE_SPACE_TYPE_STAGE.** The STAGE reference space is a runtime-defined flat,
rectangular space that is empty and can be walked around on. The origin is on the floor at the center of the rectangle, with +Y up, and the X and Z axes aligned with the rectangle edges. The runtime may not be able to locate spaces relative to the stage reference space if the user has not yet defined one within the runtime-specific UI. Applications can use `xrGetReferenceSpaceBoundsRect` to determine the extents of the stage reference space's XZ bounds rectangle, if defined.

Stage space is useful when an application needs to render standing-scale content (no bounds) or room-scale content (with bounds) that is relative to the physical floor.

When the user redefines the origin or bounds of the current stage space, or the runtime otherwise switches to a new stage definition, the runtime must queue the `XrEventDataReferenceSpaceChangePending` event, with the new stage space origin only taking effect for `xrLocateSpace` or `xrLocateViews` calls whose `XrTime` parameter is greater than or equal to the `changeTime` provided in that event.

When views, controllers or other spaces experience tracking loss relative to the stage space, runtimes should continue to provide inferred or last-known position and orientation values. These inferred poses can, for example, be based on neck model updates, inertial dead reckoning, or a last-known position, so long as it is still reasonable for the application to use that pose. While a runtime is providing position data, it must continue to set `XR_SPACE_LOCATION_POSITION_VALID_BIT` and `XR_VIEW_STATE_POSITION_VALID_BIT`. It can clear `XR_SPACE_LOCATION_POSITION_TRACKED_BIT` and `XR_VIEW_STATE_POSITION_TRACKED_BIT` to indicate that the position is inferred or last-known in this way.

When tracking is recovered, runtimes should snap the pose of other spaces back into position relative to the stage space's original origin.

XR systems may have limited real world spatial ranges in which users can freely move around while remaining tracked. Applications may wish to query these boundaries and alter application behavior or content placement to ensure the user can complete the experience while remaining within the boundary. Applications can query this information using `xrGetReferenceSpaceBoundsRect`.

When called, `xrGetReferenceSpaceBoundsRect` should return the extents of a rectangle that is clear of obstacles down to the floor, allowing where the user can freely move while remaining tracked, if available for that reference space. The returned extent represents the dimensions of an axis-aligned bounding box where the `XrExtent2Df::width` and `XrExtent2Df::height` fields correspond to the X and Z axes of the provided space, with the extents centered at the origin of the space. Not all systems or spaces may support boundaries. If a runtime is unable to provide bounds for a given space, `XR_SPACE_BOUNDS_UNAVAILABLE` will be returned and all fields of `bounds` will be set to 0.

The returned extents are expressed relative to the natural origin of the provided `XrReferenceSpaceType` and must not incorporate any origin offsets specified by the application during calls to `xrCreateReferenceSpace`. 
The runtime must return XR_ERROR_REFERENCE_SPACE_UNSUPPORTED if the XrReferenceSpaceType passed in createInfo is not supported by this session.

When a runtime will begin operating with updated space bounds, the runtime must queue a corresponding XrEventDataReferenceSpaceChangePending event.

```c
XrResult xrGetReferenceSpaceBoundsRect(
    XrSession session,
    XrReferenceSpaceType referenceSpaceType,
    XrExtent2Df* bounds);
```

**Parameter Descriptions**

- **type** is the XrStructureType of this structure.
- **session** is a handle to an XrSession previously created with xrCreateSession.
- **referenceSpaceType** is the reference space type whose bounds should be retrieved.
- **bounds** is the returned space extents.

**Valid Usage (Implicit)**

- **session** must be a valid XrSession handle
- **referenceSpaceType** must be a valid XrReferenceSpaceType value
- **bounds** must be a pointer to an XrExtent2Df structure
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING
• XR_SPACE_BOUNDS_UNAVAILABLE

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_REFERENCE_SPACE_UNSUPPORTED

The XrEventDataReferenceSpaceChangePending event is sent to the application to notify it that the origin (and perhaps the bounds) of a reference space is changing. This may occur due to the user recentering the space explicitly, or the runtime otherwise switching to a different space definition.

The reference space change must only take effect for xrLocateSpace or xrLocateViews calls whose XrTime parameter is greater than or equal to the changeTime provided in that event. Runtimes should provide a changeTime to applications that allows for a deep render pipeline to present frames that are already in flight using the previous definition of the space. Runtimes should choose a changeTime that is midway between the displayTime of future frames to avoid threshold issues with applications that calculate future frame times using displayPeriod.

The pose provided here must only describe the change in the natural origin of the reference space and must not incorporate any origin offsets specified by the application during calls to xrCreateReferenceSpace. If the runtime does not know the location of the space's new origin relative to its previous origin, poseValid must be false, and the position and orientation of poseInPreviousSpace are undefined.
typedef struct XrEventDataReferenceSpaceChangePending {
    XrStructureType         type;
    const void*             next;
    XrSession               session;
    XrReferenceSpaceType    referenceSpaceType;
    XrTime                  changeTime;
    XrBool32                poseValid;
    XrPosef                 poseInPreviousSpace;
} XrEventDataReferenceSpaceChangePending;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **session** is the XrSession for which the reference space is changing.
- **referenceSpaceType** is the XrReferenceSpaceType that is changing.
- **changeTime** is the target XrTime after which xrLocateSpace or xrLocateViews will return values that respect this change.
- **poseValid** is true if the runtime can determine the pose of the new space in the previous space before the change.
- **poseInPreviousSpace** is an XrPosef defining the position and orientation of the new reference space's natural origin within the natural reference frame of its previous space.

**Valid Usage (Implicit)**

- **type** must be XR_TYPE_EVENT_DATA_REFERENCE_SPACE_CHANGE_PENDING
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **session** must be a valid XrSession handle
- **referenceSpaceType** must be a valid XrReferenceSpaceType value

### 7.2. Action Spaces

An XrSpace handle for a pose action is created using xrCreateActionSpace, by specifying the chosen pose action and a pose within the action's natural reference frame.

Runtimes support suggested pose action bindings to well-known user paths with .../pose subpaths if they support tracking for that particular identifier.
Some example well-known pose action paths:

- `/user/hand/left/input/grip`
- `/user/hand/left/input/aim`
- `/user/hand/right/input/grip`
- `/user/hand/right/input/aim`

For definitions of these well-known pose device paths, see the discussion of device input subpaths in the Semantic Paths chapter.

### 7.2.1. Action Spaces Lifetime

**XrSpace** handles created for a pose action **must** be unlocatable unless the action set that contains the corresponding pose action was set as active via the most recent **xrSyncActions** call. If the underlying device that is active for the action changes, the device this space is tracking **must** only change to track the new device when **xrSyncActions** is called.

If **xrLocateSpace** is called with an unlocatable action space, the implementation **must** return no position or orientation and both **XR_SPACE_LOCATION_POSITION_VALID_BIT** and **XR_SPACE_LOCATION_ORIENTATION_VALID_BIT** **must** be unset. If **XrSpaceVelocity** is also supplied, **XR_SPACE_VELOCITY_LINEAR_VALID_BIT** and **XR_SPACE_VELOCITY_ANGULAR_VALID_BIT** **must** be unset. If **xrLocateViews** is called with an unlocatable action space, the implementation **must** return no position or orientation and both **XR_VIEW_STATE_POSITION_VALID_BIT** and **XR_VIEW_STATE_ORIENTATION_VALID_BIT** **must** be unset.

### 7.3. Space Lifecycle

There are a small set of core APIs that allow applications to reason about reference spaces, action spaces, and their relative locations.

#### 7.3.1. xrEnumerateReferenceSpaces

The **xrEnumerateReferenceSpaces** function is defined as:

```c
XrResult xrEnumerateReferenceSpaces(  
    XrSession session,  
    uint32_t spaceCapacityInput,  
    uint32_t* spaceCountOutput,  
    XrReferenceSpaceType* spaces);  
```
Parameter Descriptions

- **session** is a handle to an XrSession previously created with xrCreateSession.
- **spaceCapacityInput** is the capacity of the spaces array, or 0 to indicate a request to retrieve the required capacity.
- **spaceCountOutput** is a pointer to the count of spaces written, or a pointer to the required capacity in the case that spaceCapacityInput is insufficient.
- **spaces** is a pointer to an application-allocated array that will be filled with the enumerant of each supported reference space. It can be NULL if spaceCapacityInput is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required spaces size.

Enumerates the set of reference space types that this runtime supports for a given session. Runtimes must always return identical buffer contents from this enumeration for the lifetime of the session.

If a session enumerates support for a given reference space type, calls to xrCreateReferenceSpace must succeed for that session, with any transient unavailability of poses expressed later during calls to xrLocateSpace.

Valid Usage (Implicit)

- **session** must be a valid XrSession handle
- **spaceCountOutput** must be a pointer to a uint32_t value
- If spaceCapacityInput is not 0, **spaces** must be a pointer to an array of spaceCapacityInput XrReferenceSpaceType values
### Return Codes

**Success**
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_SIZE_INSUFFICIENT

### 7.3.2. `xrCreateReferenceSpace`

The `xrCreateReferenceSpace` function is defined as:

```c
XrResult xrCreateReferenceSpace(
    XrSession session, 
    const XrReferenceSpaceCreateInfo* createInfo, 
    XrSpace* space);
```

#### Parameter Descriptions

- `session` is a handle to an `XrSession` previously created with `xrCreateSession`.
- `createInfo` is the `XrReferenceSpaceCreateInfo` used to specify the space.
- `space` is the returned space handle.

Creates an `XrSpace` handle based on a chosen reference space. Application can provide an `XrPosef` to define the position and orientation of the new space's origin within the natural reference frame of the reference space.

Multiple `XrSpace` handles may exist simultaneously, up to some limit imposed by the runtime. The `XrSpace` handle must be eventually freed via the `xrDestroySpace` function.

The runtime must return XR_ERROR_REFERENCE_SPACE_UNSUPPORTED if the given reference space type is not
Valid Usage (Implicit)

- **session** must be a valid `XrSession` handle
- **createInfo** must be a pointer to a valid `XrReferenceSpaceCreateInfo` structure
- **space** must be a pointer to an `XrSpace` handle

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_LIMIT_REACHED`
- `XR_ERROR_REFERENCE_SPACE_UNSUPPORTED`
- `XR_ERROR_POSE_INVALID`

The `XrReferenceSpaceCreateInfo` structure is defined as:

```c
typedef struct XrReferenceSpaceCreateInfo {
    XrStructureType         type;
    const void*             next;
    XrReferenceSpaceType    referenceSpaceType;
    XrPosef                 poseInReferenceSpace;
} XrReferenceSpaceCreateInfo;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **referenceSpaceType** is the chosen XrReferenceSpaceType.
- **poseInReferenceSpace** is an XrPosef defining the position and orientation of the new space’s origin within the natural reference frame of the reference space.

Valid Usage (Implicit)

- **type** must be XR_TYPE_REFERENCE_SPACE_CREATE_INFO
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **referenceSpaceType** must be a valid XrReferenceSpaceType value

7.3.3. xrCreateActionSpace

The `xrCreateActionSpace` function is defined as:

```
XrResult xrCreateActionSpace(
    XrSession session,
    const XrActionSpaceCreateInfo* createInfo,
    XrSpace* space);
```

Parameter Descriptions

- **session** is the XrSession to create the action space in.
- **createInfo** is the XrActionSpaceCreateInfo used to specify the space.
- **space** is the returned space handle.

Creates an XrSpace handle based on a chosen pose action. Application can provide an XrPosef to define the position and orientation of the new space’s origin within the natural reference frame of the action space.

Multiple XrSpace handles may exist simultaneously, up to some limit imposed by the runtime. The XrSpace handle must be eventually freed via the xrDestroySpace function or by destroying the parent
The runtime must return XR_ERROR_ACTION_TYPE_MISMATCH if the action provided in `action` is not of type XR_ACTION_TYPE_POSE_INPUT.

### Valid Usage (Implicit)

- `session` must be a valid `XrSession` handle
- `createInfo` must be a pointer to a valid `XrActionSpaceCreateInfo` structure
- `space` must be a pointer to an `XrSpace` handle

### Return Codes

#### Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

#### Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_POSE_INVALID
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_PATH_INVALID
- XR_ERROR_ACTION_TYPE_MISMATCH

The `XrActionSpaceCreateInfo` structure is defined as:
typedef struct XrActionSpaceCreateInfo {
    XrStructureType    type;
    const void*        next;
    XrAction           action;
    XrPath             subactionPath;
    XrPosef            poseInActionSpace;
} XrActionSpaceCreateInfo;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **action** is a handle to a pose XrAction previously created with xrCreateAction.
- **subactionPath** is XR_NULL_PATH or an XrPath that was specified when the action was created. If subactionPath is a valid path not specified when the action was created the runtime must return XR_ERROR_PATH_UNSUPPORTED. If this parameter is set, the runtime must create a space that is relative to only that subaction’s pose binding.
- **poseInActionSpace** is an XrPosef defining the position and orientation of the new space’s origin within the natural reference frame of the pose action.

**Valid Usage (Implicit)**

- **type** must be XR_TYPE_ACTION_SPACE_CREATE_INFO
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **action** must be a valid XrAction handle

### 7.3.4. xrDestroySpace

The xrDestroySpace function is defined as:

```
XrResult xrDestroySpace(
    XrSpace     space);
```
Parameter Descriptions

- `space` is a handle to an `XrSpace` previously created by a function such as `xrCreateReferenceSpace`.

*XrSpace* handles are destroyed using `xrDestroySpace`. The runtime *may* still use this space if there are active dependencies (e.g., compositions in progress).

Valid Usage (Implicit)

- `space` must be a valid `XrSpace` handle

Thread Safety

- Access to `space`, and any child handles, must be externally synchronized

Return Codes

**Success**

- `XR_SUCCESS`

**Failure**

- `XR_ERROR_HANDLE_INVALID`

7.4. Locating Spaces

Applications use the `xrLocateSpace` function to find the pose of an `XrSpace`’s origin within a base `XrSpace` at a given historical or predicted time. If an application wants to know the velocity of the space's origin, it can chain an `XrSpaceVelocity` structure to the `next` pointer of the `XrSpaceLocation` structure when calling the `xrLocateSpace` function. Applications should inspect the output `XrSpaceLocationFlagBits` and `XrSpaceVelocityFlagBits` to determine the validity and tracking status of the components of the location.

7.4.1. `xrLocateSpace`

`xrLocateSpace` provides the physical location of a space in a base space at a specified time, if currently known by the runtime.
XrResult xrLocateSpace(
    XrSpace space,
    XrSpace baseSpace,
    XrTime time,
    XrSpaceLocation* location);

**Parameter Descriptions**

- `space` identifies the target space to locate.
- `baseSpace` identifies the underlying space in which to locate `space`.
- `time` is the time for which the location should be provided.
- `location` provides the location of `space` in `baseSpace`.

For a `time` in the past, the runtime **should** locate the spaces based on the runtime's most accurate current understanding of how the world was at that historical time.

For a `time` in the future, the runtime **should** locate the spaces based on the runtime's most up-to-date prediction of how the world will be at that future time.

The minimum valid range of values for `time` are described in [Prediction Time Limits](#). For values of `time` outside this range, `xrLocateSpace` **may** return a location with no position and `XR_SPACE_LOCATION_POSITION_VALID_BIT` unset.

Some devices improve their understanding of the world as the device is used. The location returned by `xrLocateSpace` for a given `space`, `baseSpace` and `time` **may** change over time, even for spaces that track static objects, as one or both spaces adjust their origins.

During tracking loss of `space` relative to `baseSpace`, runtimes **should** continue to provide inferred or last-known position and orientation values. These inferred poses can, for example, be based on neck model updates, inertial dead reckoning, or a last-known position, so long as it is still reasonable for the application to use that pose. While a runtime is providing position data, it **must** continue to set `XR_SPACE_LOCATION_POSITION_VALID_BIT` but it **can** clear `XR_SPACE_LOCATION_POSITION_TRACKED_BIT` to indicate that the position is inferred or last-known in this way.

If the runtime has not yet observed even a last-known pose for how to locate `space` in `baseSpace` (e.g. one space is an action space bound to a motion controller that has not yet been detected, or the two spaces are in disconnected fragments of the runtime’s tracked volume), the runtime **should** return a location with no position and `XR_SPACE_LOCATION_POSITION_VALID_BIT` unset.

The runtime **must** return a location with both `XR_SPACE_LOCATION_POSITION_VALID_BIT` and `XR_SPACE_LOCATION_POSITION_TRACKED_BIT` set when locating `space` and `baseSpace` if both spaces were created relative to the same entity (e.g. two action spaces for the same action), even if the entity is currently untracked. The location in this case is the difference in the two spaces' application-specified
transforms relative to that common entity.

The runtime should return a location with `XR_SPACE_LOCATION_POSITION_VALID_BIT` set and `XR_SPACE_LOCATION_POSITION_TRACKED_BIT` unset for spaces tracking two static entities in the world when their relative pose is known to the runtime. This enables applications to make use of the runtime's latest knowledge of the world, even during tracking loss.

If an `XrSpaceVelocity` structure is chained to the next pointer of `XrSpaceLocation` and the velocity is observed or can be calculated by the runtime, the runtime must fill in the linear velocity of the origin of space within the reference frame of `baseSpace` and set the `XR_SPACE_VELOCITY_LINEAR_VALID_BIT`. Similarly, if an `XrSpaceVelocity` structure is chained to the next pointer of `XrSpaceLocation` and the angular velocity is observed or can be calculated by the runtime, the runtime must fill in the angular velocity of the origin of space within the reference frame of `baseSpace` and set the `XR_SPACE_VELOCITY_ANGULAR_VALID_BIT`.

The following example code shows how an application can get both the location and velocity of a space within a base space using the `xrLocateSpace` function by chaining an `XrSpaceVelocity` to the next pointer of `XrSpaceLocation` and calling `xrLocateSpace`.

```c
XrSpace space; // previously initialized
XrSpace baseSpace; // previously initialized
XrTime time; // previously initialized

XrSpaceVelocity velocity {XR_TYPE_SPACE_VELOCITY};
XrSpaceLocation location {XR_TYPE_SPACE_LOCATION, &velocity};
xrLocateSpace(space, baseSpace, time, &location);
```

Valid Usage (Implicit)

- `space` must be a valid `XrSpace` handle
- `baseSpace` must be a valid `XrSpace` handle
- `location` must be a pointer to an `XrSpaceLocation` structure
- Both of `baseSpace` and `space` must have been created, allocated, or retrieved from the same `XrSession`
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_TIME_INVALID

The XrSpaceLocation structure is defined as:

typedef struct XrSpaceLocation {
    XrStructureType         type;
    void*                   next;
    XrSpaceLocationFlags    locationFlags;
    XrPosef                 pose;
} XrSpaceLocation;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain, such as XrSpaceVelocity.
- **locationFlags** is a bitfield, with bit masks defined in XrSpaceLocationFlagBits, to indicate which members contain valid data. If none of the bits are set, no other fields in this structure should be considered to be valid or meaningful.
- **pose** is an XrPose defining the position and orientation of the origin of xrLocateSpace::space within the reference frame of xrLocateSpace::baseSpace.
Valid Usage (Implicit)

- **type** must be XR_TYPE_SPACE_LOCATION
- **next** must be **NULL** or a valid pointer to the **next** structure in a structure chain. See also: XrEyeGazeSampleTimeEXT, XrSpaceVelocity
- **locationFlags** must be 0 or a valid combination of XrSpaceLocationFlagBits values

The **locationFlags** member is a bitwise-OR of zero or more of the following flags:

```c
// Flag bits for XrSpaceLocationFlags
static const XrSpaceLocationFlags XR_SPACE_LOCATION_ORIENTATION_VALID_BIT = 0x00000001;
static const XrSpaceLocationFlags XR_SPACE_LOCATION_POSITION_VALID_BIT = 0x00000002;
static const XrSpaceLocationFlags XR_SPACE_LOCATION_ORIENTATION_TRACKED_BIT = 0x00000004;
static const XrSpaceLocationFlags XR_SPACE_LOCATION_POSITION_TRACKED_BIT = 0x00000008;
```

where the flags have the following meaning:
Flag Descriptions

- **XR_SPACE_LOCATION_ORIENTATION_VALID_BIT** indicates that the pose field's orientation field contains valid data. For a space location tracking a device with its own inertial tracking, **XR_SPACE_LOCATION_ORIENTATION_TRACKED_BIT** should remain set when this bit is set. Applications **must** not read the pose field's orientation if this flag is unset.

- **XR_SPACE_LOCATION_POSITION_VALID_BIT** indicates that the pose field's position field contains valid data. When a space location loses tracking, runtimes **should** continue to provide valid but untracked position values that are inferred or last-known, so long as it's still meaningful for the application to use that position, clearing **XR_SPACE_LOCATION_POSITION_TRACKED_BIT** until positional tracking is recovered. Applications **must** not read the pose field's position if this flag is unset.

- **XR_SPACE_LOCATION_ORIENTATION_TRACKED_BIT** indicates that the pose field's orientation field represents an actively tracked orientation. For a space location tracking a device with its own inertial tracking, this bit **should** remain set when **XR_SPACE_LOCATION_ORIENTATION_VALID_BIT** is set. For a space location tracking an object whose orientation is no longer known during tracking loss (e.g. an observed QR code), runtimes **should** continue to provide valid but untracked orientation values, so long as it's still meaningful for the application to use that orientation.

- **XR_SPACE_LOCATION_POSITION_TRACKED_BIT** indicates that the pose field's position field represents an actively tracked position. When a space location loses tracking, runtimes **should** continue to provide valid but untracked position values that are inferred or last-known, e.g. based on neck model updates, inertial dead reckoning, or a last-known position, so long as it's still meaningful for the application to use that position.

The **XrSpaceVelocity** structure is defined as:

```c
typedef struct XrSpaceVelocity {
    XrStructureType        type;
    void*                   next;
    XrSpaceVelocityFlags    velocityFlags;
    XrVector3f              linearVelocity;
    XrVector3f              angularVelocity;
} XrSpaceVelocity;
```
Member Descriptions

• **type** is the XrStructureType of this structure.

• **next** is **NULL** or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

• **velocityFlags** is a bitfield, with bit masks defined in XrSpaceVelocityFlagBits, to indicate which members contain valid data. If none of the bits are set, no other fields in this structure should be considered to be valid or meaningful.

• **linearVelocity** is the relative linear velocity of the origin of xrLocateSpace::space with respect to and expressed in the reference frame of xrLocateSpace::baseSpace, in units of meters per second.

• **angularVelocity** is the relative angular velocity of xrLocateSpace::space with respect to xrLocateSpace::baseSpace. The vector’s direction is expressed in the reference frame of xrLocateSpace::baseSpace and is parallel to the rotational axis of xrLocateSpace::space. The vector’s magnitude is the relative angular speed of xrLocateSpace::space in radians per second. The vector follows the right-hand rule for torque/rotation.

Valid Usage (Implicit)

• **type** must be XR_TYPE_SPACE_VELOCITY

• **next** must be **NULL** or a valid pointer to the next structure in a structure chain

• **velocityFlags** must be 0 or a valid combination of XrSpaceVelocityFlagBits values

The **velocityFlags** member is a bitwise-OR of zero or more of the following flags:

```c
#include <openxr/xr.h>

// Flag bits for XrSpaceVelocityFlags
static const XrSpaceVelocityFlags XR_SPACE_VELOCITY_LINEAR_VALID_BIT = 0x00000001;
static const XrSpaceVelocityFlags XR_SPACE_VELOCITY_ANGULAR_VALID_BIT = 0x00000002;
```

where the flags have the following meaning:
Flag Descriptions

- **XR_SPACE_VELOCITY_LINEAR_VALID_BIT** — Indicates that the `linearVelocity` member contains valid data. Applications **must** not read the `linearVelocity` field if this flag is unset.

- **XR_SPACE_VELOCITY_ANGULAR_VALID_BIT** — Indicates that the `angularVelocity` member contains valid data. Applications **must** not read the `angularVelocity` field if this flag is unset.
A view configuration is a semantically meaningful set of one or more views for which an application can render images. A primary view configuration is a view configuration intended to be presented to the viewer interacting with the XR application. This distinction allows the later addition of additional views, for example views which are intended for spectators.

A typical head-mounted VR system has a view configuration with two views, while a typical phone-based AR system has a view configuration with a single view. A simple multi-wall projection-based (CAVE-like) VR system may have a view configuration with at least one view for each display surface (wall, floor, ceiling) in the room.

For any supported form factor, a system will support one or more primary view configurations. Supporting more than one primary view configuration can be useful if a system supports a special view configuration optimized for the hardware but also supports a more broadly used view configuration as a compatibility fallback.

View configurations are identified with an XrViewConfigurationType.

### 8.1. Primary View Configurations

```c
typedef enum XrViewConfigurationType {
    XR_VIEW_CONFIGURATION_TYPE_PRIMARY_MONO = 1,
    XR_VIEW_CONFIGURATION_TYPE_PRIMARY_STEREO = 2,
    XR_VIEW_CONFIGURATION_TYPE_PRIMARY_QUAD_VARJO = 1000037000,
    XR_VIEW_CONFIGURATION_TYPE_SECONDARY_MONO_FIRST_PERSON_OBSERVER_MSFT = 1000054000,
    XR_VIEW_CONFIGURATION_TYPE_MAX_ENUM = 0x7FFFFFFF
} XrViewConfigurationType;
```

The application selects its primary view configuration type when calling `xrBeginSession`, and that configuration remains constant for the lifetime of the session, until `xrEndSession` is called.

The number of views and the semantic meaning of each view index within a given view configuration is well-defined, specified below for all core view configurations. The predefined primary view configuration types are:
Enumerant Descriptions

- **XR_VIEW_CONFIGURATION_TYPE_PRIMARY_MONO.** One view representing the form factor's one primary display. For example, an AR phone's screen. This configuration requires one element in `XrViewConfigurationProperties` and one projection in each `XrCompositionLayerProjection` layer.

- **XR_VIEW_CONFIGURATION_TYPE_PRIMARY_STEREO.** Two views representing the form factor's two primary displays, which map to a left-eye and right-eye view. This configuration requires two views in `XrViewConfigurationProperties` and two views in each `XrCompositionLayerProjection` layer. View index 0 **must** represent the left eye and view index 1 **must** represent the right eye.

### 8.2. View Configuration API

First an application needs to select which primary view configuration it wants to use. If it supports multiple configurations, an application **can** call `xrEnumerateViewConfigurations` before creating an `XrSession` to get a list of the view configuration types supported for a given system.

The application **can** then call `xrGetViewConfigurationProperties` and `xrEnumerateViewConfigurationViews` to get detailed information about each view configuration type and its individual views.

#### 8.2.1. `xrEnumerateViewConfigurations`

The `xrEnumerateViewConfigurations` function is defined as:

```
XrResult xrEnumerateViewConfigurations(
    XrInstance instance,                       
    XrSystemId systemId,                      
    uint32_t viewConfigurationTypeCapacityInput,  
    uint32_t* viewConfigurationTypeCountOutput,  
    XrViewConfigurationType* viewConfigurationTypes);
```
Parameter Descriptions

- **instance** is the instance from which **systemId** was retrieved.
- **systemId** is the **XrSystemId** whose view configurations will be enumerated.
- **viewConfigurationsTypeCapacityInput** is the capacity of the **viewConfigurations** array, or 0 to indicate a request to retrieve the required capacity.
- **viewConfigurationsTypeCountOutput** is a pointer to the count of **viewConfigurations** written, or a pointer to the required capacity in the case that **viewConfigurationsTypeCapacityInput** is insufficient.
- **viewConfigurationsTypes** is a pointer to an array of **XrViewConfigurationType** values, but can be **NULL** if **viewConfigurationsTypeCapacityInput** is 0.
- See **Buffer Size Parameters** chapter for a detailed description of retrieving the required **viewConfigurations** size.

**xrEnumerateViewConfigurations** enumerates the view configuration types supported by the **XrSystemId**. The supported set for that system must not change during the lifetime of its **XrInstance**. The returned list of primary view configurations should be in order from what the runtime considered highest to lowest user preference. Thus the first enumerated view configuration type should be the one the runtime prefers the application to use if possible.

Runtimes must always return identical buffer contents from this enumeration for the given **systemId** and for the lifetime of the instance.

Valid Usage (Implicit)

- **instance** must be a valid **XrInstance** handle
- **viewConfigurationTypeCountOutput** must be a pointer to a **uint32_t** value
- If **viewConfigurationTypeCapacityInput** is not 0, **viewConfigurationsTypes** must be a pointer to an array of **viewConfigurationTypeCapacityInput** **XrViewConfigurationType** values
Return Codes

Success
  • XR_SUCCESS

Failure
  • XR_ERROR_VALIDATION_FAILURE
  • XR_ERROR_RUNTIME_FAILURE
  • XR_ERROR_HANDLE_INVALID
  • XR_ERROR_INSTANCE_LOST
  • XR_ERROR_SIZE_INSUFFICIENT
  • XR_ERROR_SYSTEM_INVALID

8.2.2. xrGetViewConfigurationProperties

The `xrGetViewConfigurationProperties` function is defined as:

```c
XrResult xrGetViewConfigurationProperties(
    XrInstance                                  instance,
    XrSystemId                                  systemId,
    XrViewConfigurationType                     viewConfigurationType,
    XrViewConfigurationProperties*              configurationProperties);
```

Parameter Descriptions

- **instance** is the instance from which **systemId** was retrieved.
- **systemId** is the **XrSystemId** whose view configuration is being queried.
- **viewConfigurationType** is the **XrViewConfigurationType** of the configuration to get.
- **configurationProperties** is a pointer to view configuration properties to return.

`xrGetViewConfigurationProperties` queries properties of an individual view configuration. Applications **must** use one of the supported view configuration types returned by `xrEnumerateViewConfigurations`. If `viewConfigurationType` is not supported by this **XrInstance** the runtime **must** return **XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED**.
Valid Usage (Implicit)

- **instance** must be a valid `XrInstance` handle
- **viewConfigurationType** must be a valid `XrViewConfigurationType` value
- **configurationProperties** must be a pointer to an `XrViewConfigurationProperties` structure

Return Codes

**Success**
- `XR_SUCCESS`

**Failure**
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED`
- `XR_ERROR_SYSTEM_INVALID`

8.2.3. `XrViewConfigurationProperties`

The `XrViewConfigurationProperties` structure is defined as:

```c
typedef struct XrViewConfigurationProperties {
    XrStructureType          type;
    void*                     next;
    XrViewConfigurationType   viewConfigurationType;
    XrBool32                  fovMutable;
} XrViewConfigurationProperties;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **viewConfigurationType** is the `XrViewConfigurationType` of the configuration.
- **fovMutable** indicates if the view field of view can be modified by the application.

Valid Usage (Implicit)

- **type** must be `XR_TYPE_VIEW_CONFIGURATION_PROPERTIES`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- **viewConfigurationType** must be a valid `XrViewConfigurationType` value

8.2.4. `xrEnumerateViewConfigurationViews`

The `xrEnumerateViewConfigurationViews` function is defined as:

```c
XrResult xrEnumerateViewConfigurationViews(
    XrInstance instance,
    XrSystemId systemId,
    XrViewConfigurationType viewConfigurationType,
    uint32_t viewCapacityInput,
    uint32_t* viewCountOutput,
    XrViewConfigurationView* views);
```
Parameter Descriptions

- `instance` is the instance from which `systemId` was retrieved.
- `systemId` is the `XrSystemId` whose view configuration is being queried.
- `viewConfigurationType` is the `XrViewConfigurationType` of the configuration to get.
- `viewCapacityInput` is the capacity of the `views` array, or 0 to indicate a request to retrieve the required capacity.
- `viewCountOutput` is a pointer to the count of `views` written, or a pointer to the required capacity in the case that `viewCapacityInput` is 0.
- `views` is a pointer to an array of `XrViewConfigurationView` values, but can be `NULL` if `viewCapacityInput` is 0.

Each `XrViewConfigurationType` defines the number of views associated with it. Applications can query more details of each view element using `xrEnumerateViewConfigurationViews`. If the supplied `viewConfigurationType` is not supported by this `XrInstance` and `XrSystemId`, the runtime must return `XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED`.

Runtimes must always return identical buffer contents from this enumeration for the given `systemId` and `viewConfigurationType` for the lifetime of the instance.

Valid Usage (Implicit)

- `instance` must be a valid `XrInstance` handle
- `viewConfigurationType` must be a valid `XrViewConfigurationType` value
- `viewCountOutput` must be a pointer to a `uint32_t` value
- If `viewCapacityInput` is not 0, `views` must be a pointer to an array of `viewCapacityInput` `XrViewConfigurationView` structures
Return Codes

Success
• XR_SUCCESS

Failure
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SIZE_INSUFFICIENT
• XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED
• XR_ERROR_SYSTEM_INVALID

8.2.5. XrViewConfigurationView

Each XrViewConfigurationView specifies properties related to rendering of an individual view within a view configuration.

The XrViewConfigurationView structure is defined as:

typedef struct XrViewConfigurationView {
    XrStructureType type;
    void* next;
    uint32_t recommendedImageRectWidth;
    uint32_t maxImageRectWidth;
    uint32_t recommendedImageRectHeight;
    uint32_t maxImageRectHeight;
    uint32_t recommendedSwapchainSampleCount;
    uint32_t maxSwapchainSampleCount;
} XrViewConfigurationView;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **recommendedImageRectWidth** is the optimal width of `imageRect` to use when rendering this view into a swapchain.
- **maxImageRectWidth** is the maximum width of `imageRect` supported when rendering this view into a swapchain.
- **recommendedImageRectHeight** is the optimal height of `imageRect` to use when rendering this view into a swapchain.
- **maxImageRectHeight** is the maximum height of `imageRect` supported when rendering this view into a swapchain.
- **recommendedSwapchainSampleCount** is the recommended number of sub-data element samples to create for each swapchain image that will be rendered into for this view.
- **maxSwapchainSampleCount** is the maximum number of sub-data element samples supported for swapchain images that will be rendered into for this view.

See `XrSwapchainSubImage` for more information about `imageRect` values, and `XrSwapchainCreateInfo` for more information about creating swapchains appropriately sized to support those `imageRect` values.

The array of `XrViewConfigurationView` returned by the runtime **must** adhere to the rules defined in `XrViewConfigurationType`, such as the count and association to the left and right eyes.

Valid Usage (Implicit)

- **type** **must** be `XR_TYPE_VIEW_CONFIGURATION_VIEW`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrFoveatedViewConfigurationViewVARJO`, `XrViewConfigurationDepthRangeEXT`, `XrViewConfigurationViewFovEPIC`

8.3. Example View Configuration Code

```c
XrInstance instance; // previously initialized
XrSystemId system;   // previously initialized
XrSession session;   // previously initialized
XrSpace sceneSpace;  // previously initialized

// Enumerate the view configurations paths.
```
uint32_t configurationCount;
CHK_XR(xrEnumerateViewConfigurations(instance, system, 0, &configurationCount, nullptr));

std::vector<XrViewConfigurationType> configurationTypes(configurationCount);
CHK_XR(xrEnumerateViewConfigurations(instance, system, configurationCount,
               &configurationCount, configurationTypes.data()));

bool configFound = false;
for(uint32_t i = 0; i < configurationCount; ++i)
{
    if (configurationTypes[i] == XR_VIEW_CONFIGURATION_TYPE_PRIMARY_STEREO)
    {
        configFound = true;
        break;   // Pick the first supported, i.e. preferred, view configuration.
    }
}

if (!configFound)
    return;   // Cannot support any view configuration of this system.

// Get detailed information of each view element.
uint32_t viewCount;
CHK_XR(xrEnumerateViewConfigurationViews(instance, system,
               XR_VIEW_CONFIGURATION_TYPE_PRIMARY_STEREO,
               0,
               &viewCount,
               nullptr));

std::vector<XrViewConfigurationView> configViews(viewCount,
               {XR_TYPE_VIEW_CONFIGURATION_VIEW});
CHK_XR(xrEnumerateViewConfigurationViews(instance, system,
               XR_VIEW_CONFIGURATION_TYPE_PRIMARY_STEREO,
               viewCount,
               &viewCount,
               configViews.data()));

// Set the primary view configuration for the session.
XrSessionBeginInfo beginInfo = {XR_TYPE_SESSION_BEGIN_INFO};
beginInfo.primaryViewConfigurationType = XR_VIEW_CONFIGURATION_TYPE_PRIMARY_STEREO;
CHK_XR(xrBeginSession(session, &beginInfo));

// Allocate a buffer according to viewCount.
std::vector<XrView> views(viewCount, {XR_TYPE_VIEW});

// Run a per-frame loop.
while (!quit)
{
    // Wait for a new frame.
XrFrameWaitInfo frameWaitInfo{XR_TYPE_FRAME_WAIT_INFO};
XrFrameState frameState{XR_TYPE_FRAME_STATE};
CHK_XR(xrWaitFrame(session, &frameWaitInfo, &frameState));

// Begin frame immediately before GPU work
XrFrameBeginInfo frameBeginInfo { XR_TYPE_FRAME_BEGIN_INFO };
CHK_XR(xrBeginFrame(session, &frameBeginInfo));

std::vector<XrCompositionLayerBaseHeader*> layers;
XrCompositionLayerProjectionView projViews[2] = { /*...*/ };
XrCompositionLayerProjection layerProj{ XR_TYPE_COMPOSITION_LAYER_PROJECTION};

if (frameState.shouldRender) {
    XrViewLocateInfo viewLocateInfo{XR_TYPE_VIEW_LOCATE_INFO};
    viewLocateInfo.displayTime = frameState.predictedDisplayTime;
    viewLocateInfo.space = sceneSpace;

    XrViewState viewState{XR_TYPE_VIEW_STATE};
    XrView views[2] = { {XR_TYPE_VIEW}, {XR_TYPE_VIEW}};
    uint32_t viewCountOutput;
    CHK_XR(xrLocateViews(session, &viewLocateInfo, &viewState, configViews.size(),
                           &viewCountOutput, views));

    // ...
    // Use viewState and frameState for scene render, and fill in projViews[2]
    // ...

    // Assemble composition layers structure
    layerProj.layerFlags = XR_COMPOSITION_LAYER_BLEND_TEXTURE_SOURCE_ALPHA_BIT;
    layerProj.space = sceneSpace;
    layerProj.viewCount = 2;
    layerProj.views = projViews;
    layers.push_back(reinterpret_cast<XrCompositionLayerBaseHeader*>(&layerProj));
}

// End frame and submit layers, even if layers is empty due to shouldRender = false
XrFrameEndInfo frameEndInfo{ XR_TYPE_FRAME_END_INFO};
frameEndInfo.displayTime = frameState.predictedDisplayTime;
frameEndInfo.environmentBlendMode = XR_ENVIRONMENT_BLEND_MODE_OPAQUE;
frameEndInfo.layerCount = (uint32_t)layers.size();
frameEndInfo.layers = layers.data();
CHK_XR(xrEndFrame(session, &frameEndInfo));
}
Chapter 9. Session

XR_DEFINE_HANDLE(XrSession)

A session represents an application’s intention to display XR content to the user.

9.1. Session Lifecycle

A typical XR session coordinates the application and the runtime through session control functions and session state events.

1. The application creates a session by choosing a system and a graphics API and passing them into `xrCreateSession`. The newly created session is in the `XR_SESSION_STATE_IDLE` state.

2. The application then monitors for session state changes via `XrEventDataSessionStateChanged` events.

3. When the runtime determines that the system is ready to start transitioning to this session’s XR content, the application receives a notification of session state change
to **XR_SESSION_STATE_READY**. Once the application is also ready to proceed and display its XR content, it calls **xrBeginSession** and starts its frame loop, which begins a **running session**.

4. While the session is running, the application is expected to continuously execute its frame loop by calling **xrWaitFrame**, **xrBeginFrame** and **xrEndFrame** each frame, establishing synchronization with the runtime. Once the runtime is synchronized with the application’s frame loop and ready to display application’s frames, the session moves into the **XR_SESSION_STATE_SYNCHRONIZED** state. In this state, the submitted frames will not be displayed or visible to the user yet.

5. When the runtime intends to display frames from the application, it notifies with **XR_SESSION_STATE_VISIBLE** state, and sets **XrFrameState::shouldRender** to **true** in **xrWaitFrame**. The application should render XR content and submit the composition layers to **xrEndFrame**.

6. When the runtime determines the application is eligible to receive XR inputs, e.g. motion controller or hand tracking inputs, it notifies with **XR_SESSION_STATE_FOCUSED** state. The application can expect to receive active action inputs.

7. When the runtime determines the application has lost XR input focus, it moves the session state from **XR_SESSION_STATE_FOCUSED** to **XR_SESSION_STATE_VISIBLE** state. The application may need to change its own internal state while input is unavailable. Since the session is still visible, the application needs to render and submit frames at full frame rate, but may wish to change visually to indicate its input suspended state. When the runtime returns XR focus back to the application, it moves the session state back to **XR_SESSION_STATE_FOCUSED**.

8. When the runtime needs to end a **running session** due to the user closing or switching the application, the runtime will change the session state through appropriate intermediate ones and finally to **XR_SESSION_STATE_STOPPING**. When the application receives the **XR_SESSION_STATE_STOPPING** event, it should stop its frame loop and then call **xrEndSession** to tell the runtime to stop the **running session**.

9. After **xrEndSession**, the runtime transitions the session state to **XR_SESSION_STATE_IDLE**. If the XR session is temporarily paused in the background, the runtime will keep the session state at **XR_SESSION_STATE_IDLE** and later transition the session state back to **XR_SESSION_STATE_READY** when the XR session is resumed. If the runtime determines that its use of this XR session has concluded, it will transition the session state from **XR_SESSION_STATE_IDLE** to **XR_SESSION_STATE_EXITING**.

10. When the application receives the **XR_SESSION_STATE_EXITING** event, it releases the resources related to the session and calls **xrDestroySession**.

A session is considered **running** after a successful call to **xrBeginSession** and remains running until any call is made to **xrEndSession**. Certain functions are only valid to call when a session is running, such as **xrWaitFrame**, or else the **XR_ERROR_SESSION_NOT_RUNNING** error **must** be returned by the runtime.
A session is considered **not running** before a successful call to `xrBeginSession` and becomes not running again after any call is made to `xrEndSession`. Certain functions are only valid to call when a session is not running, such as `xrBeginSession`, or else the `XR_ERROR_SESSION_RUNNING` error **must** be returned by the runtime.

If an error is returned from `xrBeginSession`, the session remains in its current running or not running state. Calling `xrEndSession` always transitions a session to the not running state, regardless of any errors returned.

Only running sessions may become focused sessions that receive XR input. When a session is **not running**, the application **must** not submit frames. This is important because without a running session, the runtime no longer has to spend resources on sub-systems (tracking etc.) that are no longer needed by the application.

An application **must** call `xrBeginSession` when the session is in the `XR_SESSION_STATE_READY` state, or `XR_ERROR_SESSION_NOT_READY` will be returned; it **must** call `xrEndSession` when the session is in the `XR_SESSION_STATE_STOPPING` state, otherwise `XR_ERROR_SESSION_NOT_STOPPING` will be returned. This is to allow the runtimes to seamlessly transition from one application’s session to another.

The application **can** call `xrDestroySession` at any time during the session life cycle, however, it **must** stop using the `XrSession` handle immediately in all threads and stop using any related resources. Therefore, it’s typically undesirable to destroy a running session and instead it’s recommended to wait for `XR_SESSION_STATE_EXITING` to destroy a session.

### 9.2. Session Creation

To present graphical content on an output device, OpenXR applications need to pick a graphics API which is supported by the runtime. Unextended OpenXR does not support any graphics APIs natively but provides a number of extensions of which each runtime can support any subset. These extensions can be activated during `XrInstance` create time.

During `XrSession` creation the application **must** provide information about which graphics API it intends to use by adding an `XrGraphicsBinding*` struct of one (and only one) of the enabled graphics API extensions to the next chain of `XrSessionCreateInfo`. The application **must** call the `xrGet*GraphicsRequirements` method (where * is a placeholder) provided by the chosen graphics API extension before attempting to create the session (for example, `xrGetD3D11GraphicsRequirementsKHR` `xrGetD3D12GraphicsRequirementsKHR` `xrGetOpenGLGraphicsRequirementsKHR` `xrGetVulkanGraphicsRequirementsKHR` `xrGetVulkanGraphicsRequirements2KHR`).

Unless specified differently in the graphics API extension, the application is responsible for creating a valid graphics device binding based on the requirements returned by `xrGet*GraphicsRequirements` methods (for details refer to the extension specification of the graphics API).

The `xrCreateSession` function is defined as:
XrResult xrCreateSession(
    XrInstance instance,
    const XrSessionCreateInfo* createInfo,
    XrSession* session);

Parameter Descriptions

- **instance** is the instance from which systemId was retrieved.
- **createInfo** is a pointer to an XrSessionCreateInfo structure containing information about how to create the session.
- **session** is a pointer to a handle in which the created XrSession is returned.

Creates a session using the provided createInfo and returns a handle to that session. This session is created in the XR_SESSION_STATE_IDLE state, and a corresponding XrEventDataSessionStateChanged event to the XR_SESSION_STATE_IDLE state must be generated as the first such event for the new session.

The runtime must return XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING (XR_ERROR_VALIDATION_FAILURE may be returned due to legacy behavior) on calls to xrCreateSession if a function named like xrGet*GraphicsRequirements has not been called for the same instance and XrSessionCreateInfo::systemId. (See graphics binding extensions for details.)

Valid Usage (Implicit)

- **instance** must be a valid XrInstance handle
- **createInfo** must be a pointer to a valid XrSessionCreateInfo structure
- **session** must be a pointer to an XrSession handle
Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_SYSTEM_INVALID
- XR_ERROR_INITIALIZATION_FAILED
- XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING
- XR_ERROR_GRAPHICS_DEVICE_INVALID

The XrSessionCreateInfo structure is defined as:

```c
typedef struct XrSessionCreateInfo {
    XrStructureType         type;
    const void*             next;
    XrSessionCreateFlags    createFlags;
    XrSystemId              systemId;
} XrSessionCreateInfo;
```

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR. Note that in most cases one graphics API extension specific struct needs to be in this next chain.
- **createFlags** identifies XrSessionCreateFlags that apply to the creation.
- **systemId** is the XrSystemId representing the system of devices to be used by this session.
Valid Usage

• systemId must be a valid XrSystemId or XR_ERROR_SYSTEM_INVALID must be returned.
• next, unless otherwise specified via an extension, must contain exactly one graphics API binding structure (a structure whose name begins with “XrGraphicsBinding”) or XR_ERROR_GRAPHICS_DEVICE_INVALID must be returned.

Valid Usage (Implicit)

• type must be XR_TYPE_SESSION_CREATE_INFO
• next must be NULL or a valid pointer to the next structure in a structure chain. See also: XrGraphicsBindingD3D11KHR, XrGraphicsBindingD3D12KHR, XrGraphicsBindingEGLMNDX, XrGraphicsBindingOpenGLESAndroidKHR, XrGraphicsBindingOpenGLWin32KHR, XrGraphicsBindingOpenGLXcbKHR, XrGraphicsBindingOpenGLXlibKHR, XrGraphicsBindingVulkanKHR, XrHolographicWindowAttachmentMSFT, XrSessionCreateInfoOverlayEXTX
• createFlags must be 0

The XrSessionCreateFlags include:

// Flag bits for XrSessionCreateFlags

There are currently no session creation flags. This is reserved for future use.

The xrDestroySession function is defined as.

```c
XrResult xrDestroySession(
    XrSession session);
```

Parameter Descriptions

• session is the session to destroy.

XrSession handles are destroyed using xrDestroySession. When an XrSession is destroyed, all handles that are children of that XrSession are also destroyed.
The application is responsible for ensuring that it has no calls using `session` in progress when the session is destroyed.

`xrDestroySession` can be called when the session is in any session state.

**Valid Usage (Implicit)**

- `session` must be a valid `XrSession` handle

**Thread Safety**

- Access to `session`, and any child handles, must be externally synchronized

**Return Codes**

**Success**

- `XR_SUCCESS`

**Failure**

- `XR_ERROR_HANDLE_INVALID`

### 9.3. Session Control

The `xrBeginSession` function is defined as:

```c
XrResult xrBeginSession(
    XrSession session,
    const XrSessionBeginInfo* beginInfo);
```

**Parameter Descriptions**

- `session` is a valid `XrSession` handle.
- `beginInfo` is a pointer to an `XrSessionBeginInfo` structure.

When the application receives `XrEventDataSessionStateChanged` event with the `XR_SESSION_STATE_READY` state, the application should then call `xrBeginSession` to start rendering frames for display to the user.
After this function successfully returns, the session is considered to be running. The application should then start its frame loop consisting of some sequence of `xrWaitFrame/xrBeginFrame/xrEndFrame` calls.

If the session is already running when the application calls `xrBeginSession`, the runtime must return error `XR_ERROR_SESSION_RUNNING`. If the session is not running when the application calls `xrBeginSession`, but the session is not yet in the `XR_SESSION_STATE_READY` state, the runtime must return error `XR_ERROR_SESSION_NOT_READY`.

Note that a runtime may decide not to show the user any given frame from a session at any time, for example if the user has switched to a different application's running session. The application should check whether `xrWaitFrame` returns an `XrFrameState` with `shouldRender` set to true before rendering a given frame to determine whether that frame will be visible to the user.

Runtime session frame state must start in a reset state when a session transitions to running so that no state is carried over from when the same session was previously running.

If `primaryViewConfigurationType` in `beginInfo` is not supported by the `XrSystemId` used to create the session, the runtime must return `XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED`.

### Valid Usage (Implicit)

- `session` must be a valid `XrSession` handle
- `beginInfo` must be a pointer to a valid `XrSessionBeginInfo` structure

### Return Codes

#### Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

#### Failure

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED`
- `XR_ERROR_SESSION_RUNNING`
- `XR_ERROR_SESSION_NOT_READY`
The **XrSessionBeginInfo** structure is defined as:

```c
typedef struct XrSessionBeginInfo {
    XrStructureType            type;
    const void*                next;
    XrViewConfigurationType    primaryViewConfigurationType;
} XrSessionBeginInfo;
```

### Member Descriptions

- **type** is the **XrStructureType** of this structure.
- **next** is **NULL** or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **primaryViewConfigurationType** is the **XrViewConfigurationType** to use during this session to provide images for the form factor’s primary displays.

### Valid Usage (Implicit)

- **type** must be **XR_TYPE_SESSION_BEGIN_INFO**
- **next** must be **NULL** or a valid pointer to the next structure in a structure chain. See also: **XrSecondaryViewConfigurationSessionBeginInfoMSFT**
- **primaryViewConfigurationType** must be a valid **XrViewConfigurationType** value

The **xrEndSession** function is defined as:

```c
XrResult xrEndSession(       
    XrSession                                   session);
```

### Parameter Descriptions

- **session** is a handle to a running **XrSession**.

When the application receives **XrEventDataSessionStateChanged** event with the **XR_SESSION_STATE_STOPPING** state, the application should stop its frame loop and then call **xrEndSession** to end the running session. This function signals to the runtime that the application will no longer call...
xrWaitFrame, xrBeginFrame or xrEndFrame from any thread allowing the runtime to safely transition the session to XR_SESSION_STATE_IDLE. The application must also avoid reading input state or sending haptic output after calling xrEndSession.

If the session is not running when the application calls xrEndSession, the runtime must return error XR_ERROR_SESSION_NOT_RUNNING. If the session is still running when the application calls xrEndSession, but the session is not yet in the XR_SESSION_STATE_STOPPING state, the runtime must return error XR_ERROR_SESSION_NOT_STOPPING.

If the application wishes to exit a running session, the application can call xrRequestExitSession so that the session transitions from XR_SESSION_STATE_IDLE to XR_SESSION_STATE_EXITING.

Valid Usage (Implicit)

- session must be a valid XrSession handle

Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_SESSION_NOT_STOPPING
- XR_ERROR_SESSION_NOT_RUNNING

When an application wishes to exit a running session, it can call xrRequestExitSession, requesting that the runtime transition through the various intermediate session states including XR_SESSION_STATE_STOPPING to XR_SESSION_STATE_EXITING.

On platforms where an application's lifecycle is managed by the system, session state changes may be implicitly triggered by application lifecycle state changes. On such platforms, using platform-specific methods to alter application lifecycle state may be the preferred method of provoking session state changes. The behavior of xrRequestExitSession is not altered, however explicit session exit may not interact with the platform-specific application lifecycle.
The `xrRequestExitSession` function is defined as:

```c
XrResult xrRequestExitSession(
    XrSession                                   session);
```

### Parameter Descriptions

- `session` is a handle to a running `XrSession`.

If `session` is not running when `xrRequestExitSession` is called, `XR_ERROR_SESSION_NOT_RUNNING` must be returned.

### Valid Usage (Implicit)

- `session` must be a valid `XrSession` handle

### Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_SESSION_NOT_RUNNING`

### 9.4. Session States

While events can be expanded upon, there are a minimum set of lifecycle events which can occur which all OpenXR applications must be aware of. These events are detailed below.
9.4.1. XrEventDataSessionStateChanged

The XrEventDataSessionStateChanged structure is defined as:

```c
typedef struct XrEventDataSessionStateChanged {
    XrStructureType    type;
    const void*         next;
    XrSession           session;
    XrSessionState      state;
    XrTime              time;
} XrEventDataSessionStateChanged;
```

**Member Descriptions**

- `type` is the XrStructureType of this structure.
- `next` is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- `session` is the XrSession which has changed state.
- `state` is the current XrSessionState of the session.
- `time` is an XrTime which indicates the time of the state change.

Receiving the XrEventDataSessionStateChanged event structure indicates that the application has changed lifecycle state.

**Valid Usage (Implicit)**

- `type` must be XR_TYPE_EVENT_DATA_SESSION_STATE_CHANGED
- `next` must be NULL or a valid pointer to the next structure in a structure chain
- `session` must be a valid XrSession handle
- `state` must be a valid XrSessionState value

The XrSessionState enumerates the possible session lifecycle states:
typedef enum XrSessionState {
    XR_SESSION_STATE_UNKNOWN = 0,
    XR_SESSION_STATE_IDLE = 1,
    XR_SESSION_STATE_READY = 2,
    XR_SESSION_STATE_SYNCHRONIZED = 3,
    XR_SESSION_STATE_VISIBLE = 4,
    XR_SESSION_STATE_FOCUSED = 5,
    XR_SESSION_STATE_STOPPING = 6,
    XR_SESSION_STATE_LOSS_PENDING = 7,
    XR_SESSION_STATE_EXITING = 8,
    XR_SESSION_STATE_MAX_ENUM = 0x7FFFFFFF
} XrSessionState;

Enumerant Descriptions

- **XR_SESSION_STATE_UNKNOWN**. An unknown state. The runtime must not return this value in an XrEventDataSessionStateChanged event.

- **XR_SESSION_STATE_IDLE**. The initial state after calling xrCreateSession or returned to after calling xrEndSession.

- **XR_SESSION_STATE_READY**. The application is ready to call xrBeginSession and sync its frame loop with the runtime.

- **XR_SESSION_STATE_SYNCHRONIZED**. The application has synced its frame loop with the runtime but is not visible to the user.

- **XR_SESSION_STATE_VISIBLE**. The application has synced its frame loop with the runtime and is visible to the user but cannot receive XR input.

- **XR_SESSION_STATE_FOCUSED**. The application has synced its frame loop with the runtime, is visible to the user and can receive XR input.

- **XR_SESSION_STATE_STOPPING**. The application should exit its frame loop and call xrEndSession.

- **XR_SESSION_STATE_LOSS_PENDING**. The session is in the process of being lost. The application should destroy the current session and can optionally recreate it.

- **XR_SESSION_STATE_EXITING**. The application should end its XR experience and not automatically restart it.

The **XR_SESSION_STATE_UNKNOWN** state must not be returned by the runtime, and is only defined to avoid 0 being a valid state.

Receiving the **XR_SESSION_STATE_IDLE** state indicates that the runtime considers the session is idle. Applications in this state should minimize resource consumption but continue to call xrPollEvent at some reasonable cadence.
Receiving the `XR_SESSION_STATE_READY` state indicates that the runtime desires the application to prepare rendering resources, begin its session and synchronize its frame loop with the runtime. The application does this by successfully calling `xrBeginSession` and then running its frame loop by calling `xWaitFrame`, `xBeginFrame` and `xEndFrame` in a loop. If the runtime wishes to return the session to the `XR_SESSION_STATE_IDLE` state, it must wait until the application calls `xBeginSession`. After returning from the `xBeginSession` call, the runtime may then immediately transition forward through the `XR_SESSION_STATE_SYNCHRONIZED` state to the `XR_SESSION_STATE_STOPPING` state, to request that the application end this session. If the system supports a user engagement sensor and runtime is in `XR_SESSION_STATE_IDLE` state, the runtime should not transition to the `XR_SESSION_STATE_READY` state until the user starts engaging with the device.

Receiving the `XR_SESSION_STATE_SYNCHRONIZED` state indicates that the application has synchronized its frame loop with the runtime, but its frames are not visible to the user. The application should continue running its frame loop by calling `xWaitFrame`, `xBeginFrame` and `xEndFrame`, although it should avoid heavy GPU work so that other visible applications can take CPU and GPU precedence. The application can save resources here by skipping rendering and not submitting any composition layers until `xWaitFrame` returns an `XrFrameState` with `shouldRender` set to true. A runtime may use this frame synchronization to facilitate seamless switching from a previous XR application to this application on a frame boundary.

Receiving the `XR_SESSION_STATE_VISIBLE` state indicates that the application has synchronized its frame loop with the runtime, and the session’s frames will be visible to the user, but the session is not eligible to receive XR input. An application may be visible but not have focus, for example when the runtime is composing a modal pop-up on top of the application’s rendered frames. The application should continue running its frame loop, rendering and submitting its composition layers, although it may wish to pause its experience, as users cannot interact with the application at this time. It is important for applications to continue rendering when visible, even when they do not have focus, so the user continues to see something reasonable underneath modal pop-ups. Runtimes should make input actions inactive while the application is unfocused, and applications should react to an inactive input action by skipping rendering of that action’s input avatar (depictions of hands or other tracked objects controlled by the user).

Receiving the `XR_SESSION_STATE_FOCUSED` state indicates that the application has synchronized its frame loop with the runtime, the session’s frames will be visible to the user, and the session is eligible to receive XR input. The runtime should only give one session XR input focus at any given time. The application should be running its frame loop, rendering and submitting composition layers, including input avatars (depictions of hands or other tracked objects controlled by the user) for any input actions that are active. The runtime should avoid rendering its own input avatars when an application is focused, unless input from a given source is being captured by the runtime at the moment.

Receiving the `XR_SESSION_STATE_STOPPING` state indicates that the runtime has determined that the application should halt its rendering loop. Applications should exit their rendering loop and call `xEndSession` when in this state. A possible reason for this would be to minimize contention between multiple applications. If the system supports a user engagement sensor and the session is running, the runtime should transition to the `XR_SESSION_STATE_STOPPING` state when the user stops engaging with
Receiving the `XR_SESSION_STATE_EXITING` state indicates the runtime wishes the application to terminate its XR experience, typically due to a user request via a runtime user interface. Applications should gracefully end their process when in this state if they do not have a non-XR user experience.

Receiving the `XR_SESSION_STATE_LOSS_PENDING` state indicates the runtime is no longer able to operate with the current session, for example due to the loss of a display hardware connection. An application should call `xrDestroySession` and may end its process or decide to poll `xrGetSystem` at some reasonable cadence to get a new `XrSystemId`, and re-initialize all graphics resources related to the new system, and then create a new session using `xrCreateSession`. After the event is queued, subsequent calls to functions that accept `XrSession` parameters must no longer return any success code other than `XR_SESSION_LOSS_PENDING` for the given `XrSession` handle. The `XR_SESSION_LOSS_PENDING` success result is returned for an unspecified grace period of time, and the functions that return it simulate success in their behavior. If the runtime has no reasonable way to successfully complete a given function (e.g. `xrCreateSwapchain`) when a lost session is pending, or if the runtime is not able to provide the application a grace period, the runtime may return `XR_ERROR_SESSION_LOST`. Thereafter, functions which accept `XrSession` parameters for the lost session may return `XR_ERROR_SESSION_LOST` to indicate that the function failed and the given session was lost. The `XrSession` handle and child handles are henceforth unusable and should be destroyed by the application in order to immediately free up resources associated with those handles.
Chapter 10. Rendering

10.1. Swapchain Image Management

XR_DEFINE_HANDLE(XrSwapchain)

Normal XR applications will want to present rendered images to the user. To allow this, the runtime provides images organized in swapchains for the application to render into. The runtime must allow applications to create multiple swapchains.

Swapchain image format support by the runtime is specified by the xrEnumerateSwapchainFormats function. Runtimes should support R8G8B8A8 and R8G8B8A8 sRGB formats if possible.

Swapchain images can be 2D or 2D Array.

Rendering operations involving composition of submitted layers should be assumed to be internally performed by the runtime in linear color space. Images submitted in sRGB color space must be created using an API-specific sRGB format (e.g. DXGI_FORMAT_R8G8B8A8_UNORM_SRGB, GL_SRGB8_ALPHA8, VK_FORMAT_R8G8B8A8_SRGB) to apply automatic sRGB-to-linear conversion when read by the runtime. All other formats will be treated as linear values.

Note
OpenXR applications should avoid submitting linear encoded 8 bit color data (e.g. DXGI_FORMAT_R8G8B8A8_UNORM) whenever possible as it may result in color banding.


Note
DXGI resources will be created with their associated TYPELESS format, but the runtime will use the application-specified format for reading the data.

The xrEnumerateSwapchainFormats function is defined as:
XrResult xrEnumerateSwapchainFormats(
    XrSession session,
    uint32_t formatCapacityInput,
    uint32_t* formatCountOutput,
    int64_t* formats);

Parameter Descriptions

- **session** is the session that enumerates the supported formats.
- **formatCapacityInput** is the capacity of the formats, or 0 to retrieve the required capacity.
- **formatCountOutput** is a pointer to the count of uint64_t formats written, or a pointer to the required capacity in the case that formatCapacityInput is insufficient.
- **formats** is a pointer to an array of int64_t format ids, but can be NULL if formatCapacityInput is 0. The format ids are specific to the specified graphics API.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required formats size.

xrEnumerateSwapchainFormats enumerates the texture formats supported by the current session. The type of formats returned are dependent on the graphics API specified in xrCreateSession. For example, if a DirectX graphics API was specified, then the enumerated formats correspond to the DXGI formats, such as DXGI_FORMAT_R8G8B8A8_UNORM_SRGB. Texture formats should be in order from highest to lowest runtime preference. The application should use the highest preference format that it supports for optimal performance and quality.

With an OpenGL-based graphics API, the texture formats correspond to OpenGL internal formats.

With a Direct3D-based graphics API, xrEnumerateSwapchainFormats never returns typeless formats (e.g. DXGI_FORMAT_R8G8B8A8_TYPELESS). Only concrete formats are returned, and only concrete formats may be specified by applications for swapchain creation.

Runtimes must always return identical buffer contents from this enumeration for the lifetime of the session.

Valid Usage (Implicit)

- **session** must be a valid XrSession handle
- **formatCountOutput** must be a pointer to a uint32_t value
- If formatCapacityInput is not 0, **formats** must be a pointer to an array of formatCapacityInput int64_t values
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_SIZE_INSUFFICIENT

XrSwapchainUsageFlags specify the intended usage of the swapchain images. When images are created, the runtime needs to know how the images are used in a way that requires more information than simply the image format. The XrSwapchainCreateInfo passed to xrCreateSwapchain should match the intended usage or else undefined behavior may result when the application works with the images.

Flags include:

```
// Flag bits for XrSwapchainUsageFlags
static const XrSwapchainUsageFlags XR_SWAPCHAIN_USAGE_COLOR_ATTACHMENT_BIT = 0x00000001;
static const XrSwapchainUsageFlags XR_SWAPCHAIN_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT = 0x00000002;
static const XrSwapchainUsageFlags XR_SWAPCHAIN_USAGE_UNORDERED_ACCESS_BIT = 0x00000004;
static const XrSwapchainUsageFlags XR_SWAPCHAIN_USAGE_TRANSFER_SRC_BIT = 0x00000008;
static const XrSwapchainUsageFlags XR_SWAPCHAIN_USAGE_TRANSFER_DST_BIT = 0x00000010;
static const XrSwapchainUsageFlags XR_SWAPCHAIN_USAGE_SAMPLED_BIT = 0x00000020;
static const XrSwapchainUsageFlags XR_SWAPCHAIN_USAGE_MUTABLE_FORMAT_BIT = 0x00000040;
static const XrSwapchainUsageFlags XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_MND = 0x00000080;
static const XrSwapchainUsageFlags XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_KHR = 0x00000080;  // alias of XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_MND
```
Flag Descriptions

- **XR_SWAPCHAIN_USAGE_COLOR_ATTACHMENT_BIT** — Specifies that the image **may** be a color rendering target.
- **XR_SWAPCHAIN_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT** — Specifies that the image **may** be a depth/stencil rendering target.
- **XR_SWAPCHAIN_USAGE_UNORDERED_ACCESS_BIT** — Specifies that the image **may** be accessed out of order and that access **may** be via atomic operations.
- **XR_SWAPCHAIN_USAGE_TRANSFER_SRC_BIT** — Specifies that the image **may** be used as the source of a transfer operation.
- **XR_SWAPCHAIN_USAGE_TRANSFER_DST_BIT** — Specifies that the image **may** be used as the destination of a transfer operation.
- **XR_SWAPCHAIN_USAGE_SAMPLED_BIT** — Specifies that the image **may** be sampled by a shader.
- **XR_SWAPCHAIN_USAGE_MUTABLE_FORMAT_BIT** — Specifies that the image **may** be reinterpreted as another image format.
- **XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_MND** — Specifies that the image **may** be used as a input attachment. (Added by the XR_MND_swapchain_usage_input_attachment_bit extension)
- **XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_KHR** — Specifies that the image **may** be used as a input attachment. (Added by the XR_KHR_swapchain_usage_input_attachment_bit extension)

The **xrCreateSwapchain** function is defined as:

```c
XrResult xrCreateSwapchain(
    XrSession session,
    const XrSwapchainCreateInfo* createInfo,
    XrSwapchain* swapchain);
```

Parameter Descriptions

- **session** is the session that creates the image.
- **createInfo** is a pointer to an **XrSwapchainCreateInfo** structure containing parameters to be used to create the image.
- **swapchain** is a pointer to a handle in which the created **XrSwapchain** is returned.

Creates an **XrSwapchain** handle. The returned swapchain handle **may** be subsequently used in API calls. Multiple **XrSwapchain** handles may exist simultaneously, up to some limit imposed by the
The runtime must eventually free the `XrSwapchain` handle via the `xrDestroySwapchain` function. The runtime must return `XR_ERROR_SWAPCHAIN_FORMAT_UNSUPPORTED` if the image format specified in the `XrSwapchainCreateInfo` is unsupported. The runtime must return `XR_ERROR_FEATURE_UNSUPPORTED` if any bit of the create flags specified in the `XrSwapchainCreateInfo` is unsupported.

**Valid Usage (Implicit)**

- `session` must be a valid `XrSession` handle
- `createInfo` must be a pointer to a valid `XrSwapchainCreateInfo` structure
- `swapchain` must be a pointer to an `XrSwapchain` handle

**Return Codes**

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_LIMIT_REACHED`
- `XR_ERROR_SWAPCHAIN_FORMAT_UNSUPPORTED`
- `XR_ERROR_FEATURE_UNSUPPORTED`

The `XrSwapchainCreateInfo` structure is defined as:
```c
typedef struct XrSwapchainCreateInfo {
    XrStructureType           type;
    const void*               next;
    XrSwapchainCreateFlags    createFlags;
    XrSwapchainUsageFlags     usageFlags;
    int64_t                   format;
    uint32_t                  sampleCount;
    uint32_t                  width;
    uint32_t                  height;
    uint32_t                  faceCount;
    uint32_t                  arraySize;
    uint32_t                  mipCount;
} XrSwapchainCreateInfo;
```
**Member Descriptions**

- **type** is the XrStructureType of this structure.

- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

- **createFlags** is a bitmask of XrSwapchainCreateFlagBits describing additional properties of the swapchain.

- **usageFlags** is a bitmask of XrSwapchainUsageFlagBits describing the intended usage of the swapchain's images. The usage flags define how the corresponding graphics API objects are created. A mismatch may result in swapchain images that do not support the application's usage.

- **format** is a graphics API-specific texture format identifier. For example, if the graphics API specified in xrCreateSession is Vulkan, then this format is a Vulkan format such as VK_FORMAT_R8G8B8A8_SRGB. The format identifies the format that the runtime will interpret the texture as upon submission. Valid formats are indicated by xrEnumerateSwapchainFormats.

- **sampleCount** is the number of sub-data element samples in the image, must not be 0 or greater than the graphics API's maximum limit.

- **width** is the width of the image, must not be 0 or greater than the graphics API's maximum limit.

- **height** is the height of the image, must not be 0 or greater than the graphics API's maximum limit.

- **faceCount** is the number of faces, which can be either 6 (for cubemaps) or 1.

- **arraySize** is the number of array layers in the image or 1 for a 2D image, must not be 0 or greater than the graphics API's maximum limit.

- **mipCount** describes the number of levels of detail available for minified sampling of the image, must not be 0 or greater than the graphics API's maximum limit.

**Valid Usage (Implicit)**

- **type** must be XR_TYPE_SWAPCHAIN_CREATE_INFO

- **next** must be NULL or a valid pointer to the next structure in a structure chain. See also: XrAndroidSurfaceSwapchainCreateInfoFB, XrSecondaryViewConfigurationSwapchainCreateInfoMSFT, XrSwapchainCreateInfoFoveationFB, XrVulkanSwapchainCreateInfoMETA

- **createFlags** must be 0 or a valid combination of XrSwapchainCreateFlagBits values

- **usageFlags** must be 0 or a valid combination of XrSwapchainUsageFlagBits values
The createFlags are a combination of the following:

```c
// Flag bits for XrSwapchainCreateFlags
static const XrSwapchainCreateFlags XR_SWAPCHAIN_CREATE_PROTECTED_CONTENT_BIT = 0x00000001;
static const XrSwapchainCreateFlags XR_SWAPCHAIN_CREATE_STATIC_IMAGE_BIT = 0x00000002;
```

### Flag Descriptions

- **XR_SWAPCHAIN_CREATE_PROTECTED_CONTENT_BIT** indicates that the swapchain’s images will be protected from CPU access, using a mechanism such as Vulkan protected memory.
- **XR_SWAPCHAIN_CREATE_STATIC_IMAGE_BIT** indicates that the application will acquire and release only one image to this swapchain over its entire lifetime. The runtime must allocate only one swapchain image.

A runtime may implement any of these, but is not required to. A runtime must return XR_ERROR_FEATURE_UNSUPPORTED from `xrCreateSwapchain` if an XrSwapchainCreateFlags bit is requested but not implemented.

The number of images in each swapchain is implementation-defined except in the case of a static swapchain. To obtain the number of images actually allocated, call `xrEnumerateSwapchainImages`.

With a Direct3D-based graphics API, the swapchain returned by `xrCreateSwapchain` will be a typeless format if the requested format has a typeless analogue. Applications are required to reinterpret the swapchain as a compatible non-typeless type. Upon submitting such swapchains to the runtime, they are interpreted as the format specified by the application in the `XrSwapchainCreateInfo`.

Swapchains will be created with graphics API-specific flags appropriate to the type of underlying image and its usage. Extensions may exist to further assist the runtime in choosing how to create swapchains.

Runtimes must honor underlying graphics API limits when creating resources.

`xrEnumerateSwapchainFormats` never returns typeless formats (e.g. `DXGI_FORMAT_R8G8B8A8_TYPELESS`). Only concrete formats are returned, and only concrete formats may be specified by applications for swapchain creation.

The `xrDestroySwapchain` function is defined as:
XrResult xrDestroySwapchain(
    XrSwapchain swapchain);

Parameter Descriptions

- swapchain is the swapchain to destroy.

All submitted graphics API commands that refer to swapchain must have completed execution. Runtimes may continue to utilize swapchain images after xrDestroySwapchain is called.

Valid Usage (Implicit)

- swapchain must be a valid XrSwapchain handle

Thread Safety

- Access to swapchain, and any child handles, must be externally synchronized

Return Codes

**Success**

- XR_SUCCESS

**Failure**

- XR_ERROR_HANDLE_INVALID

Swapchain images are acquired, waited on, and released by index, but the number of images in a swapchain is implementation-defined. Additionally, rendering to images requires access to the underlying image primitive of the graphics API being used. Applications may query and cache the images at any time after swapchain creation.

The xrEnumerateSwapchainImages function is defined as:

---

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XrResult xrEnumerateSwapchainImages(
    XrSwapchain swapchain,
    uint32_t imageCapacityInput,
    uint32_t* imageCountOutput,
    XrSwapchainImageBaseHeader* images);

Parameter Descriptions

- **swapchain** is the XrSwapchain to get images from.
- **imageCapacityInput** is the capacity of the images array, or 0 to indicate a request to retrieve the required capacity.
- **imageCountOutput** is a pointer to the count of images written, or a pointer to the required capacity in the case that imageCapacityInput is insufficient.
- **images** is a pointer to an array of graphics API-specific XrSwapchainImage structures, all of the same type, based on XrSwapchainImageBaseHeader. It can be NULL if imageCapacityInput is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required images size.

Fills an array of graphics API-specific XrSwapchainImage structures. The resources must be constant and valid for the lifetime of the XrSwapchain.

Runtimes must always return identical buffer contents from this enumeration for the lifetime of the swapchain.

Note: images is a pointer to an array of structures of graphics API-specific type, not an array of structure pointers.

The pointer submitted as images will be treated as an array of the expected graphics API-specific type based on the graphics API used at session creation time. If the type member of any array element accessed in this way does not match the expected value, the runtime must return XR_ERROR_VALIDATION_FAILURE.

Note

Under a typical memory model, a runtime must treat the supplied pointer as an opaque blob beginning with XrSwapchainImageBaseHeader, until after it has verified the type.
Valid Usage (Implicit)

- **swapchain** must be a valid `XrSwapchain` handle
- **imageCountOutput** must be a pointer to a `uint32_t` value
- If `imageCapacityInput` is not 0, **images** must be a pointer to an array of `imageCapacityInput` `XrSwapchainImageBaseHeader`-based structures. See also: `XrSwapchainImageD3D11KHR`, `XrSwapchainImageD3D12KHR`, `XrSwapchainImageOpenGLESKHR`, `XrSwapchainImageOpenGLKHR`, `XrSwapchainImageVulkanKHR

Return Codes

**Success**
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_SIZE_INSUFFICIENT

The `XrSwapchainImageBaseHeader` structure is defined as:

```c
typedef struct XrSwapchainImageBaseHeader {
    XrStructureType    type;
    void*              next;
} XrSwapchainImageBaseHeader;
```
Member Descriptions

• **type** is the XrStructureType of this structure. This base structure itself has no associated XrStructureType value.

• **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

The XrSwapchainImageBaseHeader is a base structure that can be overridden by a graphics API-specific XrSwapchainImage* child structure.

Valid Usage (Implicit)

• **type** must be one of the following XrStructureType values:
  - XR_TYPE_SWAPCHAIN_IMAGE_D3D11_KHR
  - XR_TYPE_SWAPCHAIN_IMAGE_D3D12_KHR
  - XR_TYPE_SWAPCHAIN_IMAGE_OPENGL_ES_KHR
  - XR_TYPE_SWAPCHAIN_IMAGE_OPENGL_KHR
  - XR_TYPE_SWAPCHAIN_IMAGE_VULKAN_KHR

• **next** must be NULL or a valid pointer to the next structure in a structure chain

Before an application can start building graphics API command buffers that refer to an image in a swapchain, it must acquire the image from the swapchain. The acquire operation determines the index of the next image that will be used in the swapchain. The order in which images are acquired is undefined. The runtime must allow the application to acquire more than one image from a single swapchain at a time, for example if the application implements a multiple frame deep rendering pipeline.

The xrAcquireSwapchainImage function is defined as:

```c
XrResult xrAcquireSwapchainImage(
    XrSwapchain swapchain,                     // swapchain,                        
    const XrSwapchainImageAcquireInfo* acquireInfo,   // acquireInfo,                   
    uint32_t* index);                              // index);                         
```

Parameter Descriptions

• **swapchain** is the swapchain from which to acquire an image.

• **acquireInfo** exists for extensibility purposes, it is NULL or a pointer to a valid XrSwapchainImageAcquireInfo.

• **index** is the returned image index that has been acquired.
Acquires the image corresponding to the index position in the array returned by xrEnumerateSwapchainImages. The runtime must return XR_ERROR_CALL_ORDER_INVALID if the next available index has already been acquired and not yet released with xrReleaseSwapchainImage. If the swapchain was created with the XR_SWAPCHAIN_CREATE_STATIC_IMAGE_BIT set in XrSwapchainCreateInfo::createFlags, this function must not have been previously called for this swapchain. The runtime must return XR_ERROR_CALL_ORDER_INVALID if a swapchain created with the XR_SWAPCHAIN_CREATE_STATIC_IMAGE_BIT set in XrSwapchainCreateInfo::createFlags and this function has been successfully called previously for this swapchain.

### Valid Usage (Implicit)

- **swapchain** must be a valid XrSwapchain handle
- If acquireInfo is not NULL, acquireInfo must be a pointer to a valid XrSwapchainImageAcquireInfo structure
- index must be a pointer to a uint32_t value

### Return Codes

**Success**
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_CALL_ORDER_INVALID

The XrSwapchainImageAcquireInfo structure is defined as:

```c
typedef struct XrSwapchainImageAcquireInfo {
    XrStructureType    type;
    const void*        next;
} XrSwapchainImageAcquireInfo;
```
Member Descriptions

• `type` is the `XrStructureType` of this structure.
• `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

Because this structure only exists to support extension-specific structures, `xrAcquireSwapchainImage` will accept a `NULL` argument for `acquireInfo` for applications that are not using any relevant extensions.

Valid Usage (Implicit)

• `type` must be `XR_TYPE_SWAPCHAIN_IMAGE_ACQUIRE_INFO`
• `next` must be `NULL` or a valid pointer to the next structure in a structure chain

The `xrWaitSwapchainImage` function is defined as:

```c
XrResult xrWaitSwapchainImage(
    XrSwapchain swapchain,
    const XrSwapchainImageWaitInfo* waitInfo);
```

Parameter Descriptions

• `swapchain` is the swapchain from which to wait for an image.
• `waitInfo` is a pointer to an `XrSwapchainImageWaitInfo` structure.

Before an application can begin writing to a swapchain image, it must first wait on the image to avoid writing to it before the compositor has finished reading from it. `xrWaitSwapchainImage` will implicitly wait on the oldest acquired swapchain image which has not yet been successfully waited on. Once a swapchain image has been successfully waited on without timeout, the app must release before waiting on the next acquired swapchain image.

This function may block for longer than the timeout specified in `XrSwapchainImageWaitInfo` due to scheduling or contention.

If the timeout expires without the image becoming available for writing, `XR_TIMEOUT_EXPIRED` must be returned. If `xrWaitSwapchainImage` returns `XR_TIMEOUT_EXPIRED`, the next call to `xrWaitSwapchainImage` will wait on the same image index again until the function succeeds with `XR_SUCCESS`. Note that this is not an error code; `XR_SUCCEEDED(XR_TIMEOUT_EXPIRED)` is `true`. 

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The runtime **must** eventually relinquish ownership of a swapchain image to the application and **must** not block indefinitely.

The runtime **must** return `XR_ERROR_CALL_ORDER_INVALID` if no image has been acquired by calling `xrAcquireSwapchainImage`.

### Valid Usage (Implicit)

- **swapchain** **must** be a valid `XrSwapchain` handle
- **waitInfo** **must** be a pointer to a valid `XrSwapchainImageWaitInfo` structure

### Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`
- `XR_TIMEOUT_EXPIRED`

**Failure**

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_CALL_ORDER_INVALID`

The `XrSwapchainImageWaitInfo` structure describes a swapchain image wait operation. It is defined as:

```c
typedef struct XrSwapchainImageWaitInfo {
    XrStructureType    type;
    const void*        next;
    XrDuration         timeout;
} XrSwapchainImageWaitInfo;
```
**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **timeout** indicates how many nanoseconds the call should block waiting for the image to become available for writing.

**Valid Usage (Implicit)**

- **type** must be XR_TYPE_SWAPCHAIN_IMAGE_WAIT_INFO
- **next** must be NULL or a valid pointer to the next structure in a structure chain

Once an application is done submitting commands that reference the swapchain image, the application must release the swapchain image. **xrReleaseSwapchainImage** will implicitly release the oldest swapchain image which has been acquired. The swapchain image must have been successfully waited on without timeout before it is released. **xrEndFrame** will use the most recently released swapchain image. In each frame submitted to the compositor only one image index from each swapchain will be used. Note that in case the swapchain contains 2D image arrays, one array is referenced per swapchain index and thus the whole image array can be used in one frame.

The **xrReleaseSwapchainImage** function is defined as:

```c
XrResult xrReleaseSwapchainImage(
    XrSwapchain                                 swapchain,
    const XrSwapchainImageReleaseInfo*          releaseInfo);
```

**Parameter Descriptions**

- **swapchain** is the XrSwapchain from which to release an image.
- **releaseInfo** exists for extensibility purposes, it is NULL or a pointer to a valid XrSwapchainImageReleaseInfo.

If the **swapchain** was created with the XR_SWAPCHAIN_CREATE_STATIC_IMAGE_BIT set in XrSwapchainCreateInfo::createFlags structure, this function must not have been previously called for this swapchain.

The runtime must return XR_ERROR_CALL_ORDER_INVALID if no image has been waited on by calling...
Valid Usage (Implicit)

- `swapchain` must be a valid `XrSwapchain` handle
- If `releaseInfo` is not `NULL`, `releaseInfo` must be a pointer to a valid `XrSwapchainImageReleaseInfo` structure

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_CALL_ORDER_INVALID`

The `XrSwapchainImageReleaseInfo` structure is defined as:

```c
typedef struct XrSwapchainImageReleaseInfo {
    XrStructureType    type;
    const void*        next;
} XrSwapchainImageReleaseInfo;
```

Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

Because this structure only exists to support extension-specific structures, `xrReleaseSwapchainImage`
will accept a NULL argument for `releaseInfo` for applications that are not using any relevant extensions.

### Valid Usage (Implicit)

- **type** must be `XR_TYPE_SWAPCHAIN_IMAGE_RELEASE_INFO`
- **next** must be NULL or a valid pointer to the next structure in a structure chain

## 10.2. View and Projection State

An application uses `xrLocateViews` to retrieve the viewer pose and projection parameters needed to render each view for use in a composition projection layer.

The `xrLocateViews` function is defined as:

```c
XrResult xrLocateViews(
    XrSession session,
    const XrViewLocateInfo* viewLocateInfo,
    XrViewState* viewState,
    uint32_t viewCapacityInput,
    uint32_t* viewCountOutput,
    XrView* views);
```

### Parameter Descriptions

- **session** is a handle to the provided `XrSession`.
- **viewLocateInfo** is a pointer to a valid `XrViewLocateInfo` structure.
- **viewState** is the output structure with the viewer state information.
- **viewCapacityInput** is an input parameter which specifies the capacity of the `views` array. The required capacity **must** be same as defined by the corresponding `XrViewConfigurationType`.
- **viewCountOutput** is an output parameter which identifies the valid count of `views`.
- **views** is an array of `XrView`.

See **Buffer Size Parameters** chapter for a detailed description of retrieving the required `views` size.

The `xrLocateViews` function returns the view and projection info for a particular display time. This time is typically the target display time for a given frame. Repeatedly calling `xrLocateViews` with the same time **may** not necessarily return the same result. Instead the prediction gets increasingly

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accurate as the function is called closer to the given time for which a prediction is made. This allows an application to get the predicted views as late as possible in its pipeline to get the least amount of latency and prediction error.

`xrLocateViews` returns an array of `XrView` elements, one for each view of the specified view configuration type, along with an `XrViewState` containing additional state data shared across all views. The eye each view corresponds to is statically defined in `XrViewConfigurationType` in case the application wants to apply eye-specific rendering traits. The `XrViewState` and `XrView` member data may change on subsequent calls to `xrLocateViews`, and so applications must not assume it to be constant.

### Valid Usage (Implicit)

- `session` **must** be a valid `XrSession` handle
- `viewLocateInfo` **must** be a pointer to a valid `XrViewLocateInfo` structure
- `ViewState` **must** be a pointer to an `XrViewState` structure
- `viewCountOutput` **must** be a pointer to a `uint32_t` value
- If `viewCapacityInput` is not 0, `views` **must** be a pointer to an array of `viewCapacityInput` `XrView` structures

### Return Codes

**Success**
- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_SIZE_INSUFFICIENT`
- `XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED`
- `XR_ERROR_TIME_INVALID`

The `XrViewLocateInfo` structure is defined as:
typedef struct XrViewLocateInfo {
    XrStructureType type;
    const void* next;
    XrViewConfigurationType viewConfigurationType;
    XrTime displayTime;
    XrSpace space;
} XrViewLocateInfo;

**Member Descriptions**

- `viewConfigurationType` is `XrViewConfigurationType` to query for.
- `displayTime` is the time for which the view poses are predicted.
- `space` is the `XrSpace` in which the `pose` in each `XrView` is expressed.

The `XrViewLocateInfo` structure contains the display time and space used to locate the view `XrView` structures.

The runtime must return error `XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED` if the given `viewConfigurationType` is not one of the supported type reported by `xrEnumerateViewConfigurations`.

**Valid Usage (Implicit)**

- `type` must be `XR_TYPE_VIEW_LOCATE_INFO`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrViewLocateFoveatedRenderingVARJO`
- `viewConfigurationType` must be a valid `XrViewConfigurationType` value
- `space` must be a valid `XrSpace` handle

The `XrView` structure is defined as:

typedef struct XrView {
    XrStructureType type;
    void* next;
    XrPosef pose;
    XrFovf fov;
} XrView;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **pose** is an `XrPosef` defining the location and orientation of the view in the `space` specified by the `xrLocateViews` function.
- **fov** is the `XrFovf` for the four sides of the projection.

The `XrView` structure contains view pose and projection state necessary to render a single projection view in the view configuration.

Valid Usage (Implicit)

- **type** must be `XR_TYPE_VIEW`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

The `XrViewState` structure is defined as:

```c
typedef struct XrViewState {
    XrStructureType type;
    void* next;
    XrViewStateFlags viewStateFlags;
} XrViewState;
```

Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **viewStateFlags** is a bitmask of `XrViewStateFlagBits` indicating state for all views.

The `XrViewState` contains additional view state from `xrLocateViews` common to all views of the active view configuration.
Valid Usage (Implicit)

• **type** must be XR_TYPE_VIEW_STATE
• **next** must be NULL or a valid pointer to the next structure in a structure chain
• **viewStateFlags** must be 0 or a valid combination of XrViewStateFlagBits values

The `XrViewStateFlags` specifies the validity and quality of the corresponding `XrView` array returned by `xrLocateViews`.

Flags include:

```c
// Flag bits for XrViewStateFlags
static const XrViewStateFlags XR_VIEW_STATE_ORIENTATION_VALID_BIT = 0x00000001;
static const XrViewStateFlags XR_VIEW_STATE_POSITION_VALID_BIT = 0x00000002;
static const XrViewStateFlags XR_VIEW_STATE_ORIENTATION_TRACKED_BIT = 0x00000004;
static const XrViewStateFlags XR_VIEW_STATE_POSITION_TRACKED_BIT = 0x00000008;
```

Flag Descriptions

• **XR_VIEW_STATE_ORIENTATION_VALID_BIT** indicates whether all `XrView` orientations contain valid data. Applications **must** not read any of the `XrView` pose orientation fields if this flag is unset. **XR_VIEW_STATE_ORIENTATION_TRACKED_BIT** should generally remain set when this bit is set for views on a tracked headset or handheld device.

• **XR_VIEW_STATE_POSITION_VALID_BIT** indicates whether all `XrView` positions contain valid data. Applications **must** not read any of the `XrView`::pose position fields if this flag is unset. When a view loses tracking, runtimes **should** continue to provide valid but untracked view position values that are inferred or last-known, so long as it's still meaningful for the application to render content using that position, clearing **XR_VIEW_STATE_POSITION_TRACKED_BIT** until tracking is recovered.

• **XR_VIEW_STATE_ORIENTATION_TRACKED_BIT** indicates whether all `XrView` orientations represent an actively tracked orientation. This bit **should** generally remain set when **XR_VIEW_STATE_ORIENTATION_VALID_BIT** is set for views on a tracked headset or handheld device.

• **XR_VIEW_STATE_POSITION_TRACKED_BIT** indicates whether all `XrView` positions represent an actively tracked position. When a view loses tracking, runtimes **should** continue to provide valid but untracked view position values that are inferred or last-known, e.g. based on neck model updates, inertial dead reckoning, or a last-known position, so long as it's still meaningful for the application to render content using that position.
10.3. Frame Synchronization

An application synchronizes its rendering loop to the runtime by calling \texttt{xrWaitFrame}.

The \texttt{xrWaitFrame} function is defined as:

\begin{verbatim}
XrResult xrWaitFrame(
    XrSession session,
    const XrFrameWaitInfo* frameWaitInfo,
    XrFrameState* frameState);
\end{verbatim}

\textbf{Parameter Descriptions}

- \texttt{session} is a valid \texttt{XrSession} handle.
- \texttt{frameWaitInfo} exists for extensibility purposes, it is \texttt{NULL} or a pointer to a valid \texttt{XrFrameWaitInfo}.
- \texttt{frameState} is a pointer to a valid \texttt{XrFrameState}, an output parameter.

\texttt{xrWaitFrame} throttles the application frame loop in order to synchronize application frame submissions with the display. \texttt{xrWaitFrame} returns a predicted display time for the next time that the runtime predicts a composites frame will be displayed. The runtime \texttt{may} affect this computation by changing the return values and throttling of \texttt{xrWaitFrame} in response to feedback from frame submission and completion times in \texttt{xrEndFrame}. An application \texttt{must} eventually match each \texttt{xrWaitFrame} call with one call to \texttt{xrBeginFrame}. A subsequent \texttt{xrWaitFrame} call \texttt{must} block until the previous frame has been begun with \texttt{xrBeginFrame} and \texttt{must} unblock independently of the corresponding call to \texttt{xrEndFrame}. When less than one frame interval has passed since the previous return from \texttt{xrWaitFrame}, the runtime \texttt{should} block until the beginning of the next frame interval. If more than one frame interval has passed since the last return from \texttt{xrWaitFrame}, the runtime \texttt{may} return immediately or block until the beginning of the next frame interval.

In the case that an application has pipelined frame submissions, the application \texttt{should} compute the appropriate target display time using both the predicted display time and predicted display interval. The application \texttt{should} use the computed target display time when requesting space and view locations for rendering.

The \texttt{XrFrameState::predictedDisplayTime} returned by \texttt{xrWaitFrame} \texttt{must} be monotonically increasing.

The runtime \texttt{may} dynamically adjust the start time of the frame interval relative to the display hardware's refresh cycle to minimize graphics processor contention between the application and the compositor.
xrWaitFrame must be callable from any thread, including a different thread than xrBeginFrame/xrEndFrame are being called from.

Calling xrWaitFrame must be externally synchronized by the application, concurrent calls may result in undefined behavior.

The runtime must return XR_ERROR_SESSION_NOT_RUNNING if the session is not running.

**Note**

The engine simulation should advance based on the display time. Every stage in the engine pipeline should use the exact same display time for one particular application-generated frame. An accurate and consistent display time across all stages and threads in the engine pipeline is important to avoid object motion judder. If the application has multiple pipeline stages, the application should pass its computed display time through its pipeline, as xrWaitFrame must be called only once per frame.

**Valid Usage (Implicit)**

- **session** must be a valid XrSession handle
- If frameWaitInfo is not NULL, **frameWaitInfo** must be a pointer to a valid XrFrameWaitInfo structure
- **frameState** must be a pointer to an XrFrameState structure

**Thread Safety**

- Access to the **session** parameter by any other xrWaitFrame call must be externally synchronized
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_SESSION_NOT_RUNNING

The XrFrameWaitInfo structure is defined as:

typedef struct XrFrameWaitInfo {
    XrStructureType   type;
    const void*       next;
} XrFrameWaitInfo;

Member Descriptions

• type is the XrStructureType of this structure.
• next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

Because this structure only exists to support extension-specific structures, xrWaitFrame must accept a NULL argument for frameWaitInfo for applications that are not using any relevant extensions.

Valid Usage (Implicit)

• type must be XR_TYPE_FRAME_WAIT_INFO
• next must be NULL or a valid pointer to the next structure in a structure chain

The XrFrameState structure is defined as:
typedef struct XrFrameState {
    XrStructureType    type;
    void*              next;
    XrTime             predictedDisplayTime;
    XrDuration         predictedDisplayPeriod;
    XrBool32           shouldRender;
} XrFrameState;

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **predictedDisplayTime** is the anticipated display `XrTime` for the next application-generated frame.
- **predictedDisplayPeriod** is the `XrDuration` of the display period for the next application-generated frame, for use in predicting display times beyond the next one.
- **shouldRender** is `XR_TRUE` if the application should render its layers as normal and submit them to `xrEndFrame`. When this value is `XR_FALSE`, the application should avoid heavy GPU work where possible, for example by skipping layer rendering and then omitting those layers when calling `xrEndFrame`.

`XrFrameState` describes the time at which the next frame will be displayed to the user. `predictedDisplayTime` must refer to the midpoint of the interval during which the frame is displayed. The runtime may report a different `predictedDisplayPeriod` from the hardware’s refresh cycle.

For any frame where `shouldRender` is `XR_FALSE`, the application should avoid heavy GPU work for that frame, for example by not rendering its layers. This typically happens when the application is transitioning into or out of a running session, or when some system UI is fully covering the application at the moment. As long as the session is running, the application should keep running the frame loop to maintain the frame synchronization to the runtime, even if this requires calling `xrEndFrame` with all layers omitted.

**Valid Usage (Implicit)**

- **type** must be `XR_TYPE_FRAME_STATE`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrSecondaryViewConfigurationFrameStateMSFT`
10.4. Frame Submission

Every application must call `xrBeginFrame` before calling `xrEndFrame`, and should call `xrEndFrame` before calling `xrBeginFrame` again. Calling `xrEndFrame` again without a prior call to `xrBeginFrame` must result in `XR_ERROR_CALL_ORDER_INVALID` being returned by `xrEndFrame`. An application may call `xrBeginFrame` again if the prior `xrEndFrame` fails or if the application wishes to discard an in-progress frame. A successful call to `xrBeginFrame` again with no intervening `xrEndFrame` call must result in the success code `XR_FRAME_DISCARDED` being returned from `xrBeginFrame`. In this case it is assumed that the `xrBeginFrame` refers to the next frame and the previously begun frame is forfeited by the application. An application may call `xrEndFrame` without having called `xrReleaseSwapchainImage` since the previous call to `xrEndFrame` for any swapchain passed to `xrEndFrame`. Applications should call `xrBeginFrame` right before executing any graphics device work for a given frame, as opposed to calling it afterwards. The runtime must only compose frames whose `xrBeginFrame` and `xrEndFrame` both return success codes. While `xrBeginFrame` and `xrEndFrame` do not need to be called on the same thread, the application must handle synchronization if they are called on separate threads.

The `xrBeginFrame` function is defined as:

```c
XrResult xrBeginFrame(
    XrSession session,
    const XrFrameBeginInfo* frameBeginInfo);
```

**Parameter Descriptions**

- `session` is a valid `XrSession` handle.
- `frameBeginInfo` exists for extensibility purposes, it is `NULL` or a pointer to a valid `XrFrameBeginInfo`.

`xrBeginFrame` is called prior to the start of frame rendering. The application should still call `xrBeginFrame` but omit rendering work for the frame if `XrFrameState::shouldRender` is `XR_FALSE`.

Runtimes must not perform frame synchronization or throttling through the `xrBeginFrame` function and should instead do so through `xrWaitFrame`.

The runtime must return the error code `XR_ERROR_CALL_ORDER_INVALID` if there was no corresponding successful call to `xrWaitFrame`.

The runtime must return the success code `XR_FRAME_DISCARDED` if a prior `xrBeginFrame` has been called without an intervening call to `xrEndFrame`.

The runtime must return `XR_ERROR_SESSION_NOT_RUNNING` if the `session` is not running.
Valid Usage (Implicit)

- **session** must be a valid `XrSession` handle
- If `frameBeginInfo` is not NULL, `frameBeginInfo` must be a pointer to a valid `XrFrameBeginInfo` structure

Thread Safety

- Access to the `session` parameter by any other `xrBeginFrame` or `xrEndFrame` call must be externally synchronized

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`
- `XR_FRAME_DISCARDED`

Failure

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_SESSION_NOT_RUNNING`
- `XR_ERROR_CALL_ORDER_INVALID`

The `XrFrameBeginInfo` structure is defined as:

typedef struct XrFrameBeginInfo {
    XrStructureType type;
    const void* next;
} XrFrameBeginInfo;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

Because this structure only exists to support extension-specific structures, *xrBeginFrame* will accept a NULL argument for *frameBeginInfo* for applications that are not using any relevant extensions.

Valid Usage (Implicit)

- **type** must be XR_TYPE_FRAME_BEGIN_INFO
- **next** must be NULL or a valid pointer to the next structure in a structure chain

The *xrEndFrame* function is defined as:

```c
XrResult xrEndFrame(
    XrSession                                   session,
    const XrFrameEndInfo*                       frameEndInfo);
```

Parameter Descriptions

- **session** is a valid XrSession handle.
- **frameEndInfo** is a pointer to a valid XrFrameEndInfo.

*xrEndFrame* may return immediately to the application. XrFrameEndInfo::displayTime should be computed using values returned by *xrWaitFrame*. The runtime should be robust against variations in the timing of calls to *xrWaitFrame*, since a pipelined system may call *xrWaitFrame* on a separate thread from *xrBeginFrame* and *xrEndFrame* without any synchronization guarantees.

*Note*

An accurate predicted display time is very important to avoid black pull-in by reprojection and to reduce motion judder in case the runtime does not implement a translational reprojection. Reprojection should never display images before the display refresh period they were predicted for, even if they are completed early, because this will cause motion judder just the same. In other words, the better the predicted display time, the less latency experienced by the user.
Every call to `xrEndFrame` must be preceded by a successful call to `xrBeginFrame`. Failure to do so must result in `XR_ERROR_CALL_ORDER_INVALID` being returned by `xrEndFrame`. `XrFrameEndInfo` may reference swapchains into which the application has rendered for this frame. From each `XrSwapchain` only one image index is implicitly referenced per frame, the one corresponding to the last call to `xrReleaseSwapchainImage`. However, a specific swapchain (and by extension a specific swapchain image index) may be referenced in `XrFrameEndInfo` multiple times. This can be used for example to render a side by side image into a single swapchain image and referencing it twice with differing image rectangles in different layers.

If no layers are provided then the display must be cleared.

- `XR_ERROR_LAYER_INVALID` must be returned if an unknown, unsupported layer type, or `NULL` pointer is passed as one of the `XrFrameEndInfo::layers`.
- `XR_ERROR_LAYER_INVALID` must be returned if a layer references a swapchain that has no released swapchain image.
- `XR_ERROR_LAYER_LIMIT_EXCEEDED` must be returned if `XrFrameEndInfo::layerCount` exceeds `XrSystemGraphicsProperties::maxLayerCount` or if the runtime is unable to composite the specified layers due to resource constraints.
- `XR_ERROR_SWAPCHAIN_RECT_INVALID` must be returned if `XrFrameEndInfo::layers` contains a composition layer which references pixels outside of the associated swapchain image or if negatively sized.
- `XR_ERROR_ENVIRONMENT_BLEND_MODE_UNSUPPORTED` must be returned if `XrFrameEndInfo::environmentBlendMode` is not supported.
- `XR_ERROR_SESSION_NOT_RUNNING` must be returned if the `session` is not running.

**Note**

Applications should discard frames for which `xrEndFrame` returns a recoverable error over attempting to resubmit the frame with different frame parameters to provide a more consistent experience across different runtime implementations.

<table>
<thead>
<tr>
<th>Valid Usage (Implicit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- <code>session</code> must be a valid <code>XrSession</code> handle</td>
</tr>
<tr>
<td>- <code>frameEndInfo</code> must be a pointer to a valid <code>XrFrameEndInfo</code> structure</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thread Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Access to the <code>session</code> parameter by any other <code>xrBeginFrame</code> or <code>xrEndFrame</code> call must be externally synchronized</td>
</tr>
</tbody>
</table>
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_TIME_INVALID
- XR_ERROR_SWAPCHAIN_RECT_INVALID
- XR_ERROR_SESSION_NOT_RUNNING
- XR_ERROR_POSE_INVALID
- XR_ERROR_LAYER_LIMIT_EXCEEDED
- XR_ERROR_LAYER_INVALID
- XR_ERROR_ENVIRONMENT_BLEND_MODE_UNSUPPORTED
- XR_ERROR_CALL_ORDER_INVALID

The XrFrameEndInfo structure is defined as:

typedef struct XrFrameEndInfo {
    XrStructureType                               type;
    const void*                                   next;
    XrTime                                        displayTime;
    XrEnvironmentBlendMode                        environmentBlendMode;
    uint32_t                                      layerCount;
    const XrCompositionLayerBaseHeader* const*    layers;
} XrFrameEndInfo;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **displayTime** is the `XrTime` at which this frame **should** be displayed.
- **environmentBlendMode** is the `XrEnvironmentBlendMode` value representing the desired **environment blend mode** for this frame.
- **layerCount** is the number of composition layers in this frame. The maximum supported layer count is identified by `XrSystemGraphicsProperties::maxLayerCount`. If `layerCount` is greater than the maximum supported layer count then **`XR_ERROR_LAYER_LIMIT_EXCEEDED`** must be returned.
- **layers** is a pointer to an array of `XrCompositionLayerBaseHeader` pointers.

Valid Usage (Implicit)

- **type** **must** be `XR_TYPE_FRAME_END_INFO`
- **next** **must** be `NULL` or a valid pointer to the **next** structure in a structure chain. See also: `XrSecondaryViewConfigurationFrameEndInfoMSFT`
- **environmentBlendMode** **must** be a valid `XrEnvironmentBlendMode` value
- If **layerCount** is not 0, **layers** **must** be a pointer to an array of **layerCount** valid `XrCompositionLayerBaseHeader`-based structures. See also: `XrCompositionLayerCubeKHR`, `XrCompositionLayerCylinderKHR`, `XrCompositionLayerEquirect2KHR`, `XrCompositionLayerEquirectKHR`, `XrCompositionLayerProjection`, `XrCompositionLayerQuad`

All layers submitted to `xrEndFrame` will be presented to the primary view configuration of the running session.

10.4.1. Frame Rate

For every application-generated frame, the application **may** call `xrEndFrame` to submit the application-generated composition layers. In addition, the application **must** call `xrWaitFrame` when the application is ready to begin preparing the next set of frame layers. `xrEndFrame` **may** return immediately to the application, but `xrWaitFrame` **must** block for an amount of time that depends on throttling of the application by the runtime. The earliest the runtime will return from `xrWaitFrame` is when it determines that the application **should** start drawing the next frame.
10.4.2. Compositing

Composition layers are submitted by the application via the `xrEndFrame` call. All composition layers to be drawn must be submitted with every `xrEndFrame` call. A layer that is omitted in this call will not be drawn by the runtime layer compositor. All views associated with projection layers must be supplied, or `XR_ERROR_VALIDATION_FAILURE` must be returned by `xrEndFrame`.

Composition layers must be drawn in the same order as they are specified in via `XrFrameEndInfo`, with the 0th layer drawn first. Layers must be drawn with a “painter’s algorithm,” with each successive layer potentially overwriting the destination layers whether or not the new layers are virtually closer to the viewer.

10.4.3. Composition Layer Flags

The `XrCompositionLayerFlagBits` bitfield is specified as:

```c
// Flag bits for XrCompositionLayerFlags
static const XrCompositionLayerFlags
    XR_COMPOSITION_LAYER_CORRECT_CHROMATIC_ABERRATION_BIT = 0x00000001;
static const XrCompositionLayerFlags XR_COMPOSITION_LAYER_BLEND_TEXTURE_SOURCE_ALPHA_BIT
    = 0x00000002;
static const XrCompositionLayerFlags XR_COMPOSITION_LAYER_UNPREMULTIPLIED_ALPHA_BIT = 0x00000004;
```

`XrCompositionLayerFlags` specify options for individual composition layers.

**Flag Descriptions**

- `XR_COMPOSITION_LAYER_CORRECT_CHROMATIC_ABERRATION_BIT` — Enables chromatic aberration correction when not done by default.
- `XR_COMPOSITION_LAYER_BLEND_TEXTURE_SOURCE_ALPHA_BIT` — Enables the layer texture alpha channel.
- `XR_COMPOSITION_LAYER_UNPREMULTIPLIED_ALPHA_BIT` — Indicates the texture color channels have not been premultiplied by the texture alpha channel.

10.4.4. Composition Layer Blending

All types of composition layers are subject to blending with other layers. Blending of layers can be controlled by layer per-texel source alpha. Layer swapchain textures may contain an alpha channel, depending on the image format. If a submitted swapchain’s texture format does not include an alpha channel or if the `XR_COMPOSITION_LAYER_BLEND_TEXTURE_SOURCE_ALPHA_BIT` is unset, then the layer alpha is
initialized to one.

If the swapchain texture format color encoding is other than RGBA, it is converted to RGBA.

If the texture color channels are encoded without premultiplying by alpha, the `XR_COMPOSITION_LAYER_UNPREMULTIPLIED_ALPHA_BIT` should be set. The effect of this bit alters the layer color as follows:

\[
\text{LayerColor.RGB} \times= \text{LayerColor.A}
\]

LayerColor is then clamped to a range of \([0.0, 1.0]\).

The layer blending operation is defined as:

\[
\text{CompositeColor} = \text{LayerColor} + \text{CompositeColor} \times (1 - \text{LayerColor.A})
\]

Before the first layer is composited, all components of CompositeColor are initialized to zero.

### 10.4.5. Composition Layer Types

Composition layers allow an application to offload the composition of the final image to a runtime-supplied compositor. This reduces the application's rendering complexity since details such as frame-rate interpolation and distortion correction can be performed by the runtime. The core specification defines `XrCompositionLayerProjection` and `XrCompositionLayerQuad` layer types.

The projection layer type represents planar projected images rendered from the eye point of each eye using a perspective projection. This layer type is typically used to render the virtual world from the user's perspective.

The quad layer type describes a posable planar rectangle in the virtual world for displaying two-dimensional content. Quad layers can subtend a smaller portion of the display's field of view, allowing a better match between the resolutions of the `XrSwapchain` image and footprint of that image in the final composition. This improves legibility for user interface elements or heads-up displays and allows optimal sampling during any composition distortion corrections the runtime might employ.

The classes below describe the layer types in the layer composition system.

The `XrCompositionLayerBaseHeader` structure is defined as:
typedef struct XrCompositionLayerBaseHeader {
    XrStructureType          type;
    const void*              next;
    XrCompositionLayerFlags  layerFlags;
    XrSpace                  space;
} XrCompositionLayerBaseHeader;

### Member Descriptions

- **type** is the `XrStructureType` of this structure. This base structure itself has no associated `XrStructureType` value.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **layerFlags** is a bitmask of `XrCompositionLayerFlagBits` describing flags to apply to the layer.
- **space** is the `XrSpace` in which the layer will be kept stable over time.

All composition layer structures begin with the elements described in the `XrCompositionLayerBaseHeader`. The `XrCompositionLayerBaseHeader` structure is not intended to be directly used, but forms a basis for defining current and future structures containing composition layer information. The `XrFrameEndInfo` structure contains an array of pointers to these polymorphic header structures. All composition layer type pointers must be type-castable as an `XrCompositionLayerBaseHeader` pointer.

### Valid Usage (Implicit)

- **type** must be one of the following `XrStructureType` values:
  - `XR_TYPE_COMPOSITION_LAYER_CUBE_KHR`
  - `XR_TYPE_COMPOSITION_LAYER_CYLINDER_KHR`
  - `XR_TYPE_COMPOSITION_LAYER_EQUIRECT2_KHR`
  - `XR_TYPE_COMPOSITION_LAYER_EQUIRECT_KHR`
  - `XR_TYPE_COMPOSITION_LAYER_PROJECTION`, `XR_TYPE_COMPOSITION_LAYER_QUAD`

- **next** must be `NULL` or a valid pointer to the next structure in a structure chain. See also:
  - `XrCompositionLayerAlphaBlendFB`
  - `XrCompositionLayerColorScaleBiasKHR`
  - `XrCompositionLayerImageLayoutFB`
  - `XrCompositionLayerPasssthroughFB`
  - `XrCompositionLayerSecureContentFB`
  - `XrCompositionLayerSettingsFB`

- **layerFlags** must be `0` or a valid combination of `XrCompositionLayerFlagBits` values
- **space** must be a valid `XrSpace` handle

Many composition layer structures also contain one or more references to generic layer data stored in an `XrSwapchainSubImage` structure.

The `XrSwapchainSubImage` structure is defined as:
typedef struct XrSwapchainSubImage {
    XrSwapchain    swapchain;
    XrRect2Di      imageRect;
    uint32_t       imageArrayIndex;
} XrSwapchainSubImage;

Member Descriptions

- **swapchain** is the XrSwapchain to be displayed.

- **imageRect** is an XrRect2Di representing the valid portion of the image to use, in pixels. It also implicitly defines the transform from normalized image coordinates into pixel coordinates. The coordinate origin depends on which graphics API is being used. See the graphics API extension details for more information on the coordinate origin definition. Note that the compositor may bleed in pixels from outside the bounds in some cases, for instance due to mipmapping.

- **imageArrayIndex** is the image array index, with 0 meaning the first or only array element.

Valid Usage (Implicit)

- **swapchain** must be a valid XrSwapchain handle

Runtimes must return XR_ERROR_VALIDATION_FAILURE if the XrSwapchainSubImage::imageArrayIndex is equal to or greater than the XrSwapchainCreateInfo::arraySize that the XrSwapchainSubImage::swapchain was created with.

Projection Composition

The XrCompositionLayerProjection layer represents planar projected images rendered from the eye point of each eye using a standard perspective projection.

The XrCompositionLayerProjection structure is defined as:
typedef struct XrCompositionLayerProjection {
    XrStructureType type;
    const void* next;
    XrCompositionLayerFlags layerFlags;
    XrSpace space;
    uint32_t viewCount;
    const XrCompositionLayerProjectionView* views;
} XrCompositionLayerProjection;

### Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **layerFlags** is a bitmask of `XrCompositionLayerFlagBits` describing flags to apply to the layer.
- **space** is the `XrSpace` in which the pose of each `XrCompositionLayerProjectionView` is evaluated over time by the compositor.
- **viewCount** is the count of views in the `views` array. This **must** be equal to the number of view poses returned by `xrLocateViews`.
- **views** is the array of type `XrCompositionLayerProjectionView` containing each projection layer view.

### Note

Because a runtime may reproject the layer over time, a projection layer should specify an `XrSpace` in which to maximize stability of the layer content. For example, a projection layer containing world-locked content should use an `XrSpace` which is also world-locked, such as the `LOCAL` or `STAGE` reference spaces. In the case that the projection layer should be head-locked, such as a heads up display, the `VIEW` reference space would provide the highest quality layer reprojection.
Valid Usage (Implicit)

- **type** must be XR_TYPE_COMPOSITION_LAYER_PROJECTION
- **next** must be NULL or a valid pointer to the next structure in a structure chain. See also: XrCompositionLayerDepthTestVARJO, XrCompositionLayerReprojectionInfoMSFT, XrCompositionLayerReprojectionPlaneOverrideMSFT
- **layerFlags** must be 0 or a valid combination of XrCompositionLayerFlagBits values
- **space** must be a valid XrSpace handle
- **views** must be a pointer to an array of viewCount valid XrCompositionLayerProjectionView structures
- The viewCount parameter must be greater than 0

The XrCompositionLayerProjectionView structure is defined as:

```c
typedef struct XrCompositionLayerProjectionView {
    XrStructureType        type;
    const void*            next;
    XrPosef                pose;
    XrFovf                 fov;
    XrSwapchainSubImage    subImage;
} XrCompositionLayerProjectionView;
```

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **pose** is an XrPosef defining the location and orientation of this projection element in the space of the corresponding XrCompositionLayerProjectionView.
- **fov** is the XrFovf for this projection element.
- **subImage** is the image layer XrSwapchainSubImage to use.

The count and order of view poses submitted with XrCompositionLayerProjection must be the same order as that returned by xrLocateViews. The XrCompositionLayerProjectionView::pose and XrCompositionLayerProjectionView::fov should almost always derive from XrView::pose and XrView::fov as found in the xrLocateViews::views array. However, applications may submit an XrCompositionLayerProjectionView which has a different view or FOV than that from xrLocateViews.
In this case, the runtime will map the view and FOV to the system display appropriately. In the case that two submitted views within a single layer overlap, they must be composited in view array order.

**Valid Usage (Implicit)**

- **type** must be `XR_TYPE_COMPOSITION_LAYER_PROJECTION_VIEW`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrCompositionLayerDepthInfoKHR`, `XrCompositionLayerSpaceWarpInfoFB`
- **subImage** must be a valid `XrSwapchainSubImage` structure

**Quad Layer Composition**

The `XrCompositionLayerQuad` structure defined as:

```c
typedef struct XrCompositionLayerQuad {
    XrStructureType type;
    const void* next;
    XrCompositionLayerFlags layerFlags;
    XrSpace space;
    XrEyeVisibility eyeVisibility;
    XrSwapchainSubImage subImage;
    XrPosef pose;
    XrExtent2Df size;
} XrCompositionLayerQuad;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **layerFlags** is a bitmask of `XrCompositionLayerFlagBits` describing flags to apply to the layer.
- **space** is the `XrSpace` in which the **pose** of the quad layer is evaluated over time.
- **eyeVisibility** is the `XrEyeVisibility` for this layer.
- **subImage** is the image layer `XrSwapchainSubImage` to use.
- **pose** is an `XrPosef` defining the position and orientation of the quad in the reference frame of the **space**.
- **size** is the width and height of the quad in meters.
The **XrCompositionLayerQuad** layer is useful for user interface elements or 2D content rendered into the virtual world. The layer’s **XrSwapchainSubImage::swapchain** image is applied to a quad in the virtual world space. Only front face of the quad surface is visible; the back face is not visible and must not be drawn by the runtime. A quad layer has no thickness; it is a two-dimensional object positioned and oriented in 3D space. The position of a quad refers to the center of the quad within the given **XrSpace**. The orientation of the quad refers to the orientation of the normal vector from the front face. The size of a quad refers to the quad’s size in the x-y plane of the given **XrSpace**’s coordinate system. A quad with a position of \{0,0,0\}, rotation of \{0,0,0,1\} (no rotation), and a size of \{1,1\} refers to a 1 meter x 1 meter quad centered at \{0,0,0\} with its front face normal vector coinciding with the +z axis.

### Valid Usage (Implicit)

- **type** must be **XR_TYPE_COMPOSITION_LAYER_QUAD**
- **next** must be **NULL** or a valid pointer to the next structure in a structure chain
- **layerFlags** must be \(0\) or a valid combination of **XrCompositionLayerFlagBits** values
- **space** must be a valid **XrSpace** handle
- **eyeVisibility** must be a valid **XrEyeVisibility** value
- **subImage** must be a valid **XrSwapchainSubImage** structure

The **XrEyeVisibility** enum selects which of the viewer’s eyes to display a layer to:

```c
typedef enum XrEyeVisibility {
    XR_EYE_VISIBILITY_BOTH = 0,
    XR_EYE_VISIBILITY_LEFT = 1,
    XR_EYE_VISIBILITY_RIGHT = 2,
    XR_EYE_VISIBILITY_MAX_ENUM = 0x7FFFFFFF
} XrEyeVisibility;
```

### Enumerant Descriptions

- **XR_EYE_VISIBILITY_BOTH** displays the layer to both eyes.
- **XR_EYE_VISIBILITY_LEFT** displays the layer to the viewer’s physical left eye.
- **XR_EYE_VISIBILITY_RIGHT** displays the layer to the viewer’s physical right eye.

### 10.4.6. Environment Blend Mode

After the compositor has blended and flattened all layers (including any layers added by the runtime
itself), it will then present this image to the system’s display. The composites image will then blend with the user’s view of the physical world behind the displays in one of three modes, based on the application’s chosen environment blend mode. VR applications will generally choose the XR_ENVIRONMENT_BLEND_MODE_OPAQUE blend mode, while AR applications will generally choose either the XR_ENVIRONMENT_BLEND_MODE_ADDITIVE or XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND mode.

Applications select their environment blend mode each frame as part of their call to xrEndFrame. The application can inspect the set of supported environment blend modes for a given system using xrEnumerateEnvironmentBlendModes, and prepare their assets and rendering techniques differently based on the blend mode they choose. For example, a black shadow rendered using the XR_ENVIRONMENT_BLEND_MODE_ADDITIVE blend mode will appear transparent, and so an application in that mode may render a glow as a grounding effect around the black shadow to ensure the shadow can be seen. Similarly, an application designed for XR_ENVIRONMENT_BLEND_MODE_OPAQUE or XR_ENVIRONMENT_BLEND_MODE_ADDITIVE rendering may choose to leave garbage in their alpha channel as a side effect of a rendering optimization, but this garbage would appear as visible display artifacts if the environment blend mode was instead XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND.

Not all systems will support all environment blend modes. For example, a VR headset may not support the XR_ENVIRONMENT_BLEND_MODE_ADDITIVE or XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND modes unless it has video passthrough, while an AR headset with an additive display may not support the XR_ENVIRONMENT_BLEND_MODE_OPAQUE or XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND modes.

For devices that can support multiple environment blend modes, such as AR phones with video passthrough, the runtime may optimize power consumption on the device in response to the environment blend mode that the application chooses each frame. For example, if an application on a video passthrough phone knows that it is currently rendering a 360-degree background covering all screen pixels, it can submit frames with an environment blend mode of XR_ENVIRONMENT_BLEND_MODE_OPAQUE, saving the runtime the cost of compositing a camera-based underlay of the physical world behind the application’s layers.

The xrEnumerateEnvironmentBlendModes function is defined as:

```c
XrResult xrEnumerateEnvironmentBlendModes(
    XrInstance instance,
    XrSystemId systemId,
    XrViewConfigurationType viewConfigurationType,
    uint32_t environmentBlendModeCapacityInput,
    uint32_t* environmentBlendModeCountOutput,
    XrEnvironmentBlendMode* environmentBlendModes);
```
Parameter Descriptions

- `instance` is the instance from which `systemId` was retrieved.
- `systemId` is the `XrSystemId` whose environment blend modes will be enumerated.
- `viewConfigurationType` is the `XrViewConfigurationType` to enumerate.
- `environmentBlendModeCapacityInput` is the capacity of the `environmentBlendModes` array, or 0 to indicate a request to retrieve the required capacity.
- `environmentBlendModeCountOutput` is a pointer to the count of `environmentBlendModes` written, or a pointer to the required capacity in the case that `environmentBlendModeCapacityInput` is insufficient.
- `environmentBlendModes` is a pointer to an array of `XrEnvironmentBlendMode` values, but can be `NULL` if `environmentBlendModeCapacityInput` is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required `environmentBlendModes` size.

Enumerates the set of environment blend modes that this runtime supports for a given view configuration of the system. Environment blend modes should be in order from highest to lowest runtime preference.

Runtimes must always return identical buffer contents from this enumeration for the given `systemId` and `viewConfigurationType` for the lifetime of the instance.

Valid Usage (Implicit)

- `instance` must be a valid `XrInstance` handle
- `viewConfigurationType` must be a valid `XrViewConfigurationType` value
- `environmentBlendModeCountOutput` must be a pointer to a `uint32_t` value
- If `environmentBlendModeCapacityInput` is not 0, `environmentBlendModes` must be a pointer to an array of `environmentBlendModeCapacityInput` `XrEnvironmentBlendMode` values
The possible blend modes are specified by the `XrEnvironmentBlendMode` enumeration:

```c
typedef enum XrEnvironmentBlendMode {
    XR_ENVIRONMENT_BLEND_MODE_OPAQUE = 1,
    XR_ENVIRONMENT_BLEND_MODE_ADDITIVE = 2,
    XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND = 3,
    XR_ENVIRONMENT_BLEND_MODE_MAX_ENUM = 0x7FFFFFFF
} XrEnvironmentBlendMode;
```
Enumerant Descriptions

- **XR_ENVIRONMENT_BLEND_MODE_OPAQUE.** The composition layers will be displayed with no view of the physical world behind them. The composited image will be interpreted as an RGB image, ignoring the composited alpha channel. This is the typical mode for VR experiences, although this mode can also be supported on devices that support video passthrough.

- **XR_ENVIRONMENT_BLEND_MODE_ADDITIVE.** The composition layers will be additively blended with the real world behind the display. The composited image will be interpreted as an RGB image, ignoring the composited alpha channel during the additive blending. This will cause black composited pixels to appear transparent. This is the typical mode for an AR experience on a see-through headset with an additive display, although this mode can also be supported on devices that support video passthrough.

- **XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND.** The composition layers will be alpha-blended with the real world behind the display. The composited image will be interpreted as an RGBA image, with the composited alpha channel determining each pixel's level of blending with the real world behind the display. This is the typical mode for an AR experience on a phone or headset that supports video passthrough.
Chapter 11. Input and Haptics

11.1. Action Overview

OpenXR applications communicate with input devices using XrActions. Actions are created at initialization time and later used to request input device state, create action spaces, or control haptic events. Input action handles represent ‘actions’ that the application is interested in obtaining the state of, not direct input device hardware. For example, instead of the application directly querying the state of the A button when interacting with a menu, an OpenXR application instead creates a menu_select action at startup then asks OpenXR for the state of the action.

The application recommends that the action be assigned to a specific input source on the input device for a known interaction profile, but runtimes have the ability to choose a different control depending on user preference, input device availability, or any other reason. This abstraction ensures that applications can run on a wide variety of input hardware and maximize user accessibility.

Example usage:

```c
XrInstance instance; // previously initialized
XrSession session; // previously initialized

// Create an action set
XrActionSetCreateInfo actionSetInfo{XR_TYPE_ACTION_SET_CREATE_INFO};
strncpy(actionSetInfo.actionSetName, "gameplay");
strncpy(actionSetInfo.localizedActionSetName, "Gameplay");
actionSetInfo.priority = 0;
XrActionSet inGameActionSet;
CHK_XR(xrCreateActionSet(instance, &actionSetInfo, &inGameActionSet));

// create a "teleport" input action
XrActionCreateInfo actioninfo{XR_TYPE_ACTION_CREATE_INFO};
strncpy(actioninfo.actionName, "teleport");
actioninfo.actionType = XR_ACTION_TYPE_BOOLEAN_INPUT;
strncpy(actioninfo.localizedActionName, "Teleport");
XrAction teleportAction;
CHK_XR(xrCreateAction(inGameActionSet, &actioninfo, &teleportAction));

// create a "player_hit" output action
XrActionCreateInfo hapticsactioninfo{XR_TYPE_ACTION_CREATE_INFO};
strncpy(hapticsactioninfo.actionName, "player_hit");
hapticsactioninfo.actionType = XR_ACTION_TYPE_VIBRATION_OUTPUT;
strncpy(hapticsactioninfo.localizedActionName, "Player hit");
XrAction hapticsAction;
CHK_XR(xrCreateAction(inGameActionSet, &hapticsactioninfo, &hapticsAction));
```
XrPath triggerClickPath, hapticPath;
CHK_XR(xrStringToPath(instance, "/user/hand/right/input/trigger/click", &triggerClickPath));
CHK_XR(xrStringToPath(instance, "/user/hand/right/output/haptic", &hapticPath));

XrPath interactionProfilePath;
CHK_XR(xrStringToPath(instance, "/interaction_profiles/vendor_x/profile_x", &interactionProfilePath));

XrActionSuggestedBinding bindings[2];
bindings[0].action = teleportAction;
bindings[0].binding = triggerClickPath;
bindings[1].action = hapticsAction;
bindings[1].binding = hapticPath;

XrInteractionProfileSuggestedBinding
suggestedBindings{XR_TYPE_INTERACTION_PROFILE_SUGGESTED_BINDING};
suggestedBindings.interactionProfile = interactionProfilePath;
suggestedBindings.suggestedBindings = bindings;
suggestedBindings.countSuggestedBindings = 2;
CHK_XR(xrSuggestInteractionProfileBindings(instance, &suggestedBindings));

XrSessionActionSetsAttachInfo attachInfo{XR_TYPE_SESSION_ACTION_SETS_ATTACH_INFO};
attachInfo.countActionSets = 1;
attachInfo.actionSets = &inGameActionSet;
CHK_XR(xrAttachSessionActionSets(session, &attachInfo));

// application main loop
while (1)
{
    // sync action data
    XrActiveActionSet activeActionSet{inGameActionSet, XR_NULL_PATH};
    XrActionsSyncInfo syncInfo{XR_TYPE_ACTIONS_SYNC_INFO};
    syncInfo.countActiveActionSets = 1;
    syncInfo.activeActionSets = &activeActionSet;
   CHK_XR(xrSyncActions(session, &syncInfo));

    // query input action state
    XrActionStateBoolean teleportState{XR_TYPE_ACTION_STATE_BOOLEAN};
    XrActionStateGetInfo getInfo{XR_TYPE_ACTION_STATE_GET_INFO};
    getInfo.action = teleportAction;
    CHK_XR(xrGetActionStateBoolean(session, &getInfo, &teleportState));

    if (teleportState.changedSinceLastSync && teleportState.currentState)
    {
        // fire haptics using output action
        XrHapticVibration vibration{XR_TYPE_HAPTIC_VIBRATION};
        vibration.amplitude = 0.5;
    }
11.2. Action Sets

Action sets are application-defined collections of actions. They are attached to a given XrSession with a xrAttachSessionActionSets call. They are enabled or disabled by the application via xrSyncActions depending on the current application context. For example, a game may have one set of actions that apply to controlling a character and another set for navigating a menu system. When these actions are grouped into two XrActionSet handles they can be selectively enabled and disabled using a single function call.

Actions are passed a handle to their XrActionSet when they are created.

Action sets are created by calling xrCreateActionSet:

The xrCreateActionSet function is defined as:

```
xrCreateActionSet(
    XrInstance                                  instance,  
    const XrActionSetCreateInfo*                createInfo,  
    XrActionSet*                                actionSet);
```

**Parameter Descriptions**

- **instance** is a handle to an XrInstance.
- **createInfo** is a pointer to a valid XrActionSetCreateInfo structure that defines the action set being created.
- **actionSet** is a pointer to an XrActionSet where the created action set is returned.
The `xrCreateActionSet` function creates an action set and returns a handle to the created action set.

### Valid Usage (Implicit)

- `instance` must be a valid `XrInstance` handle
- `createInfo` must be a pointer to a valid `XrActionSetCreateInfo` structure
- `actionSet` must be a pointer to an `XrActionSet` handle

### Return Codes

**Success**
- `XR_SUCCESS`

**Failure**
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_LIMIT_REACHED`
- `XR_ERROR_PATH_FORMAT_INVALID`
- `XR_ERROR_NAME_INVALID`
- `XR_ERROR_NAME_DUPLICATED`
- `XR_ERROR_LOCALIZED_NAME_INVALID`
- `XR_ERROR_LOCALIZED_NAME_DUPLICATED`

The `XrActionSetCreateInfo` structure is defined as:

```c
typedef struct XrActionSetCreateInfo {
    XrStructureType         type;
    const void*              next;
    char                     actionSetName[XR_MAX_ACTION_SET_NAME_SIZE];
    char                     localizedActionSetName[XR_MAX_LOCALIZED_ACTION_SET_NAME_SIZE];
    uint32_t                 priority;
} XrActionSetCreateInfo;
```
Member Descriptions

- **type** is the XrStructureType of this structure.

- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.

- **actionSetName** is an array containing a NULL terminated non-empty string with the name of this action set.

- **localizedActionSetName** is an array containing a NULL terminated UTF-8 string that can be presented to the user as a description of the action set. This string should be presented in the system's current active locale.

- **priority** defines which action sets' actions are active on a given input source when actions on multiple active action sets are bound to the same input source. Larger priority numbers take precedence over smaller priority numbers.

When multiple actions are bound to the same input source, the priority of each action set determines which bindings are suppressed. Runtimes must ignore input sources from action sets with a lower priority number if those specific input sources are also present in active actions within a higher priority action set. If multiple action sets with the same priority are bound to the same input source and that is the highest priority number, runtimes must process all those bindings at the same time.

Two actions are considered to be bound to the same input source if they use the same identifier and optional location path segments, even if they have different component segments.

When runtimes are ignoring bindings because of priority, they must treat the binding to that input source as though they do not exist. That means the isActive field must be XR_FALSE when retrieving action data, and that the runtime must not provide any visual, haptic, or other feedback related to the binding of that action to that input source. Other actions in the same action set which are bound to input sources that do not collide are not affected and are processed as normal.

If actionSetName or localizedActionSetName are empty strings, the runtime must return XR_ERROR_NAME_INVALID or XR_ERROR_LOCALIZED_NAME_INVALID respectively. If actionSetName or localizedActionSetName are duplicates of the corresponding field for any existing action set in the specified instance, the runtime must return XR_ERROR_NAME_DUPlicated or XR_ERROR_LOCALIZED_NAME_DUPlicated respectively. If the conflicting action set is destroyed, the conflicting field is no longer considered duplicated. If actionSetName contains characters which are not allowed in a single level of a well-formed path string, the runtime must return XR_ERROR_PATH_FORMAT_INVALID.
Valid Usage (Implicit)

- **type** must be XR_TYPE_ACTION_SET_CREATE_INFO
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **actionSetName** must be a null-terminated UTF-8 string whose length is less than or equal to XR_MAX_ACTION_SET_NAME_SIZE
- **localizedActionSetName** must be a null-terminated UTF-8 string whose length is less than or equal to XR_MAX_LOCALIZED_ACTION_SET_NAME_SIZE

The `xrDestroyActionSet` function is defined as:

```c
XrResult xrDestroyActionSet(
    XrActionSet actionSet);
```

Parameter Descriptions

- **actionSet** is the action set to destroy.

Action set handles can be destroyed by calling `xrDestroyActionSet`. When an action set handle is destroyed, all handles of actions in that action set are also destroyed.

The implementation must not free underlying resources for the action set while there are other valid handles that refer to those resources. The implementation may release resources for an action set when all of the action spaces for actions in that action set have been destroyed. See Action Spaces Lifetime for details.

Resources for all action sets in an instance must be freed when the instance containing those actions sets is destroyed.

Valid Usage (Implicit)

- **actionSet** must be a valid `XrActionSet` handle

Thread Safety

- Access to **actionSet**, and any child handles, must be externally synchronized.
11.3. Creating Actions

 Action handles are used to refer to individual actions when retrieving action data, creating action spaces, or sending haptic events.

 The `xrCreateAction` function is defined as:

```c
XrResult xrCreateAction(
    XrActionSet actionSet, 
    const XrActionCreateInfo* createInfo, 
    XrAction* action);
```

### Parameter Descriptions

- `actionSet` is a handle to an `XrActionSet`.
- `createInfo` is a pointer to a valid `XrActionCreateInfo` structure that defines the action being created.
- `action` is a pointer to an `XrAction` where the created action is returned.

`xrCreateAction` creates an action and returns its handle.

If `actionSet` has been included in a call to `xrAttachSessionActionSets`, the implementation **must** return `XR_ERROR_ACTIONSETS_ALREADY_ATTACHED`.
Valid Usage (Implicit)

- `actionSet` must be a valid `XrActionSet` handle
- `createInfo` must be a pointer to a valid `XrActionCreateInfo` structure
- `action` must be a pointer to an `XrAction` handle

Return Codes

Success

- XR_SUCCESS

Failure

- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_PATH_INVALID
- XR_ERROR_PATH_FORMAT_INVALID
- XR_ERROR_NAME_INVALID
- XR_ERROR_NAME_DUPLICATED
- XR_ERROR_LOCALIZED_NAME_INVALID
- XR_ERROR_LOCALIZED_NAME_DUPLICATED
- XR_ERROR_ACTIONSETS_ALREADY_ATTACHED

The `XrActionCreateInfo` structure is defined as:
typedef struct XrActionCreateInfo {
    XrStructureType    type;
    const void*        next;
    char               actionName[XR_MAX_ACTION_NAME_SIZE];
    XrActionType       actionType;
    uint32_t           countSubactionPaths;
    const XrPath*      subactionPaths;
    char               localizedActionName[XR_MAX_LOCALIZED_ACTION_NAME_SIZE];
} XrActionCreateInfo;

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **actionName** is an array containing a NULL terminated string with the name of this action.
- **actionType** is the `XrActionType` of the action to be created.
- **countSubactionPaths** is the number of elements in the `subactionPaths` array. If `subactionPaths` is NULL, this parameter must be 0.
- **subactionPaths** is an array of `XrPath` or NULL. If this array is specified, it contains one or more subaction paths that the application intends to query action state for.
- **localizedActionName** is an array containing a NULL terminated UTF-8 string that can be presented to the user as a description of the action. This string should be in the system's current active locale.

Subaction paths are a mechanism that enables applications to use the same action name and handle on multiple devices. Applications can query action state using subaction paths that differentiate data coming from each device. This allows the runtime to group logically equivalent actions together in system UI. For instance, an application could create a single `pick_up` action with the `/user/hand/left` and `/user/hand/right` subaction paths and use the subaction paths to independently query the state of `pick_up_with_left_hand` and `pick_up_with_right_hand`.

Applications can create actions with or without the `subactionPaths` set to a list of paths. If this list of paths is omitted (i.e. `subactionPaths` is set to NULL, and `countSubactionPaths` is set to 0), the application is opting out of filtering action results by subaction paths and any call to get action data must also omit subaction paths.

If `subactionPaths` is specified and any of the following conditions are not satisfied, the runtime must return `XR_ERROR_PATH_UNSUPPORTED`:

- Each path provided is one of:
No path appears in the list more than once

Extensions **may** append additional top level user paths to the above list.

---

**Note**

Earlier revisions of the spec mentioned `/user` but it could not be implemented as specified and was removed as errata.

---

The runtime **must** return `XR_ERROR_PATH_UNSUPPORTED` in the following circumstances:

- The application specified subaction paths at action creation and the application called `xrGetActionState*` or a haptic function with an empty subaction path array.
- The application called `xrGetActionState*` or a haptic function with a subaction path that was not specified when the action was created.

If `actionName` or `localizedActionName` are empty strings, the runtime **must** return `XR_ERROR_NAME_INVALID` or `XR_ERROR_LOCALIZED_NAME_INVALID` respectively. If `actionName` or `localizedActionName` are duplicates of the corresponding field for any existing action in the specified action set, the runtime **must** return `XR_ERROR_NAME_DUPLICATED` or `XR_ERROR_LOCALIZED_NAME_DUPLICATED` respectively. If the conflicting action is destroyed, the conflicting field is no longer considered duplicated. If `actionName` contains characters which are not allowed in a single level of a well-formed path string, the runtime **must** return `XR_ERROR_PATH_FORMAT_INVALID`.

---

**Valid Usage (Implicit)**

- **type** **must** be `XR_TYPE_ACTION_CREATE_INFO`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **actionName** **must** be a null-terminated UTF-8 string whose length is less than or equal to `XR_MAX_ACTION_NAME_SIZE`
- **actionType** **must** be a valid `XrActionType` value
- If `countSubactionPaths` is not 0, **subactionPaths** **must** be a pointer to an array of `countSubactionPaths` valid `XrPath` values
- **localizedActionName** **must** be a null-terminated UTF-8 string whose length is less than or equal to `XR_MAX_LOCALIZED_ACTION_NAME_SIZE`

The `XrActionType` parameter takes one of the following values:
typedef enum XrActionType {
    XR_ACTION_TYPE_BOOLEAN_INPUT = 1,
    XR_ACTION_TYPE_FLOAT_INPUT = 2,
    XR_ACTION_TYPE_VECTOR2F_INPUT = 3,
    XR_ACTION_TYPE_POSE_INPUT = 4,
    XR_ACTION_TYPE_VIBRATION_OUTPUT = 100,
    XR_ACTION_TYPE_MAX_ENUM = 0x7FFFFFFF
} XrActionType;

Enumerant Descriptions

- **XR_ACTION_TYPE_BOOLEAN_INPUT**. The action can be passed to `xrGetActionStateBoolean` to retrieve a boolean value.
- **XR_ACTION_TYPE_FLOAT_INPUT**. The action can be passed to `xrGetActionStateFloat` to retrieve a float value.
- **XR_ACTION_TYPE_VECTOR2F_INPUT**. The action can be passed to `xrGetActionStateVector2f` to retrieve a 2D float vector.
- **XR_ACTION_TYPE_POSE_INPUT**. The action can be passed to `xrCreateActionSpace` to create a space.
- **XR_ACTION_TYPE_VIBRATION_OUTPUT**. The action can be passed to `xrApplyHapticFeedback` to send a haptic event to the runtime.

The `xrDestroyAction` function is defined as:

```c
XrResult xrDestroyAction(
    XrAction action);
```

Parameter Descriptions

- **action** is the action to destroy.

Action handles can be destroyed by calling `xrDestroyAction`. Handles for actions that are part of an action set are automatically destroyed when the action set's handle is destroyed.

The implementation must not destroy the underlying resources for an action when `xrDestroyAction` is called. Those resources are still used to make action spaces locatable and when processing action
priority in `xrSyncActions`. Destroying the action handle removes the application’s access to these resources, but has no other change on actions.

Resources for all actions in an instance **must** be freed when the instance containing those actions sets is destroyed.

<table>
<thead>
<tr>
<th>Valid Usage (Implicit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <code>action</code> <strong>must</strong> be a valid <code>XrAction</code> handle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thread Safety</th>
</tr>
</thead>
<tbody>
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<table>
<thead>
<tr>
<th>Return Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Success</strong></td>
</tr>
<tr>
<td>• <code>XR_SUCCESS</code></td>
</tr>
<tr>
<td><strong>Failure</strong></td>
</tr>
<tr>
<td>• <code>XR_ERROR_HANDLE_INVALID</code></td>
</tr>
</tbody>
</table>

### 11.3.1. Input Actions & Output Actions

Input actions are used to read sensors like buttons or joysticks while output actions are used for triggering haptics or motion platforms. The type of action created by `xrCreateAction` depends on the value of the `XrActionType` argument.

A given action can either be used for either input or output, but not both. Input actions are queried using one of the `xrGetActionState*` function calls, while output actions are set using the haptics calls. If either call is used with an action of the wrong type `XR_ERROR_ACTION_TYPE_MISMATCH` **must** be returned.

### 11.4. Suggested Bindings

Applications usually need to provide default bindings for their actions to runtimes so that input data can be mapped appropriately to the application’s actions. Applications **can** do this by calling `xrSuggestInteractionProfileBindings` for each interaction profile that the applications has default bindings for. If bindings are provided for an appropriate interaction profile, the runtime **may** select one and input will begin to flow. Interaction profile selection changes **must** only happen when `xrSyncActions` is called. Applications **can** call `xrGetCurrentInteractionProfile` during on a running session to learn what the active interaction profile are for a top level user path. If this value ever
changes, the runtime must send an XR_TYPE_EVENT_DATA_INTERACTION_PROFILE_CHANGED event to the application to indicate that the value should be queried again.

The bindings suggested by this system are only a hint to the runtime. Some runtimes may choose to use a different device binding depending on user preference, accessibility settings, or for any other reason. If the runtime is using the values provided by suggested bindings, it must make a best effort to convert the input value to the created action and apply certain rules to that use so that suggested bindings function in the same way across runtimes. If an input value cannot be converted to the type of the action, the value must be ignored and not contribute to the state of the action.

For actions created with XR_ACTION_TYPE_BOOLEAN_INPUT when the runtime is obeying suggested bindings: Boolean input sources must be bound directly to the action. If the path is to a scalar value, a threshold must be applied to the value and values over that threshold will be XR_TRUE. The runtime should use hysteresis when applying this threshold. The threshold and hysteresis range may vary from device to device or component to component and are left as an implementation detail. If the path refers to the parent of input values instead of to an input value itself, the runtime must use .../example/path/click instead of .../example/path if it is available. If a parent path does not have a .../click subpath, the runtime must use .../value and apply the same thresholding that would be applied to any scalar input. In any other situation the runtime may provide an alternate binding for the action or it will be unbound.

For actions created with XR_ACTION_TYPE_FLOAT_INPUT when the runtime is obeying suggested bindings: If the input value specified by the path is scalar, the input value must be bound directly to the float. If the path refers to the parent of input values instead of to an input value itself, the runtime must use /example/path/value instead of .../example/path as the source of the value. If a parent path does not have a .../value subpath, the runtime must use .../click. If the input value is boolean, the runtime must supply 0.0 or 1.0 as a conversion of the boolean value. In any other situation, the runtime may provide an alternate binding for the action or it will be unbound.

For actions created with XR_ACTION_TYPE_VECTOR2F_INPUT when the runtime is obeying suggested bindings: The suggested binding path must refer to the parent of input values instead of to the input values themselves, and that parent path must contain subpaths .../x and .../y. .../x and .../y must be bound to 'x' and 'y' of the vector, respectively. In any other situation, the runtime may provide an alternate binding for the action or it will be unbound.

For actions created with XR_ACTION_TYPE_POSE_INPUT when the runtime is obeying suggested bindings: Pose input sources must be bound directly to the action. If the path refers to the parent of input values instead of to an input value itself, the runtime must use .../example/path/pose instead of .../example/path if it is available. In any other situation the runtime may provide an alternate binding for the action or it will be unbound.

The XrEventDataInteractionProfileChanged structure is defined as:
typedef struct XrEventDataInteractionProfileChanged {
    XrStructureType    type;
    const void*        next;
    XrSession          session;
} XrEventDataInteractionProfileChanged;

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **session** is the `XrSession` for which at least one of the interaction profiles for a top level path has changed.

The `XrEventDataInteractionProfileChanged` event is sent to the application to notify it that the active input form factor for one or more top level user paths has changed. This event must only be sent for interaction profiles that the application indicated its support for via `xrSuggestInteractionProfileBindings`. This event must only be sent for running sessions.

The application can call `xrGetCurrentInteractionProfile` if it wants to change its own behavior based on the active hardware.

**Valid Usage (Implicit)**

- **type** must be `XR_TYPE_EVENT_DATA_INTERACTION_PROFILE_CHANGED`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- **session** must be a valid `XrSession` handle

The `xrSuggestInteractionProfileBindings` function is defined as:

```c
XrResult xrSuggestInteractionProfileBindings(
    XrInstance                      instance,    
    const XrInteractionProfileSuggestedBinding* suggestedBindings);
```
**Parameter Descriptions**

- `instance` is the `XrInstance` for which the application would like to set suggested bindings
- `suggestedBindings` is the `XrInteractionProfileSuggestedBinding` that the application would like to set

`xrSuggestInteractionProfileBindings` sets an interaction profile for which the application can provide default bindings. The application can call `xrSuggestInteractionProfileBindings` once per interaction profile that it supports.

The application can provide any number of bindings for each action.

If the application successfully calls `xrSuggestInteractionProfileBindings` more than once for an interaction profile, the runtime must discard the previous suggested bindings and replace them with the new suggested bindings for that profile.

If the interaction profile path does not follow the structure defined in Interaction Profiles or suggested bindings contain paths that do not follow the format defined in Device input subpaths, the runtime must return `XR_ERROR_PATH_UNSUPPORTED`. If the interaction profile or input source for any of the suggested bindings does not exist in the allowlist defined in Interaction Profile Paths, the runtime must return `XR_ERROR_PATH_UNSUPPORTED`. A runtime must accept every valid binding in the allowlist though it is free to ignore any of them.

If the action set for any action referenced in the `suggestedBindings` parameter has been included in a call to `xrAttachSessionActionSets`, the implementation must return `XR_ERROR_ACTIONSETS_ALREADY_ATTACHED`.

**Valid Usage (Implicit)**

- `instance` must be a valid `XrInstance` handle
- `suggestedBindings` must be a pointer to a valid `XrInteractionProfileSuggestedBinding` structure
Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_PATH_INVALID
- XR_ERROR_ACTIONSETS_ALREADY_AttACHED

The XrInteractionProfileSuggestedBinding structure is defined as:

typedef struct XrInteractionProfileSuggestedBinding {
    XrStructureType type;
    const void* next;
    XrPath interactionProfile;
    uint32_t countSuggestedBindings;
    const XrActionSuggestedBinding* suggestedBindings;
} XrInteractionProfileSuggestedBinding;

Member Descriptions

- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- interactionProfile is the XrPath of an interaction profile.
- countSuggestedBindings is the number of suggested bindings in the array pointed to by suggestedBindings.
- suggestedBindings is a pointer to an array of XrActionSuggestedBinding structures that define all of the application's suggested bindings for the specified interaction profile.
Valid Usage (Implicit)

- **type** must be `XR_TYPE_INTERACTION_PROFILE_SUGGESTED_BINDING`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrBindingModificationsKHR`
- **suggestedBindings** must be a pointer to an array of `countSuggestedBindings` valid `XrActionSuggestedBinding` structures
- The `countSuggestedBindings` parameter must be greater than 0

The `XrActionSuggestedBinding` structure is defined as:

```c
typedef struct XrActionSuggestedBinding {
    XrAction    action;
    XrPath      binding;
} XrActionSuggestedBinding;
```

Member Descriptions

- **action** is the `XrAction` handle for an action
- **binding** is the `XrPath` of a binding for the action specified in `action`. This path is any top level user path plus input source path, for example `/user/hand/right/input/trigger/click`. See suggested bindings for more details.

Valid Usage (Implicit)

- **action** must be a valid `XrAction` handle

The `xrAttachSessionActionSets` function is defined as:

```c
XrResult xrAttachSessionActionSets(
    XrSession session,
    const XrSessionActionSetsAttachInfo* attachInfo);
```
Parameter Descriptions

- `session` is the `XrSession` to attach the action sets to.
- `attachInfo` is the `XrSessionActionSetsAttachInfo` to provide information to attach action sets to the session.

`xrAttachSessionActionSets` attaches the `XrActionSet` handles in `attachInfo.actionSets` to the `session`. Action sets must be attached in order to be synchronized with `xrSyncActions`.

When an action set is attached to a session, that action set becomes immutable. See `xrCreateAction` and `xrSuggestInteractionProfileBindings` for details.

After action sets are attached to a session, if any unattached actions are passed to functions for the same session, then for those functions the runtime must return `XR_ERROR_ACTIONSET_NOT_ATTACHED`.

The runtime must return `XR_ERROR_ACTIONSETS_ALREADY_ATTACHED` if `xrAttachSessionActionSets` is called more than once for a given `session`.

Valid Usage (Implicit)

- `session` must be a valid `XrSession` handle
- `attachInfo` must be a pointer to a valid `XrSessionActionSetsAttachInfo` structure

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_ACTIONSETS_ALREADY_ATTACHED`

The `XrSessionActionSetsAttachInfo` structure is defined as:
typedef struct XrSessionActionSetsAttachInfo {
    XrStructureType       type;
    const void*           next;
    uint32_t              countActionSets;
    const XrActionSet*    actionSets;
} XrSessionActionSetsAttachInfo;

**Member Descriptions**

- **type** is the *XrStructureType* of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **countActionSets** is an integer specifying the number of valid elements in the *actionSets* array.
- **actionSets** is a pointer to an array of one or more *XrActionSet* handles to be attached to the session.

**Valid Usage (Implicit)**

- **type** must be *XR_TYPE_SESSION_ACTION_SETS_ATTACH_INFO*
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **actionSets** must be a pointer to an array of *countActionSets* valid *XrActionSet* handles
- The *countActionSets* parameter must be greater than 0.

The *xrGetCurrentInteractionProfile* function is defined as:

```c
XrResult xrGetCurrentInteractionProfile(
    XrSession session,
    XrPath topLevelUserPath,
    XrInteractionProfileState* interactionProfile);
```
Parameter Descriptions

- `session` is the `XrSession` for which the application would like to retrieve the current interaction profile.
- `topLevelUserPath` is the top level user path the application would like to retrieve the interaction profile for.
- `interactionProfile` is a pointer to an `XrInteractionProfileState` structure to receive the current interaction profile.

`xrGetCurrentInteractionProfile` asks the runtime for the active interaction profiles for a top level user path.

The runtime **must** return only interaction profiles for which the application has provided bindings with `xrSuggestInteractionProfileBindings` or `XR_NULL_PATH`. The runtime **may** return interaction profiles that do not represent physically present hardware, for example if the runtime is using a known interaction profile to bind to hardware that the application is not aware of. The runtime **may** return the last-known interaction profile in the event that no controllers are active.

If `xrAttachSessionActionSets` has not yet been called for the `session`, the runtime **must** return `XR_ERROR_ACTIONSET_NOT_ATTACHED`. If `topLevelUserPath` is not one of the device input subpaths described in section `/user paths`, the runtime **must** return `XR_ERROR_PATH_UNSUPPORTED`.

Valid Usage (Implicit)

- `session` **must** be a valid `XrSession` handle
- `interactionProfile` **must** be a pointer to an `XrInteractionProfileState` structure
Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_PATH_INVALID
- XR_ERROR_ACTIONSET_NOT_ATTACHED

The `XrInteractionProfileState` structure is defined as:

```c
typedef struct XrInteractionProfileState {
    XrStructureType    type;
    void*              next;
    XrPath             interactionProfile;
} XrInteractionProfileState;
```

Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- `interactionProfile` is the `XrPath` of the interaction profile path for the `topLevelUserPath` used to retrieve this state, or `XR_NULL_PATH` if there is no active interaction profile at that top level user path.

The runtime must only include interaction profiles that the application has provided bindings for via `xrSuggestInteractionProfileBindings` or `XR_NULL_PATH`. If the runtime is rebinding an interaction profile provided by the application to a device that the application did not provide bindings for, it
must return the interaction profile path that it is emulating. If the runtime is unable to provide input because it cannot emulate any of the application-provided interaction profiles, it must return XR_NULL_PATH.

Valid Usage (Implicit)

- **type** must be XR_TYPE_INTERACTION_PROFILE_STATE
- **next** must be NULL or a valid pointer to the next structure in a structure chain

11.5. Reading Input Action State

The current state of an input action can be obtained by calling the `xrGetActionState*` function call that matches the `XrActionType` provided when the action was created. If a mismatched call is used to retrieve the state **XR_ERROR_ACTION_TYPE_MISMATCH** must be returned. `xrGetActionState*` calls for an action in an action set never bound to the session with `xrAttachSessionActionSets` must return **XR_ERROR_ACTIONSET_NOT_ATTACHED**.

The result of calls to `xrGetActionState*` for an `XrAction` and subaction path must not change between calls to `xrSyncActions`. When the combination of the parent `XrActionSet` and subaction path for an action is passed to `xrSyncActions`, the runtime must update the results from `xrGetActionState*` after this call with any changes to the state of the underlying hardware. When the parent action set and subaction path for an action is removed from or added to the list of active action sets passed to `xrSyncActions`, the runtime must update `isActive` to reflect the new active state after this call. In all cases the runtime must not change the results of `xrGetActionState*` calls between calls to `xrSyncActions`.

When `xrGetActionState*` or haptic output functions are called while the session is not focused, the runtime must set the `isActive` value to XR_FALSE and suppress all haptic output. Furthermore, the runtime should stop all in-progress haptic events when a session loses focus.

When retrieving action state, `lastChangeTime` must be set to the runtime's best estimate of when the physical state of the part of the device bound to that action last changed.

The `currentState` value is computed based on the current sync, combining the underlying input sources bound to the provided `subactionPaths` within this action.

The `changedSinceLastSync` value must be XR_TRUE if the computed `currentState` value differs from the `currentState` value that would have been computed as of the previous sync for the same `subactionPaths`. If there is no previous sync, or the action was not active for the previous sync, the `changedSinceLastSync` value must be set to XR_FALSE.

The `isActive` value must be XR_TRUE whenever an action is bound and a source is providing state data for the current sync. If the action is unbound or no source is present, the `isActive` value must be XR_FALSE. For any action which is inactive, the runtime must return zero (or XR_FALSE) for state,
XR_FALSE for changedSinceLastSync, and 0 for lastChangeTime.

11.5.1. Resolving a single action bound to multiple inputs or outputs

It is often the case that a single action will be bound to multiple physical inputs simultaneously. In these circumstances, the runtime must resolve the ambiguity in that multiple binding as follows:

The current state value is selected based on the type of the action:

- **Boolean actions** - The current state must be the result of a boolean OR of all bound inputs
- **Float actions** - The current state must be the state of the input with the largest absolute value
- **Vector2 actions** - The current state must be the state of the input with the longest length
- **Pose actions** - The runtime must select a single pose source when the action is created or bound and use that value consistently. The runtime should use subaction paths specified by the application to make this choice where possible.
- **Haptic actions** - The runtime must send output events to all bound haptic devices

11.5.2. Structs to describe action and subaction paths

The XrActionStateGetInfo structure is used to provide action and subaction paths when calling xrGetActionState* function. It is defined as:

```c
typedef struct XrActionStateGetInfo {
    XrStructureType    type;
    const void*        next;
    XrAction           action;
    XrPath             subactionPath;
} XrActionStateGetInfo;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **action** is the XrAction being queried.
- **subactionPath** is the subaction path XrPath to query data from, or XR_NULL_PATH to specify all subaction paths. If the subaction path is specified, it is one of the subaction paths that were specified when the action was created. If the subaction path was not specified when the action was created, the runtime must return XR_ERROR_PATH_UNSUPPORTED. If this parameter is specified, the runtime must return data that originates only from the subaction paths specified.

See XrActionCreateInfo for a description of subaction paths, and the restrictions on their use.

Valid Usage (Implicit)

- **type** must be XR_TYPE_ACTION_STATE_GET_INFO
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **action** must be a valid XrAction handle

The XrHapticActionInfo structure is used to provide action and subaction paths when calling xr*HapticFeedback function. It is defined as:

```c
typedef struct XrHapticActionInfo {
    XrStructureType    type;
    const void*        next;
    XrAction           action;
    XrPath             subactionPath;
} XrHapticActionInfo;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **action** is the XrAction handle for the desired output haptic action.
- **subactionPath** is the subaction path XrPath of the device to send the haptic event to, or XR_NULL_PATH to specify all subaction paths. If the subaction path is specified, it is one of the subaction paths that were specified when the action was created. If the subaction path was not specified when the action was created, the runtime **must** return XR_ERROR_PATH_UNSUPPORTED. If this parameter is specified, the runtime **must** trigger the haptic events only on the device from the subaction path.

See XrActionCreateInfo for a description of subaction paths, and the restrictions on their use.

Valid Usage (Implicit)

- **type** **must** be XR_TYPE_HAPTIC_ACTION_INFO
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain
- **action** **must** be a valid XrAction handle

11.5.3. Boolean Actions

xrGetActionStateBoolean retrieves the current state of a boolean action. It is defined as:

```c
XrResult xrGetActionStateBoolean(
    XrSession session,
    const XrActionStateGetInfo* getInfo,
    XrActionStateBoolean* state);
```

Parameter Descriptions

- **session** is the XrSession to query.
- **getInfo** is a pointer to XrActionStateGetInfo to provide action and subaction paths information.
- **state** is a pointer to a valid XrActionStateBoolean into which the state will be placed.
Valid Usage (Implicit)

- **session** must be a valid `XrSession` handle
- **getInfo** must be a pointer to a valid `XrActionStateGetInfo` structure
- **state** must be a pointer to an `XrActionStateBoolean` structure

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_ACTION_TYPE_MISMATCH`
- `XR_ERROR_ACTIONSET_NOT_ATTACHED`

The `XrActionStateBoolean` structure is defined as:

```c
typedef struct XrActionStateBoolean {
    XrStructureType    type;
    void*              next;  
    XrBool32           currentState;
    XrBool32           changedSinceLastSync;
    XrTime             lastChangeTime;
    XrBool32           isActive;
} XrActionStateBoolean;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **currentState** is the current state of the action.
- **changedSinceLastSync** is XR_TRUE if the value of currentState is different than it was before the most recent call to xrSyncActions. This parameter can be combined with currentState to detect rising and falling edges since the previous call to xrSyncActions. E.g. if both changedSinceLastSync and currentState are XR_TRUE then a rising edge (XR_FALSE to XR_TRUE) has taken place.
- **lastChangeTime** is the XrTime when this action's value last changed.
- **isActive** is XR_TRUE if and only if there exists an input source that is contributing to the current state of this action.

When multiple input sources are bound to this action, the currentState follows the previously defined rule to resolve ambiguity.

Valid Usage (Implicit)

- **type** must be XR_TYPE_ACTION_STATE_BOOLEAN
- **next** must be NULL or a valid pointer to the next structure in a structure chain

11.5.4. Scalar and Vector Actions

xrGetActionStateFloat retrieves the current state of a floating-point action. It is defined as:

```
XrResult xrGetActionStateFloat(
    XrSession session,
    const XrActionStateGetInfo* getInfo,
    XrActionStateFloat* state);
```
Parameter Descriptions

- **session** is the XrSession to query.
- **getInfo** is a pointer to XrActionStateGetInfo to provide action and subaction paths information.
- **state** is a pointer to a valid XrActionStateFloat into which the state will be placed.

Valid Usage (Implicit)

- **session** must be a valid XrSession handle
- **getInfo** must be a pointer to a valid XrActionStateGetInfo structure
- **state** must be a pointer to an XrActionStateFloat structure

Return Codes

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_PATH_INVALID
- XR_ERROR_ACTION_TYPE_MISMATCH
- XR_ERROR_ACTIONSET_NOT_ATTACHED

The XrActionStateFloat structure is defined as:
typedef struct XrActionStateFloat {
    XrStructureType type;
    void* next;
    float currentState;
    XrBool32 changedSinceLastSync;
    XrTime lastChangeTime;
    XrBool32 isActive;
} XrActionStateFloat;

Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **currentState** is the current state of the Action.
- **changedSinceLastSync** is `XR_TRUE` if the value of **currentState** is different than it was before the most recent call to `xrSyncActions`.
- **lastChangeTime** is the `XrTime` in nanoseconds since this action’s value last changed.
- **isActive** is `XR_TRUE` if and only if there exists an input source that is contributing to the current state of this action.

When multiple input sources are bound to this action, the **currentState** follows the previously defined rule to resolve ambiguity.

Valid Usage (Implicit)

- **type** must be `XR_TYPE_ACTION_STATE_FLOAT`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

`xrGetActionStateVector2f` retrieves the current state of a two-dimensional vector action. It is defined as:

```c
XrResult xrGetActionStateVector2f(
    XrSession session,
    const XrActionStateGetInfo* getInfo,
    XrActionStateVector2f* state);
```
Parameter Descriptions

- **session** is the `XrSession` to query.
- **getInfo** is a pointer to `XrActionStateGetInfo` to provide action and subaction paths information.
- **state** is a pointer to a valid `XrActionStateVector2f` into which the state will be placed.

Valid Usage (Implicit)

- **session** must be a valid `XrSession` handle
- **getInfo** must be a pointer to a valid `XrActionStateGetInfo` structure
- **state** must be a pointer to an `XrActionStateVector2f` structure

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_ACTION_TYPE_MISMATCH`
- `XR_ERROR_ACTIONSET_NOT_ATTACHED`

The `XrActionStateVector2f` structure is defined as:
typedef struct XrActionStateVector2f {
    XrStructureType    type;
    void*              next;
    XrVector2f         currentState;
    XrBool32           changedSinceLastSync;
    XrTime             lastChangeTime;
    XrBool32           isActive;
} XrActionStateVector2f;

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **currentState** is the current `XrVector2f` state of the Action.
- **changedSinceLastSync** is `XR_TRUE` if the value of `currentState` is different than it was before the most recent call to `xrSyncActions`.
- **lastChangeTime** is the `XrTime` in nanoseconds since this action’s value last changed.
- **isActive** is `XR_TRUE` if and only if there exists an input source that is contributing to the current state of this action.

When multiple input sources are bound to this action, the `currentState` follows the previously defined rule to resolve ambiguity.

**Valid Usage (Implicit)**

- **type** must be `XR_TYPE_ACTION_STATE_VECTOR2F`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

### 11.5.5. Pose Actions

The `xrGetActionStatePose` function is defined as:

```c
XrResult xrGetActionStatePose(
    XrSession                                   session,
    const XrActionStateGetInfo*                getInfo,
    XrActionStatePose*                         state);
```
Parameter Descriptions

- `session` is the `XrSession` to query.
- `getInfo` is a pointer to `XrActionStateGetInfo` to provide action and subaction paths information.
- `state` is a pointer to a valid `XrActionStatePose` into which the state will be placed.

`xrGetActionStatePose` returns information about the binding and active state for the specified action. To determine the pose of this action at a historical or predicted time, the application can create an action space using `xrCreateActionSpace`. Then, after each sync, the application can locate the pose of this action space within a base space using `xrLocateSpace`.

Valid Usage (Implicit)

- `session` must be a valid `XrSession` handle
- `getInfo` must be a pointer to a valid `XrActionStateGetInfo` structure
- `state` must be a pointer to an `XrActionStatePose` structure

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_ACTION_TYPE_MISMATCH`
- `XR_ERROR_ACTIONSET_NOT_ATTACHED`

The `XrActionStatePose` structure is defined as:
typedef struct XrActionStatePose {
    XrStructureType    type;
    void*              next;
    XrBool32           isActive;
} XrActionStatePose;

### Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **isActive** is `XR_TRUE` if and only if there exists an input source that is being tracked by this pose action.

A pose action **must** not be bound to multiple input sources, according to the previously defined rule.

### Valid Usage (Implicit)

- **type** must be `XR_TYPE_ACTION_STATE_POSE`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

## 11.6. Output Actions and Haptics

Haptic feedback is sent to a device using the `xrApplyHapticFeedback` function. The `hapticEvent` points to a supported event structure. All event structures have in common that the first element is an `XrHapticBaseHeader` which can be used to determine the type of the haptic event.

Haptic feedback may be immediately halted for a haptic action using the `xrStopHapticFeedback` function.

Output action requests activate immediately and **must** not wait for the next call to `xrSyncActions`.

If a haptic event is sent to an action before a previous haptic event completes, the latest event will take precedence and the runtime **must** cancel all preceding incomplete haptic events on that action.

Output action requests **must** be discarded and have no effect on hardware if the application’s session is not focused.

Output action requests for an action in an action set never attached to the session with
xrAttachSessionActionSets must return XR_ERROR_ACTIONSET_NOT_ATTACHED.

The only haptics type supported by unextended OpenXR is XrHapticVibration.

The xrApplyHapticFeedback function is defined as:

```c
XrResult xrApplyHapticFeedback(
    XrSession session,
    const XrHapticActionInfo* hapticActionInfo,
    const XrHapticBaseHeader* hapticFeedback);
```

### Parameter Descriptions

- **session** is the XrSession to start outputting to.
- **hapticActionInfo** is a pointer to XrHapticActionInfo to provide action and subaction paths information.
- **hapticFeedback** is a pointer to a haptic event structure which starts with an XrHapticBaseHeader.

Triggers a haptic event through the specified action of type XR_ACTION_TYPE_VIBRATION_OUTPUT. The runtime should deliver this request to the appropriate device, but exactly which device, if any, this event is sent to is up to the runtime to decide. If an appropriate device is unavailable the runtime may ignore this request for haptic feedback.

If session is not focused, the runtime must return XR_SESSION_NOT_FOCUSED, and not trigger a haptic event.

If another haptic event from this session is currently happening on the device bound to this action, the runtime must interrupt that other event and replace it with the new one.

### Valid Usage (Implicit)

- **session** must be a valid XrSession handle
- **hapticActionInfo must** be a pointer to a valid XrHapticActionInfo structure
- **hapticFeedback must** be a pointer to a valid XrHapticBaseHeader-based structure. See also: XrHapticVibration
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING
• XR_SESSION_NOT_FOCUSED

Failure

• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_PATH_UNSUPPORTED
• XR_ERROR_PATH_INVALID
• XR_ERROR_ACTION_TYPE_MISMATCH
• XR_ERROR_ACTIONSET_NOT_ATTACHED

The XrHapticBaseHeader structure is defined as:

typedef struct XrHapticBaseHeader {
    XrStructureType    type;
    const void*        next;
} XrHapticBaseHeader;

Member Descriptions

• type is the XrStructureType of this structure. This base structure itself has no associated XrStructureType value.

• next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
The `XrHapticVibration` structure is defined as:

```c
typedef struct XrHapticVibration {
    XrStructureType type;
    const void*     next;
    XrDuration      duration;
    float           frequency;
    float           amplitude;
} XrHapticVibration;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **duration** is the number of nanoseconds the vibration **should** last. If `XR_MIN_HAPTIC_DURATION` is specified, the runtime **must** produce a short haptics pulse of minimal supported duration for the haptic device.
- **frequency** is the frequency of the vibration in Hz. If `XR_FREQUENCY_UNSPECIFIED` is specified, it is left to the runtime to decide the optimal frequency value to use.
- **amplitude** is the amplitude of the vibration between 0.0 and 1.0.

The `XrHapticVibration` is used in calls to `xrApplyHapticFeedback` that trigger **vibration** output actions.

The `duration`, and `frequency` parameters **may** be clamped to implementation-dependent ranges.

**Valid Usage (Implicit)**

- **type** **must** be `XR_TYPE_HAPTIC_VIBRATION`
- **next** **must** be `NULL` or a valid pointer to the **next structure in a structure chain**

`XR_MIN_HAPTIC_DURATION` is used to indicate to the runtime that a short haptic pulse of the minimal
supported duration for the haptic device.

```c
#define XR_MIN_HAPTIC_DURATION -1
```

**XR_FREQUENCY_UNSPECIFIED** is used to indicate that the application wants the runtime to decide what the optimal frequency is for the haptic pulse.

```c
#define XR_FREQUENCY_UNSPECIFIED 0
```

The `xrStopHapticFeedback` function is defined as:

```c
XrResult xrStopHapticFeedback(
    XrSession session,
    const XrHapticActionInfo* hapticActionInfo);
```

**Parameter Descriptions**

- `session` is the XrSession to stop outputting to.
- `hapticActionInfo` is a pointer to an XrHapticActionInfo to provide action and subaction path information.

If a haptic event from this XrAction is in progress, when this function is called the runtime **must** stop that event.

If `session` is not focused, the runtime **must** return XR_SESSION_NOT_FOCUSED.

**Valid Usage (Implicit)**

- `session` **must** be a valid XrSession handle
- `hapticActionInfo` **must** be a pointer to a valid XrHapticActionInfo structure
## Return Codes

### Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING
- XR_SESSION_NOT_FOCUSED

### Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_PATH_INVALID
- XR_ERROR_ACTION_TYPE_MISMATCH
- XR_ERROR_ACTIONSET_NOT_ATTACHED

## 11.7. Input Action State Synchronization

The `xrSyncActions` function is defined as:

```c
XrResult xrSyncActions(
    XrSession session,
    const XrActionsSyncInfo* syncInfo);
```

### Parameter Descriptions
- `session` is a handle to the `XrSession` that all provided action set handles belong to.
- `syncInfo` is an `XrActionsSyncInfo` providing information to synchronize action states.

`xrSyncActions` updates the current state of input actions. Repeated input action state queries between subsequent synchronization calls must return the same values. The `XrActionSet` structures referenced in the `syncInfo.activeActionSets` must have been previously attached to the session via `xrAttachSessionActionSets`. If any action sets not attached to this session are passed to `xrSyncActions` it
must return `XR_ERROR_ACTIONSET_NOT_ATTACHED`. Subsets of the bound action sets can be synchronized in order to control which actions are seen as active.

If `session` is not focused, the runtime must return `XR_SESSION_NOT_FOCUSED`, and all action states in the session must be inactive.

### Valid Usage (Implicit)

- `session` must be a valid `XrSession` handle
- `syncInfo` must be a pointer to a valid `XrActionsSyncInfo` structure

### Return Codes

**Success**
- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`
- `XR_SESSION_NOT_FOCUSED`

**Failure**
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_ACTIONSET_NOT_ATTACHED`

The `XrActionsSyncInfo` structure is defined as:

```c
typedef struct XrActionsSyncInfo {
    XrStructureType             type;
    const void*                 next;
    uint32_t                    countActiveActionSets;
    const XrActiveActionSet*    activeActionSets;
} XrActionsSyncInfo;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **countActiveActionSets** is an integer specifying the number of valid elements in the activeActionSets array.
- **activeActionSets** is NULL or a pointer to an array of one or more XrActiveActionSet structures that should be synchronized.

Valid Usage (Implicit)

- **type must** be XR_TYPE_ACTIONS_SYNC_INFO
- **next must** be NULL or a valid pointer to the next structure in a structure chain
- If **countActiveActionSets** is not 0, **activeActionSets must** be a pointer to an array of countActiveActionSets valid XrActiveActionSet structures

The XrActiveActionSet structure is defined as:

```c
typedef struct XrActiveActionSet {
    XrActionSet    actionSet;
    XrPath         subactionPath;
} XrActiveActionSet;
```

Member Descriptions

- **actionSet** is the handle of the action set to activate.
- **subactionPath** is a subaction path that was declared when one or more actions in the action set was created or XR_NULL_PATH. If the application wants to activate the action set on more than one subaction path, it can include additional XrActiveActionSet structs with the other subactionPath values. Using XR_NULL_PATH as the value for subactionPath, acts as a wildcard for all subaction paths on the actions in the action set. If the subaction path was not specified on any of the actions in the actionSet when that action was created, the runtime must return XR_ERROR_PATH_UNSUPPORTED.

This structure defines a single active action set and subaction path combination. Applications can
provide a list of these structures to the \texttt{xrSyncActions} function.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|}
\hline
\textbf{Valid Usage (Implicit)} & \\
\hline
\textbullet \hspace{0.5em} \texttt{actionSet must} be a valid \texttt{XrActionSet} handle & \\
\hline
\end{tabular}
\end{table}

### 11.8. Action Sources

An application \textbf{can} use the \texttt{xrEnumerateBoundSourcesForAction} and \texttt{xrGetInputSourceLocalizedName} calls to prompt the user which physical inputs to use in order to perform an action. A \textbf{source} is the physical control that the action is bound to within the current interaction profile as returned by \texttt{xrGetCurrentInteractionProfile}. An action \textbf{may} be bound to multiple sources at one time, for example an action named \textit{hold} could be bound to both the X and A buttons.

Once the semantic paths for the action's source are obtained, the application \textbf{can} gather additional information about the source. \texttt{xrGetInputSourceLocalizedName} returns a localized human-readable string describing the source, e.g. 'A Button'.

The \texttt{xrEnumerateBoundSourcesForAction} function is defined as:

\begin{verbatim}
XrResult xrEnumerateBoundSourcesForAction(
    XrSession session,
    const XrBoundSourcesForActionEnumerateInfo* enumerateInfo,
    uint32_t sourceCapacityInput,
    uint32_t* sourceCountOutput,
    XrPath* sources);
\end{verbatim}
Parameter Descriptions

- **session** is the XrSession being queried.
- **enumerateInfo** is an XrBoundSourcesForActionEnumerateInfo providing the query information.
- **sourceCapacityInput** is the capacity of the array, or 0 to indicate a request to retrieve the required capacity.
- **sourceCountOutput** is a pointer to the count of sources, or a pointer to the required capacity in the case that sourceCapacityInput is insufficient.
- **sources** is a pointer to an application-allocated array that will be filled with the XrPath values for all sources. It can be NULL if sourceCapacityInput is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required sources size.

If an action is unbound, xrEnumerateBoundSourcesForAction must assign 0 to the value pointed-to by sourceCountOutput and not modify the array.

xrEnumerateBoundSourcesForAction must return XR_ERROR_ACTIONSET_NOT_ATTACHED if passed an action in an action set never attached to the session with xrAttachSessionActionSets.

As bindings for actions do not change between calls to xrSyncActions, xrEnumerateBoundSourcesForAction must enumerate the same set of bound sources, or absence of bound sources, for a given query (defined by the enumerateInfo parameter) between any two calls to xrSyncActions.

Valid Usage (Implicit)

- **session** must be a valid XrSession handle
- **enumerateInfo** must be a pointer to a valid XrBoundSourcesForActionEnumerateInfo structure
- **sourceCountOutput** must be a pointer to a uint32_t value
- If sourceCapacityInput is not 0, **sources** must be a pointer to an array of sourceCapacityInput XrPath values
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_PATH_INVALID
- XR_ERROR_ACTIONSET_NOT_ATTACHED

The XrBoundSourcesForActionEnumerateInfo structure is defined as:

typedef struct XrBoundSourcesForActionEnumerateInfo {
    XrStructureType type;
    const void*    next;
    XrAction       action;
} XrBoundSourcesForActionEnumerateInfo;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **action** is the handle of the action to query.
Valid Usage (Implicit)

- **type** must be `XR_TYPE_BOUND_SOURCES_FOR_ACTION_ENUMERATE_INFO`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- **action** must be a valid `XrAction` handle

The `xrGetInputSourceLocalizedName` function is defined as:

```c
XrResult xrGetInputSourceLocalizedName(
    XrSession                                   session,
    const XrInputSourceLocalizedNameGetInfo*    getInfo,
    uint32_t                                    bufferCapacityInput,
    uint32_t*                                   bufferCountOutput,
    char*                                       buffer);
```

Parameter Descriptions

- **session** is a handle to the `XrSession` associated with the action that reported this source.
- **getInfo** is an `XrInputSourceLocalizedNameGetInfo` providing the query information.
- **bufferCapacityInput** is the capacity of the buffer, or 0 to indicate a request to retrieve the required capacity.
- **bufferCountOutput** is a pointer to the count of name characters written (including the terminating `\0`), or a pointer to the required capacity in the case that `bufferCapacityInput` is insufficient.
- **buffer** is a pointer to an application-allocated buffer that will be filled with the source name. It can be `NULL` if `bufferCapacityInput` is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required buffer size.

`xrGetInputSourceLocalizedName` returns a string for the input source in the current system locale.

If `xrAttachSessionActionSets` has not yet been called for the session, the runtime must return `XR_ERROR_ACTIONSET_NOT_ATTACHED`.
Valid Usage (Implicit)

- `session` must be a valid `XrSession` handle
- `getInfo` must be a pointer to a valid `XrInputSourceLocalizedNameGetInfo` structure
- `bufferCountOutput` must be a pointer to a `uint32_t` value
- If `bufferCapacityInput` is not 0, `buffer` must be a pointer to an array of `bufferCapacityInput` char values

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_SIZE_INSUFFICIENT`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_ACTIONSET_NOT_ATTACHED`

The `XrInputSourceLocalizedNameGetInfo` structure is defined as:

```c
typedef struct XrInputSourceLocalizedNameGetInfo {
    XrStructureType                    type;
    const void*                        next;
    XrPath                             sourcePath;
    XrInputSourceLocalizedNameFlags    whichComponents;
} XrInputSourceLocalizedNameGetInfo;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **source** is an XrPath representing the source. Typically this was returned by a call to xrEnumerateBoundSourcesForAction.
- **whichComponents** is any set of flags from XrInputSourceLocalizedNameFlagBits.

Valid Usage (Implicit)

- **type** must be XR_TYPE_INPUT_SOURCE_LOCALIZED_NAME_GET_INFO
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **whichComponents** must be a valid combination of XrInputSourceLocalizedNameFlagBits values
- **whichComponents** must not be 0

The `xrGetInputSourceLocalizedName::whichComponents` parameter takes bitwise-OR of any of the following values:

```c
// Flag bits for XrInputSourceLocalizedNameFlags
static const XrInputSourceLocalizedNameFlags XR_INPUT_SOURCE_LOCALIZED_NAME_USER_PATH_BIT = 0x00000001;
static const XrInputSourceLocalizedNameFlags XR_INPUT_SOURCE_LOCALIZED_NAME_INTERACTION_PROFILE_BIT = 0x00000002;
static const XrInputSourceLocalizedNameFlags XR_INPUT_SOURCE_LOCALIZED_NAME_COMPONENT_BIT = 0x00000004;
```

Flag Descriptions

- **XR_INPUT_SOURCE_LOCALIZED_NAME_USER_PATH_BIT** indicates that the runtime must include the user path portion of the string in the result, if available. E.g. Left Hand.
- **XR_INPUT_SOURCE_LOCALIZED_NAME_INTERACTION_PROFILE_BIT** indicates that the runtime must include the interaction profile portion of the string in the result, if available. E.g. Vive Controller.
- **XR_INPUT_SOURCE_LOCALIZED_NAME_COMPONENT_BIT** indicates that the runtime must include the input component portion of the string in the result, if available. E.g. Trigger.
Chapter 12. List of Current Extensions

- XR_KHR_android_create_instance
- XR_KHR_android_surface_swapchain
- XR_KHR_android_thread_settings
- XR_KHR_binding_modification
- XR_KHR_composition_layer_color_scale_bias
- XR_KHR_composition_layer_cube
- XR_KHR_composition_layer_cylinder
- XR_KHR_composition_layer_depth
- XR_KHR_composition_layer_equirect
- XR_KHR_composition_layer_equirect2
- XR_KHR_convert_timespec_time
- XR_KHR_D3D11_enable
- XR_KHR_D3D12_enable
- XR_KHR_loader_init
- XR_KHR_loader_init_android
- XR_KHR_opengl_enable
- XR_KHR_opengl_es_enable
- XR_KHR_swapchain_usage_input_attachment_bit
- XR_KHR_visibility_mask
- XR_KHR_vulkan_enable
- XR_KHR_vulkan_enable2
- XR_KHR_vulkan_swapchain_format_list
- XR_KHR_win32_convert_performance_counter_time
- XR_EXT_conformance_automation
- XR_EXT_debug_utils
- XR_EXT_dpad_binding
- XR_EXT_eye_gaze_interaction
- XR_EXT_hand_joints_motion_range
- XR_EXT_hand_tracking
- XR_EXT_hp_mixed_reality_controller
• XR_EXT_palm_pose
• XR_EXT_performance_settings
• XR_EXT_samsung_odyssey_controller
• XR_EXT_thermal_query
• XR_EXT_uuid
• XR_EXT_view_configuration_depth_range
• XR_EXT_win32_appcontainer_compatible
• XR_ALMALENCE_digital_lens_control
• XR_EPIC_view_configuration_fov
• XR_FB_android_surface_swapchain_create
• XR_FB_color_space
• XR_FB_composition_layer_alpha_blend
• XR_FB_composition_layer_image_layout
• XR_FB_composition_layer_secure_content
• XR_FB_composition_layer_settings
• XR_FB_display_refresh_rate
• XR_FB_foveation
• XR_FB_foveation_configuration
• XR_FB_foveation_vulkan
• XR_FB_hand_tracking_aim
• XR_FB_hand_tracking_capsules
• XR_FB_hand_tracking_mesh
• XR_FB_keyboard_tracking
• XR_FB_passthrough
• XR_FB_passthrough_keyboard_hands
• XR_FB_render_model
• XR_FB_scene
• XR_FB_space_warp
• XR_FB_spatial_entity
• XR_FB_spatial_entity_container
• XR_FB_spatial_entity_query
• XR_FB_spatial_entity_storage
• XR_FB_swapchain_update_state
• XR_FB_swapchain_update_state_android_surface
• XR_FB_swapchain_update_state_opengl_es
• XR_FB_swapchain_update_state_vulkan
• XR_FB_triangle_mesh
• XR_HTC_facial_tracking
• XR_HTC_hand_interaction
• XR_HTC_vive_cosmos_controller_interaction
• XR_HTC_vive_focus3_controller_interaction
• XR_HTC_vive_wrist_tracker_interaction
• XR_HUAWEI_controller_interaction
• XR_META_performance_metrics
• XR_META_vulkan_swapchain_create_info
• XR_MND_headless
• XR_MSFT_composition_layer_reprojection
• XR_MSFT_controller_model
• XR_MSFT_first_person_observer
• XR_MSFT_hand_interaction
• XR_MSFT_hand_tracking_mesh
• XR_MSFT_holographic_window_attachment
• XR_MSFT_perception_anchor_interop
• XR_MSFT_scene_understanding
• XR_MSFT_scene_understanding_serialization
• XR_MSFT_secondary_view_configuration
• XR_MSFT.spatial_anchor
• XR_MSFT.spatial_anchor_persistence
• XR_MSFT.spatial_graph_bridge
• XR_MSFT_unbounded_reference_space
• XR_OCULUS_android_session_state_enable
• XR_OCULUS_audio_device_guid
• XR_ULTRALEAP_hand_tracking_forearm
• XR_VALVE.analog_threshold
- XR_VARJO_composition_layer_depth_test
- XR_VARJO_environment_depth_estimation
- XR_VARJO_foveated_rendering
- XR_VARJO_marker_tracking
- XR_VARJO_quad_views
- XR_VARJO_view_offset
12.1. XR_KHR_android_create_instance

Name String
XR_KHR_android_create_instance

Extension Type
Instance extension

Registered Extension Number
9

Revision
3

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2019-07-17

IP Status
No known IP claims.

Contributors
Robert Menzel, NVIDIA
Martin Renschler, Qualcomm
Krzysztof Kosiński, Google

Overview
When the application creates an XrInstance object on Android systems, additional information from the application has to be provided to the XR runtime.

The Android XR runtime must return error XR_ERROR_VALIDATION_FAILURE if the additional information is not provided by the application or if the additional parameters are invalid.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:
• XR_TYPE_INSTANCE_CREATE_INFO_ANDROID_KHR
New Enums

New Structures

The `XrInstanceCreateInfoAndroidKHR` structure is defined as:

```c
typedef struct XrInstanceCreateInfoAndroidKHR {
    XrStructureType    type;
    const void*        next;
    void*              applicationVM;
    void*              applicationActivity;
} XrInstanceCreateInfoAndroidKHR;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **applicationVM** is a pointer to the JNI's opaque `JavaVM` structure, cast to a void pointer.
- **applicationActivity** is a JNI reference to an `android.app.Activity` that will drive the session lifecycle of this instance, cast to a void pointer.

`XrInstanceCreateInfoAndroidKHR` contains additional Android specific information needed when calling `xrCreateInstance`. The `applicationVM` field should be populated with the `JavaVM` structure received by the `JNI_OnLoad` function, while the `applicationActivity` field will typically contain a reference to a Java activity object received through an application-specific native method. The `XrInstanceCreateInfoAndroidKHR` structure must be provided in the `next` chain of the `XrInstanceCreateInfo` structure when calling `xrCreateInstance`.

**Valid Usage (Implicit)**

- The `XR_KHR_android_create_instance` extension must be enabled prior to using `XrInstanceCreateInfoAndroidKHR`
- **type** must be `XR_TYPE_INSTANCE_CREATE_INFO_ANDROID_KHR`
- **next** must be `NULL` or a valid pointer to the `next` structure in a structure chain
- **applicationVM** must be a pointer value
- **applicationActivity** must be a pointer value
New Functions

Issues

Version History

- Revision 1, 2017-05-26 (Robert Menzel)
  ◦ Initial draft
- Revision 2, 2019-01-24 (Martin Renschler)
  ◦ Added error code, reformatted
- Revision 3, 2019-07-17 (Krzysztof Kosiński)
  ◦ Non-substantive clarifications.

12.2. XR_KHR_android_surface_swapchain

Name String

XR_KHR_android_surface_swapchain

Extension Type

Instance extension

Registered Extension Number

5

Revision

4

Extension and Version Dependencies

- Requires OpenXR 1.0

Last Modified Date

2019-05-30

IP Status

No known IP claims.

Contributors

Krzysztof Kosiński, Google
Johannes van Waveren, Oculus
Martin Renschler, Qualcomm

Overview

A common activity in XR is to view an image stream. Image streams are often the result of camera
previews or decoded video streams. On Android, the basic primitive representing the producer end of an image queue is the class `android.view.Surface`. This extension provides a special swapchain that uses an `android.view.Surface` as its producer end.

**New Object Types**

**New Flag Types**

**New Enum Constants**

**New Enums**

**New Structures**

**New Functions**

To create an `XrSwapchain` object and an Android Surface object call:

```c
XrResult xrCreateSwapchainAndroidSurfaceKHR(
    XrSession        session,
    const XrSwapchainCreateInfo* info,
    XrSwapchain*     swapchain,
    jobject*         surface);
```

**Parameter Descriptions**

- `session` is an `XrSession` handle previously created with `xrCreateSession`.
- `info` is a pointer to an `XrSwapchainCreateInfo` structure.
- `swapchain` is a pointer to a handle in which the created `XrSwapchain` is returned.
- `surface` is a pointer to a `jobject` where the created Android Surface is returned.

`xrCreateSwapchainAndroidSurfaceKHR` creates an `XrSwapchain` object returned in `swapchain` and an Android Surface `jobject` returned in `surface`. The `jobject` **must** be valid to be passed back to Java code using JNI and **must** be valid to be used with ordinary Android APIs for submitting images to Surfaces. The returned `XrSwapchain` **must** be valid to be referenced in `XrSwapchainSubImage` structures to show content on the screen. The width and height passed in `XrSwapchainCreateInfo` **may** not be persistent throughout the life cycle of the created swapchain, since on Android, the size of the images is controlled by the producer and possibly changes at any time.

The only function that is allowed to be called on the `XrSwapchain` returned from this function is `xrDestroySwapchain`. For example, calling any of the functions `xrEnumerateSwapchainImages`, `xrAcquireSwapchainImage`, `xrWaitSwapchainImage` or `xrReleaseSwapchainImage` is invalid.
When the application receives the `XrEventDataSessionStateChanged` event with the `XR_SESSION_STATE_STOPPING` state, it must ensure that no threads are writing to any of the Android surfaces created with this extension before calling `xrEndSession`. The effect of writing frames to the Surface when the session is in states other than `XR_SESSION_STATE_VISIBLE` or `XR_SESSION_STATE_FOCUSED` is undefined.

`xrCreateSwapchainAndroidSurfaceKHR` must return the same set of error codes as `xrCreateSwapchain` under the same circumstances, plus `XR_ERROR_FUNCTION_UNSUPPORTED` in case the function is not supported.

### Valid Usage of `XrSwapchainCreateInfo` members

- The `XrSwapchainCreateInfo::format`, `XrSwapchainCreateInfo::sampleCount`, `XrSwapchainCreateInfo::faceCount`, `XrSwapchainCreateInfo::arraySize` and `XrSwapchainCreateInfo::mipCount` members of the structure passed as the `info` parameter must be zero.

### Valid Usage (Implicit)

- The `XR_KHR_android_surface_swapchain` extension must be enabled prior to calling `xrCreateSwapchainAndroidSurfaceKHR`
- `session` must be a valid `XrSession` handle
- `info` must be a pointer to a valid `XrSwapchainCreateInfo` structure
- `swapchain` must be a pointer to an `XrSwapchain` handle
- `surface` must be a pointer to a `jobject` value
Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED

Issues

Version History

- Revision 1, 2017-01-17 (Johannes van Waveren)
  - Initial draft
- Revision 2, 2017-10-30 (Kaye Mason)
  - Changed images to swapchains, used snippet includes. Added issue for Surfaces.
- Revision 3, 2018-05-16 (Krzysztof Kosiński)
  - Refactored to use Surface instead of SurfaceTexture.
- Revision 4, 2019-01-24 (Martin Renschler)
  - Refined the specification of the extension

12.3. XR_KHR_android_thread_settings

Name String

XR_KHR_android_thread_settings

Extension Type

Instance extension
Registered Extension Number
4

Revision
5

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2019-07-17

IP Status
No known IP claims.

Contributors
Cass Everitt, Oculus
Johannes van Waveren, Oculus
Martin Renschler, Qualcomm
Krzysztof Kosiński, Google

Overview
For XR to be comfortable, it is important for applications to deliver frames quickly and consistently. In order to make sure the important application threads get their full share of time, these threads must be identified to the system, which will adjust their scheduling priority accordingly.

New Object Types

New Flag Types

New Enum Constants

XrResult enumeration is extended with:

• XR_ERROR_ANDROID_THREAD_SETTINGS_ID_INVALID_KHR
• XR_ERROR_ANDROID_THREAD_SETTINGS_FAILURE_KHR

New Enums

The possible thread types are specified by the XrAndroidThreadTypeKHR enumeration:
typedef enum XrAndroidThreadTypeKHR {
    XR_ANDROID_THREAD_TYPE_APPLICATION_MAIN_KHR = 1,
    XR_ANDROID_THREAD_TYPE_APPLICATION_WORKER_KHR = 2,
    XR_ANDROID_THREAD_TYPE_RENDERER_MAIN_KHR = 3,
    XR_ANDROID_THREAD_TYPE_RENDERER_WORKER_KHR = 4,
    XR_ANDROID_THREAD_TYPE_MAX_ENUM_KHR = 0x7FFFFFFF
} XrAndroidThreadTypeKHR;

**Enumerants**

- **XR_ANDROID_THREAD_TYPE_APPLICATION_MAIN_KHR**
  hints the XR runtime that the thread is doing background CPU tasks

- **XR_ANDROID_THREAD_TYPE_APPLICATION_WORKER_KHR**
  hints the XR runtime that the thread is doing time critical CPU tasks

- **XR_ANDROID_THREAD_TYPE_RENDERER_MAIN_KHR**
  hints the XR runtime that the thread is doing background graphics device tasks

- **XR_ANDROID_THREAD_TYPE_RENDERER_WORKER_KHR**
  hints the XR runtime that the thread is doing time critical graphics device tasks

**New Structures**

**New Functions**

To declare a thread to be of a certain `XrAndroidThreadTypeKHR` type call:

```c
XrResult xrSetAndroidApplicationThreadKHR(
    XrSession session,
    XrAndroidThreadTypeKHR threadType,
    uint32_t threadId);
```
Parameter Descriptions

• session is a valid XrSession handle.

• threadType is a classification of the declared thread allowing the XR runtime to apply the relevant priority and attributes. If such settings fail, the runtime must return XR_ERROR_ANDROID_THREAD_SETTINGS_FAILURE_KHR.

• threadId is the kernel thread ID of the declared thread, as returned by gettid() or android.os.process.myTid(). If the thread ID is invalid, the runtime must return XR_ERROR_ANDROID_THREAD_SETTINGS_ID_INVALID_KHR.

xrSetAndroidApplicationThreadKHR allows to declare an XR-critical thread and to classify it.

Valid Usage (Implicit)

• The XR_KHR_android_thread_settings extension must be enabled prior to calling xrSetAndroidApplicationThreadKHR

• session must be a valid XrSession handle

• threadType must be a valid XrAndroidThreadTypeKHR value

Return Codes

Success

• XR_SUCCESS

• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED

• XR_ERROR_VALIDATION_FAILURE

• XR_ERROR_RUNTIME_FAILURE

• XR_ERROR_HANDLE_INVALID

• XR_ERROR_INSTANCE_LOST

• XR_ERROR_SESSION_LOST

• XR_ERROR_ANDROID_THREAD_SETTINGS_ID_INVALID_KHR

• XR_ERROR_ANDROID_THREAD_SETTINGS_FAILURE_KHR

Version History
• Revision 1, 2017-01-17 (Johannes van Waveren)
  ◦ Initial draft.
• Revision 2, 2017-10-31 (Armelle Laine)
  ◦ Move the performance settings to EXT extension.
• Revision 3, 2018-12-20 (Paul Pedriana)
  ◦ Revised the error code naming to use KHR and renamed `xrSetApplicationThreadKHR` → `xrSetAndroidApplicationThreadKHR`.
• Revision 4, 2019-01-24 (Martin Renschler)
  ◦ Added enum specification, reformatting
• Revision 5, 2019-07-17 (Krzysztof Kosiński)
  ◦ Clarify the type of thread identifier used by the extension.

### 12.4. XR_KHR_binding_modification

**Name String**

XR_KHR_binding_modification

**Extension Type**

Instance extension

**Registered Extension Number**

121

**Revision**

1

**Extension and Version Dependencies**

- Requires OpenXR 1.0

**Last Modified Date**

2020-07-29

**IP Status**

No known IP claims.

**Contributors**

Joe Ludwig, Valve

**Contacts**

Joe Ludwig, Valve
Overview

This extension adds an optional structure that can be included on the `XrInteractionProfileSuggestedBinding::next` chain passed to `xrSuggestInteractionProfileBindings` to specify additional information to modify default binding behavior.

This extension does not define any actual modification structs, but includes the list of modifications and the `XrBindingModificationBaseHeaderKHR` structure to allow other extensions to provide specific modifications.

New Object Types

New Flag Types

New Enum Constants

`XrStructureType` enumeration is extended with:

- `XR_TYPE_BINDING_MODIFICATIONS_KHR`

New Enums

New Structures

The `XrBindingModificationsKHR` structure is defined as:

```c
typedef struct XrBindingModificationsKHR {
    XrStructureType                                     type;
    const void*                                         next;
    uint32_t                                            bindingModificationCount;
    const XrBindingModificationBaseHeaderKHR* const*    bindingModifications;
} XrBindingModificationsKHR;
```

Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain.
- `bindingModificationCount` is the number of binding modifications in the array pointed to by `bindingModifications`.
- `bindingModifications` is a pointer to an array of pointers to binding modification structures based on `XrBindingModificationBaseHeaderKHR`, that define all of the application’s suggested binding modifications for the specified interaction profile.
Valid Usage (Implicit)

- The `XR_KHR_binding_modification` extension **must** be enabled prior to using `XrBindingModificationsKHR`
- **type** **must** be `XR_TYPE_BINDING_MODIFICATIONS_KHR`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- If `bindingModificationCount` is **not** 0, `bindingModifications` **must** be a pointer to an array of `bindingModificationCount` valid `XrBindingModificationBaseHeaderKHR`-based structures. See also: `XrInteractionProfileAnalogThresholdVALVE`, `XrInteractionProfileDpadBindingEXT`

The `XrBindingModificationBaseHeaderKHR` structure is defined as:

```c
typedef struct XrBindingModificationBaseHeaderKHR {
    XrStructureType type;
    const void* next;
} XrBindingModificationBaseHeaderKHR;
```

Member Descriptions

- **type** is the `XrStructureType` of this structure. This base structure itself has no associated `XrStructureType` value.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or in this extension.

The `XrBindingModificationBaseHeaderKHR` is a base structure is overridden by `XrBindingModification` child structures.

Valid Usage (Implicit)

- The `XR_KHR_binding_modification` extension **must** be enabled prior to using `XrBindingModificationBaseHeaderKHR`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain

New Functions

Issues

Version History
12.5. XR_KHR_composition_layer_color_scale_bias

Name String
   XR_KHR_composition_layer_color_scale_bias

Extension Type
   Instance extension

Registered Extension Number
   35

Revision
   5

Extension and Version Dependencies
   • Requires OpenXR 1.0

Last Modified Date
   2019-01-28

IP Status
   No known IP claims.

Contributors
   Paul Pedriana, Oculus
   Cass Everitt, Oculus
   Martin Renschler, Qualcomm

Overview

Color scale and bias are applied to a layer color during composition, after its conversion to premultiplied alpha representation.

If specified, colorScale and colorBias must be used to alter the LayerColor as follows:

• colorScale = max( vec4( 0, 0, 0, 0 ), colorScale )
• LayerColor.RGB = LayerColor.A > 0 ? LayerColor.RGB / LayerColor.A : vec3( 0, 0, 0 )
• LayerColor = LayerColor * colorScale + colorBias
• LayerColor.RGB *= LayerColor.A

This extension specifies the XrCompositionLayerColorScaleBiasKHR structure, which, if present in the
XrCompositionLayerBaseHeader::next chain, **must** be applied to the composition layer.

This extension does not define a new composition layer type, but rather it defines a transform that may be applied to the color derived from existing composition layer types.

**New Object Types**

**New Flag Types**

**New Enum Constants**

XrStructureType enumeration is extended with:

- XR_TYPE_COMPOSITION_LAYER_COLOR_SCALE_BIAS_KHR

**New Enums**

**New Structures**

The XrCompositionLayerColorScaleBiasKHR structure is defined as:

```c
typedef struct XrCompositionLayerColorScaleBiasKHR {
    XrStructureType    type;
    const void*        next;
    XrColor4f          colorScale;
    XrColor4f          colorBias;
} XrCompositionLayerColorScaleBiasKHR;
```

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **colorScale** is an XrColor4f which will modulate the color sourced from the images.
- **colorBias** is an XrColor4f which will offset the color sourced from the images.

XrCompositionLayerColorScaleBiasKHR contains the information needed to scale and bias the color of layer textures.

The XrCompositionLayerColorScaleBiasKHR structure **can** be applied by applications to composition layers by adding an instance of the struct to the XrCompositionLayerBaseHeader::next list.
Valid Usage (Implicit)

- The `XR_KHR_composition_layer_color_scale_bias` extension **must** be enabled prior to using `XrCompositionLayerColorScaleBiasKHR`
- **type** **must** be `XR_TYPE_COMPOSITION_LAYER_COLOR_SCALE_BIAS_KHR`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain

New Functions

Issues

Version History

- Revision 1, 2017-09-13 (Paul Pedriana)
  - Initial implementation.
- Revision 2, 2019-01-24 (Martin Renschler)
  - Formatting, spec language changes
- Revision 3, 2019-01-28 (Paul Pedriana)
  - Revised math to remove premultiplied alpha before applying color scale and offset, then restoring.
- Revision 4, 2019-07-17 (Cass Everitt)
  - Non-substantive updates to the spec language and equations.
- Revision 5, 2020-05-20 (Cass Everitt)
  - Changed extension name, simplified language.

12.6. XR_KHR_composition_layer_cube

Name String

```
XR_KHR_composition_layer_cube
```

Extension Type

Instance extension

Registered Extension Number

7

Revision

8
Extension and Version Dependencies

- Requires OpenXR 1.0

Last Modified Date

2019-01-24

IP Status

No known IP claims.

Contributors

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Cass Everitt, Oculus
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Gloria Kennickell, Oculus
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Contacts

Cass Everitt, Oculus
Paul Pedriana, Oculus

Overview

This extension adds an additional layer type that enables direct sampling from cubemaps.

The cube layer is the natural layer type for hardware accelerated environment maps. Without updating the image source, the user can look all around, and the compositor can display what they are looking at without intervention from the application.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_COMPOSITION_LAYER_CUBE_KHR

New Enums

New Structures

The XrCompositionLayerCubeKHR structure is defined as:
typedef struct XrCompositionLayerCubeKHR {
    XrStructureType            type;
    const void*                next;
    XrCompositionLayerFlags    layerFlags;
    XrSpace                    space;
    XrEyeVisibility            eyeVisibility;
    XrSwapchain                swapchain;
    uint32_t                   imageArrayIndex;
    XrQuaternionf              orientation;
} XrCompositionLayerCubeKHR;

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **layerFlags** is any flags to apply to this layer.
- **space** is the `XrSpace` in which the `orientation` of the cube layer is evaluated over time.
- **eye** is the eye represented by this layer.
- **swapchain** is the swapchain.
- **imageArrayIndex** is the image array index, with 0 meaning the first or only array element.
- **orientation** is the orientation of the environment map in the `space`.

`XrCompositionLayerCubeKHR` contains the information needed to render a cube map when calling `xrEndFrame`. `XrCompositionLayerCubeKHR` is an alias type for the base struct `XrCompositionLayerBaseHeader` used in `XrFrameEndInfo`. 
Valid Usage (Implicit)

- The `XR_KHR_composition_layer_cube` extension **must** be enabled prior to using `XrCompositionLayerCubeKHR`
- **type** must be `XR_TYPE_COMPOSITION_LAYER_CUBE_KHR`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- **layerFlags** must be 0 or a valid combination of `XrCompositionLayerFlagBits` values
- **space** must be a valid `XrSpace` handle
- **eyeVisibility** must be a valid `XrEyeVisibility` value
- **swapchain** must be a valid `XrSwapchain` handle
- Both of **space** and **swapchain** must have been created, allocated, or retrieved from the same `XrSession`

New Functions

Issues

Version History

- Revision 0, 2017-02-01 (Johannes van Waveren)
  - Initial draft.
- Revision 1, 2017-05-19 (Sam Martin)
  - Initial draft, moving the 3 layer types to an extension.
- Revision 2, 2017-08-30 (Paul Pedriana)
  - Updated the specification.
- Revision 3, 2017-10-12 (Cass Everitt)
  - Updated to reflect per-eye structs and the change to swapchains
- Revision 4, 2017-10-18 (Kaye Mason)
  - Update to flatten structs to remove per-eye arrays.
- Revision 5, 2017-12-05 (Paul Pedriana)
  - Updated to break out the cylinder and equirect features into separate extensions.
- Revision 6, 2017-12-07 (Paul Pedriana)
  - Updated to use transform components instead of transform matrices.
- Revision 7, 2017-12-07 (Paul Pedriana)
  - Updated to convert `XrPosef` to `XrQuaternionf` (there’s no position component).
12.7. XR_KHR_composition_layer_cylinder

**Name String**

XR_KHR_composition_layer_cylinder

**Extension Type**

Instance extension

**Registered Extension Number**

18

**Revision**

4

**Extension and Version Dependencies**

- Requires OpenXR 1.0

**Last Modified Date**

2019-01-24

**IP Status**

No known IP claims.

**Contributors**

James Hughes, Oculus
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**Contacts**

Paul Pedriana, Oculus
Cass Everitt, Oculus

**Overview**

This extension adds an additional layer type where the XR runtime must map a texture stemming from a swapchain onto the inside of a cylinder section. It can be imagined much the same way a curved television display looks to a viewer. This is not a projection type of layer but rather an object-in-world type of layer, similar to XrCompositionLayerQuad. Only the interior of the cylinder surface must be visible; the exterior of the cylinder is not visible and must not be drawn by the runtime.

The cylinder characteristics are specified by the following parameters:
XrPosef pose;
float radius;
float centralAngle;
float aspectRatio;

These can be understood via the following diagram, which is a top-down view of a horizontally oriented cylinder. The aspect ratio drives how tall the cylinder will appear based on the other parameters. Typically the aspectRatio would be set to be the aspect ratio of the texture being used, so that it looks the same within the cylinder as it does in 2D.

Figure 4. Cylinder Layer Parameters

- \( r \) — Radius
- \( a \) — Central angle in \((0, 2\pi)\)
- \( p \) — Origin of pose transform
- \( U/V \) — UV coordinates

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_COMPOSITION_LAYER_CYLINDER_KHR

New Enums
New Structures

The `XrCompositionLayerCylinderKHR` structure is defined as:

```c
typedef struct XrCompositionLayerCylinderKHR {
    XrStructureType            type;
    const void*                next;
    XrCompositionLayerFlags    layerFlags;
    XrSpace                    space;
    XrEyeVisibility            eyeVisibility;
    XrSwapchainSubImage        subImage;
    XrPosef                    pose;
    float                      radius;
    float                      centralAngle;
    float                      aspectRatio;
} XrCompositionLayerCylinderKHR;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **layerFlags** specifies options for the layer.
- **space** is the `XrSpace` in which the **pose** of the cylinder layer is evaluated over time.
- **eye** is the eye represented by this layer.
- **subImage** identifies the image `XrSwapchainSubImage` to use.
- **pose** is an `XrPosef` defining the position and orientation of the center point of the view of the cylinder within the reference frame of the **space**.
- **radius** is the non-negative radius of the cylinder. Values of zero or floating point positive infinity are treated as an infinite cylinder.
- **centralAngle** is the angle of the visible section of the cylinder, based at 0 radians, in the range of [0, 2\(\pi\)). It grows symmetrically around the 0 radian angle.
- **aspectRatio** is the ratio of the visible cylinder section width / height. The height of the cylinder is given by: (cylinder radius \(\times\) cylinder angle) / aspectRatio.

`XrCompositionLayerCylinderKHR` contains the information needed to render a texture onto a cylinder when calling `xrEndFrame`. `XrCompositionLayerCylinderKHR` is an alias type for the base struct `XrCompositionLayerBaseHeader` used in `XrFrameEndInfo`. 
Valid Usage (Implicit)

- The XR_KHR_composition_layer_cylinder extension must be enabled prior to using XrCompositionLayerCylinderKHR
- type must be XR_TYPE_COMPOSITION_LAYER_CYLINDER_KHR
- next must be NULL or a valid pointer to the next structure in a structure chain
- layerFlags must be 0 or a valid combination of XrCompositionLayerFlagBits values
- space must be a valid XrSpace handle
- eyeVisibility must be a valid XrEyeVisibility value
- subImage must be a valid XrSwapchainSubImage structure

New Functions

Issues

Version History

- Revision 1, 2017-05-19 (Paul Pedriana)
  - Initial version. This was originally part of a single extension which supported multiple such extension layer types.
- Revision 2, 2017-12-07 (Paul Pedriana)
  - Updated to use transform components instead of transform matrices.
- Revision 3, 2018-03-05 (Paul Pedriana)
  - Added improved documentation and brought the documentation in line with the existing core spec.
- Revision 4, 2019-01-24 (Martin Renschler)
  - Reformatted, spec language changes, eye parameter description update

12.8. XR_KHR_composition_layer_depth

Name String

XR_KHR_composition_layer_depth

Extension Type

Instance extension

Registered Extension Number

11
Overview

This extension defines an extra layer type which allows applications to submit depth images along with color images in projection layers, i.e. `XrCompositionLayerProjection`.

The XR runtime may use this information to perform more accurate reprojections taking depth into account. Use of this extension does not affect the order of layer composition as described in Compositing.

New Object Types

New Enum Constants

`XrStructureType` enumeration is extended with:

- `XR_TYPE_COMPOSITION_LAYER_DEPTH_INFO_KHR`

New Enums

New Structures

When submitting depth images along with projection layers, add the `XrCompositionLayerDepthInfoKHR` to the `next` chain for all `XrCompositionLayerProjectionView` structures in the given layer.

The `XrCompositionLayerDepthInfoKHR` structure is defined as:
typedef struct XrCompositionLayerDepthInfoKHR {
    XrStructureType        type;
    const void*            next;
    XrSwapchainSubImage    subImage;
    float                  minDepth;
    float                  maxDepth;
    float                  nearZ;
    float                  farZ;
} XrCompositionLayerDepthInfoKHR;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **subImage** identifies the depth image XrSwapchainSubImage to be associated with the color swapchain.
- **minDepth** and **maxDepth** are the window space depths that correspond to the near and far frustum planes, respectively. **minDepth** must be less than **maxDepth**. **minDepth** and **maxDepth** must be in the range [0, 1].
- **nearZ** and **farZ** are the positive distances in meters to the near and far frustum planes, respectively. **nearZ** and **farZ** must not be equal. **nearZ** and **farZ** must be in the range (0, +infinity].

**Note**

The window space depth values **minDepth** and **maxDepth** are akin to the parameters of glDepthRange that specify the mapping from normalized device coordinates into window space.

**Note**

A reversed mapping of depth, such that points closer to the view have a window space depth that is greater than points further away can be achieved by making **nearZ** > **farZ**.

**XrCompositionLayerDepthInfoKHR** contains the information needed to associate depth with the color information in a projection layer. When submitting depth images along with projection layers, add the **XrCompositionLayerDepthInfoKHR** to the **next** chain for all XrCompositionLayerProjectionView structures in the given layer.

The homogeneous transform from view space z to window space depth is given by the following matrix, where a = minDepth, b = maxDepth, n = nearZ, and f = farZ.
\[
T = \begin{bmatrix}
  b - a & a \\
  0 & 1
\end{bmatrix} \begin{bmatrix}
  -
  \frac{f}{f-n} & -\frac{fn}{f-n} \\
  -1 & 0
\end{bmatrix} = \begin{bmatrix}
  -\frac{bf-an}{f-n} & -\frac{fn(b-a)}{f-n} \\
  -1 & 0
\end{bmatrix}
\]

\[p_w = Tp_v\]

\[p_w = [z_w \ w_w]^t, \text{ homogeneous window space depth}\]

\[p_v = [z_v \ w_v]^t, \text{ homogeneous view space depth}\]

*Figure 5. Homogeneous transform from view space to window space depth*

Homogeneous values are constructed from real values by appending a \(w\) component with value 1.0.

General homogeneous values are projected back to real space by dividing by the \(w\) component.

---

### Valid Usage (Implicit)

- The \texttt{XR_KHR_composition_layer_depth} extension \textbf{must} be enabled prior to using \texttt{XrCompositionLayerDepthInfoKHR}

- \texttt{type} \textbf{must} be \texttt{XR_TYPE_COMPOSITION_LAYER_DEPTH_INFO_KHR}

- \texttt{next} \textbf{must} be \texttt{NULL} or a valid pointer to the \texttt{next} structure in a structure chain

- \texttt{subImage} \textbf{must} be a valid \texttt{XrSwapchainSubImage} structure

---

### New Functions

### Issues

1. Should the range of \texttt{minDepth} and \texttt{maxDepth} be constrained to \([0,1]\)?

   **RESOLVED:** Yes.

   There is no compelling mathematical reason for this constraint, however, it does not impose any hardship currently, and the constraint could be relaxed in a future version of the extension if needed.

2. Should we require \texttt{minDepth} be less than \texttt{maxDepth}?

   **RESOLVED:** Yes.

   There is no compelling mathematical reason for this constraint, however, it does not impose any
hardship currently, and the constraint could be relaxed in a future version of the extension if needed. Reverse z mappings can be achieved by making $\text{near} Z > \text{far} Z$.

3. Does this extension support view space depth images?

**RESOLVED**: No.

The formulation of the transform between view and window depths implies projected depth. A different extension would be needed to support a different interpretation of depth.

4. Is there any constraint on the resolution of the depth subimage?

**RESOLVED**: No.

The resolution of the depth image need not match that of the corresponding color image.

**Version History**

- Revision 1, 2017-08-18 (Paul Pedriana)
  - Initial proposal.
- Revision 2, 2017-10-30 (Kaye Mason)
  - Migration from Images to Swapchains.
- Revision 3, 2018-07-20 (Bryce Hutchings)
  - Support for swapchain texture arrays
- Revision 4, 2018-12-17 (Andreas Loeve Selvik)
  - depthImageRect in pixels instead of UVs
- Revision 5, 2019-01-24 (Martin Renschler)
  - changed depthSwapchain/depthImageRect/depthImageArrayIndex to XrSwapchainSubImage
  - reformat and spec language changes
  - removed vendor specific terminology
- Revision 6, 2022-02-16 (Cass Everitt)
  - Provide homogeneous transform as function of provided parameters

**12.9. XR_KHR_composition_layer_equirect**

**Name String**

XR_KHR_composition_layer_equirect

**Extension Type**

Instance extension
Overview

This extension adds an additional layer type where the XR runtime must map an equirectangular coded image stemming from a swapchain onto the inside of a sphere.

The equirect layer type provides most of the same benefits as a cubemap, but from an equirect 2D image source. This image source is appealing mostly because equirect environment maps are very common, and the highest quality you can get from them is by sampling them directly in the compositor.

This is not a projection type of layer but rather an object-in-world type of layer, similar to XrCompositionLayerQuad. Only the interior of the sphere surface must be visible; the exterior of the sphere is not visible and must not be drawn by the runtime.

New Object Types

New Flag Types

New Enum Constants
XrStructureType enumeration is extended with:

- XR_TYPE_COMPOSITION_LAYER_EQUIRECT_KHR

**New Enums**

**New Structures**

The XrCompositionLayerEquirectKHR structure is defined as:

```c
typedef struct XrCompositionLayerEquirectKHR {
    XrStructureType            type;
    const void*                next;
    XrCompositionLayerFlags    layerFlags;
    XrSpace                    space;
    XrEyeVisibility            eyeVisibility;
    XrSwapchainSubImage        subImage;
    XrPosef                    pose;
    float                      radius;
    XrVector2f                 scale;
    XrVector2f                 bias;
} XrCompositionLayerEquirectKHR;
```

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **layerFlags** specifies options for the layer.
- **space** is the XrSpace in which the pose of the equirect layer is evaluated over time.
- **eye** is the eye represented by this layer.
- **subImage** identifies the image XrSwapchainSubImage to use.
- **pose** is an XrPosef defining the position and orientation of the center point of the sphere onto which the equirect image data is mapped, relative to the reference frame of the space.
- **radius** is the non-negative radius of the sphere onto which the equirect image data is mapped. Values of zero or floating point positive infinity are treated as an infinite sphere.
- **scale** is an XrVector2f indicating a scale of the texture coordinates after the mapping to 2D.
- **bias** is an XrVector2f indicating a bias of the texture coordinates after the mapping to 2D.
XrCompositionLayerEquirectKHR contains the information needed to render an equirectangular image onto a sphere when calling xrEndFrame. XrCompositionLayerEquirectKHR is an alias type for the base struct XrCompositionLayerBaseHeader used in XrFrameEndInfo.

Valid Usage (Implicit)

- The XR_KHR_composition_layer_equirect extension must be enabled prior to using XrCompositionLayerEquirectKHR
- type must be XR_TYPE_COMPOSITION_LAYER_EQUIRECT_KHR
- next must be NULL or a valid pointer to the next structure in a structure chain
- layerFlags must be 0 or a valid combination of XrCompositionLayerFlagBits values
- space must be a valid XrSpace handle
- eyeVisibility must be a valid XrEyeVisibility value
- subImage must be a valid XrSwapchainSubImage structure

New Functions

Issues

Version History

- Revision 1, 2017-05-19 (Paul Pedriana)
  - Initial version. This was originally part of a single extension which supported multiple such extension layer types.
- Revision 2, 2017-12-07 (Paul Pedriana)
  - Updated to use transform components instead of transform matrices.
- Revision 3, 2019-01-24 (Martin Renschler)
  - Reformatted, spec language changes, eye parameter description update

12.10. XR_KHR_composition_layer_equirect2

Name String

XR_KHR_composition_layer_equirect2

Extension Type

Instance extension

Registered Extension Number

92
Overview

This extension adds an additional layer type where the XR runtime must map an equirectangular coded image stemming from a swapchain onto the inside of a sphere.

The equirect layer type provides most of the same benefits as a cubemap, but from an equirect 2D image source. This image source is appealing mostly because equirect environment maps are very common, and the highest quality you can get from them is by sampling them directly in the compositor.

This is not a projection type of layer but rather an object-in-world type of layer, similar to XrCompositionLayerQuad. Only the interior of the sphere surface must be visible; the exterior of the sphere is not visible and must not be drawn by the runtime.

This extension uses a different parameterization more in keeping with the formulation of KHR_composition_layer_cylinder but is functionally equivalent to KHR_composition_layer_equirect.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:
New Enums

New Structures

The **XrCompositionLayerEquirect2KHR** structure is defined as:

```c
typedef struct XrCompositionLayerEquirect2KHR {
    XrStructureType            type;
    const void*                next;
    XrCompositionLayerFlags    layerFlags;
    XrSpace                    space;
    XrEyeVisibility            eyeVisibility;
    XrSwapchainSubImage        subImage;
    XrPosef                    pose;
    float                      radius;
    float                      centralHorizontalAngle;
    float                      upperVerticalAngle;
    float                      lowerVerticalAngle;
} XrCompositionLayerEquirect2KHR;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **layerFlags** specifies options for the layer.
- **space** is the XrSpace in which the pose of the equirect layer is evaluated over time.
- **eye** is the eye represented by this layer.
- **subImage** identifies the image XrSwapchainSubImage to use.
- **pose** is an XrPosef defining the position and orientation of the center point of the sphere onto which the equirect image data is mapped, relative to the reference frame of the space.
- **radius** is the non-negative radius of the sphere onto which the equirect image data is mapped. Values of zero or floating point positive infinity are treated as an infinite sphere.
- **centralHorizontalAngle** defines the visible horizontal angle of the sphere, based at 0 radians, in the range of [0, 2π]. It grows symmetrically around the 0 radian angle.
- **upperVerticalAngle** defines the upper vertical angle of the visible portion of the sphere, in the range of [-π/2, π/2].
- **lowerVerticalAngle** defines the lower vertical angle of the visible portion of the sphere, in the range of [-π/2, π/2].

XrCompositionLayerEquirect2KHR contains the information needed to render an equirectangular image onto a sphere when calling xrEndFrame. XrCompositionLayerEquirect2KHR is an alias type for the base struct XrCompositionLayerBaseHeader used in XrFrameEndInfo.

Valid Usage (Implicit)

- The XR_KHR_composition_layer_equirect2 extension must be enabled prior to using XrCompositionLayerEquirect2KHR
- **type** must be XR_TYPE_COMPOSITION_LAYER_EQUIRECT2_KHR
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **layerFlags** must be 0 or a valid combination of XrCompositionLayerFlagBits values
- **space** must be a valid XrSpace handle
- **eyeVisibility** must be a valid XrEyeVisibility value
- **subImage** must be a valid XrSwapchainSubImage structure

New Functions
Issues

Version History

• Revision 1, 2020-05-08 (Cass Everitt)
  ◦ Initial version.
  ◦ Kept contributors from the original equirect extension.

12.11. XR_KHR_convert_timespec_time

Name String

XR_KHR_convert_timespec_time

Extension Type

Instance extension

Registered Extension Number

37

Revision

1

Extension and Version Dependencies

• Requires OpenXR 1.0

Last Modified Date

2019-01-24

IP Status

No known IP claims.

Contributors

Paul Pedriana, Oculus

Overview

This extension provides two functions for converting between timespec monotonic time and XrTime. The xrConvertTimespecTimeToTimeKHR function converts from timespec time to XrTime, while the xrConvertTimeToTimespecTimeKHR function converts XrTime to timespec monotonic time. The primary use case for this functionality is to be able to synchronize events between the local system and the OpenXR system.

New Object Types

New Flag Types
New Enum Constants

New Enums

New Structures

New Functions

To convert from timespec monotonic time to \texttt{XrTime}, call:

\begin{verbatim}
XrResult xrConvertTimespecTimeToTimeKHR(
    XrInstance instance,
    const struct timespec* timespecTime,
    XrTime* time);
\end{verbatim}

\begin{center}
\textbf{Parameter Descriptions}
\end{center}

- \texttt{instance} is an \texttt{XrInstance} handle previously created with \texttt{xrCreateInstance}.
- \texttt{timespecTime} is a \texttt{timespec} obtained from \texttt{clock_gettime} with \texttt{CLOCK_MONOTONIC}.
- \texttt{time} is the resulting \texttt{XrTime} that is equivalent to the \texttt{timespecTime}.

The \texttt{xrConvertTimespecTimeToTimeKHR} function converts a time obtained by the \texttt{clock_gettime} function to the equivalent \texttt{XrTime}.

If the output \texttt{time} cannot represent the input \texttt{timespecTime}, the runtime \textbf{must} return \texttt{XR_ERROR_TIME_INVALID}.

\begin{center}
\textbf{Valid Usage (Implicit)}
\end{center}

- The \texttt{XR_KHR_convert_timespec_time} extension \textbf{must} be enabled prior to calling \texttt{xrConvertTimespecTimeToTimeKHR}.
- \texttt{instance} \textbf{must} be a valid \texttt{XrInstance} handle.
- \texttt{timespecTime} \textbf{must} be a pointer to a valid \texttt{timespec} value.
- \texttt{time} \textbf{must} be a pointer to an \texttt{XrTime} value.
Return Codes

Success

- XR_SUCCESS

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_TIME_INVALID

To convert from XrTime to timespec monotonic time, call:

```c
XrResult xrConvertTimeToTimespecTimeKHR(
    XrInstance instance,
    XrTime time,
    struct timespec* timespecTime);
```

Parameter Descriptions

- `instance` is an XrInstance handle previously created with `xrCreateInstance`.
- `time` is an XrTime.
- `timespecTime` is the resulting timespec time that is equivalent to a timespec obtained from `clock_gettime` with CLOCK_MONOTONIC.

The `xrConvertTimeToTimespecTimeKHR` function converts an XrTime to time as if generated by `clock_gettime`.

If the output `timespecTime` cannot represent the input `time`, the runtime must return `XR_ERROR_TIME_INVALID`.
Valid Usage (Implicit)

- The XR_KHR_convert_timespec_time extension must be enabled prior to calling xrConvertTimeToTimespecTimeKHR
- instance must be a valid XrInstance handle
- timespecTime must be a pointer to a timespec value

Return Codes

Success

- XR_SUCCESS

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_TIME_INVALID

Issues

Version History

- Revision 1, 2019-01-24 (Paul Pedriana)
  - Initial draft

12.12. XR_KHR_D3D11_enable

Name String

XR_KHR_D3D11_enable

Extension Type

Instance extension

Registered Extension Number

28
Overview

This extension enables the use of the D3D11 graphics API in an OpenXR runtime. Without this extension, the OpenXR runtime may not be able to use any D3D11 swapchain images.

This extension provides the mechanisms necessary for an application to generate a valid \texttt{XrGraphicsBindingD3D11KHR} structure in order to create a D3D11-based \texttt{XrSession}. Note that during this process the application is responsible for creating all the required D3D11 objects, including a graphics device to be used for rendering.

This extension also provides mechanisms for the application to interact with images acquired by calling \texttt{xrEnumerateSwapchainImages}.

In order to expose the structures, types, and functions of this extension, you must define \texttt{XR_USE_GRAPHICS_API_D3D11} before including the OpenXR platform header \texttt{openxr_platform.h}, in all portions of your library or application that include it. **Swapchain Flag Bits**

All \texttt{XrSwapchainUsageFlags} values passed in a session created using \texttt{XrGraphicsBindingD3D11KHR} must be interpreted as follows by the runtime, so that the returned swapchain images used by the application may be used as if they were created with the corresponding D3D11\_BIND\_FLAG flags. The runtime may set additional bind flags but must not restrict usage.

<table>
<thead>
<tr>
<th>\texttt{XrSwapchainUsageFlagBits}</th>
<th>Corresponding D3D11 bind flag bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{XR_SWAPCHAIN_USAGE_COLOR_ATTACHMENT_BIT}</td>
<td>\texttt{D3D11_BIND_RENDER_TARGET}</td>
</tr>
<tr>
<td>\texttt{XR_SWAPCHAIN_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT}</td>
<td>\texttt{D3D11_BIND_DEPTH_STENCIL}</td>
</tr>
<tr>
<td>\texttt{XR_SWAPCHAIN_USAGE_UNORDERED_ACCESS_BIT}</td>
<td>\texttt{D3D11_BIND_UNORDERED_ACCESS}</td>
</tr>
</tbody>
</table>
### New Object Types

### New Flag Types

### New Enum Constants

The `XrStructureType` enumeration is extended with:

- `XR_TYPE_GRAPHICS_REQUIREMENTS_D3D11_KHR`
- `XR_TYPE_GRAPHICS_BINDING_D3D11_KHR`
- `XR_TYPE_SWAPCHAIN_IMAGE_D3D11_KHR`

### New Enums

### New Structures

The following structures are provided to supply supporting runtimes the necessary information required to work with the D3D11 API executing on certain operating systems.

The `XrGraphicsBindingD3D11KHR` structure is defined as:

```c
typedef struct XrGraphicsBindingD3D11KHR {
    XrStructureType    type;
    const void*        next;
    ID3D11Device*      device;
} XrGraphicsBindingD3D11KHR;
```
Member Descriptions

• **type** is the `XrStructureType` of this structure.

• **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

• **device** is a pointer to a valid `ID3D11Device` to use.

When creating a D3D11-backed `XrSession`, the application will provide a pointer to an `XrGraphicsBindingD3D11KHR` in the `XrSessionCreateInfo::next` field of structure passed to `xrCreateSession`. The D3D11 device specified in `XrGraphicsBindingD3D11KHR::device` must be created in accordance with the requirements retrieved through `xrGetD3D11GraphicsRequirementsKHR`, otherwise `xrCreateSession` must return `XR_ERROR_GRAPHICS_DEVICE_INVALID`.

Valid Usage (Implicit)

• The `XR_KHR_D3D11_enable` extension must be enabled prior to using `XrGraphicsBindingD3D11KHR`

• **type** must be `XR_TYPE_GRAPHICS_BINDING_D3D11_KHR`

• **next** must be `NULL` or a valid pointer to the next structure in a structure chain

• **device** must be a pointer to an `ID3D11Device` value

The `XrSwapchainImageD3D11KHR` structure is defined as:

```c
typedef struct XrSwapchainImageD3D11KHR {
    XrStructureType    type;
    void*               next;
    ID3D11Texture2D*    texture;
} XrSwapchainImageD3D11KHR;
```

Member Descriptions

• **type** is the `XrStructureType` of this structure.

• **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

• **texture** is a pointer to a valid `ID3D11Texture2D` to use.
If a given session was created with `XrGraphicsBindingD3D11KHR`, the following conditions **must** apply.

- Calls to `xrEnumerateSwapchainImages` on an `XrSwapchain` in that session **must** return an array of `XrSwapchainImageD3D11KHR` structures.
- Whenever an OpenXR function accepts an `XrSwapchainImageBaseHeader` pointer as a parameter in that session, the runtime **must** also accept a pointer to an `XrSwapchainImageD3D11KHR`.

The OpenXR runtime **must** interpret the top-left corner of the swapchain image as the coordinate origin unless specified otherwise by extension functionality.

The OpenXR runtime **must** interpret the swapchain images in a clip space of positive Y pointing up, near Z plane at 0, and far Z plane at 1.

### Valid Usage (Implicit)

- The `XR_KHR_D3D11_enable` extension **must** be enabled prior to using `XrSwapchainImageD3D11KHR`
- `type` **must** be `XR_TYPE_SWAPCHAIN_IMAGE_D3D11_KHR`
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain
- `texture` **must** be a pointer to an `ID3D11Texture2D` value

The `XrGraphicsRequirementsD3D11KHR` structure is defined as:

```c
typedef struct XrGraphicsRequirementsD3D11KHR {
    XrStructureType      type;
    void*                next;
    LUID                 adapterLuid;
    D3D_FEATURE_LEVEL    minFeatureLevel;
} XrGraphicsRequirementsD3D11KHR;
```

### Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `adapterLuid` identifies what graphics device needs to be used.
- `minFeatureLevel` is the minimum feature level that the D3D11 device must be initialized with.
XrGraphicsRequirementsD3D11KHR is populated by xrGetD3D11GraphicsRequirementsKHR.

**Valid Usage (Implicit)**

- The `XR_KHR_D3D11_enable` extension must be enabled prior to using XrGraphicsRequirementsD3D11KHR
- `type` must be `XR_TYPE_GRAPHICS_REQUIREMENTS_D3D11_KHR`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `adapterLuid` must be a valid `LUID` value
- `minFeatureLevel` must be a valid `D3D_FEATURE_LEVEL` value

**New Functions**

Some computer systems may have multiple graphics devices, each of which may have independent external display outputs. XR systems that connect to such graphics devices are typically connected to a single device. Applications need to know what graphics device the XR system is connected to so that they can use that graphics device to generate XR images.

To retrieve the D3D11 feature level and graphics device for an instance and system, call:

```c
XrResult xrGetD3D11GraphicsRequirementsKHR(
    XrInstance instance,
    XrSystemId systemId,
    XrGraphicsRequirementsD3D11KHR* graphicsRequirements);
```

**Parameter Descriptions**

- `instance` is an `XrInstance` handle previously created with `xrCreateInstance`.
- `systemId` is an `XrSystemId` handle for the system which will be used to create a session.
- `graphicsRequirements` is the `XrGraphicsRequirementsD3D11KHR` output structure.

The `xrGetD3D11GraphicsRequirementsKHR` function identifies to the application what graphics device (Windows LUID) needs to be used and the minimum feature level to use. The runtime must return `XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING` (`XR_ERROR_VALIDATION_FAILURE` may be returned due to legacy behavior) on calls to `xrCreateSession` if `xrGetD3D11GraphicsRequirementsKHR` has not been called for the same `instance` and `systemId`. The LUID and feature level that `xrGetD3D11GraphicsRequirementsKHR` returns must be used to create the `ID3D11Device` that the application passes to `xrCreateSession` in the `XrGraphicsBindingD3D11KHR`.
Valid Usage (Implicit)

- The XR_KHR_D3D11_enable extension must be enabled prior to calling xrGetD3D11GraphicsRequirementsKHR
- instance must be a valid XrInstance handle
- graphicsRequirements must be a pointer to an XrGraphicsRequirementsD3D11KHR structure

Return Codes

Success

- XR_SUCCESS

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SYSTEM_INVALID

Issues

Version History

- Revision 1, 2018-05-07 (Mark Young)
  ◦ Initial draft
- Revision 2, 2018-06-21 (Bryce Hutchings)
  ◦ Split XR_KHR_D3D_enable into XR_KHR_D3D11_enable
  ◦ Rename and expand xrGetD3DGraphicsDeviceKHR functionality to xrGetD3D11GraphicsRequirementsKHR
- Revision 3, 2018-11-15 (Paul Pedriana)
  ◦ Specified the swapchain texture coordinate origin.
- Revision 4, 2018-11-16 (Minmin Gong)
  ◦ Specified Y direction and Z range in clip space
- Revision 5, 2020-08-06 (Bryce Hutchings)
  ◦ Added new XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING error code
12.13. XR_KHR_D3D12_enable

Name String

XR_KHR_D3D12_enable

Extension Type

Instance extension

Registered Extension Number

29

Revision

9

Extension and Version Dependencies

• Requires OpenXR 1.0

Last Modified Date

2020-03-18

IP Status

No known IP claims.

Contributors

Bryce Hutchings, Microsoft
Paul Pedriana, Oculus
Mark Young, LunarG
Minmin Gong, Microsoft
Dan Ginsburg, Valve
Matthieu Bucchianeri, Microsoft

Overview

This extension enables the use of the D3D12 graphics API in an OpenXR runtime. Without this extension, the OpenXR runtime may not be able to use any D3D12 swapchain images.

This extension provides the mechanisms necessary for an application to generate a valid XRGraphicsBindingD3D12KHR structure in order to create a D3D12-based XrSession. Note that during this process the application is responsible for creating all the required D3D12 objects, including a
This extension also provides mechanisms for the application to interact with images acquired by calling `xrEnumerateSwapchainImages`.

In order to expose the structures, types, and functions of this extension, you **must** define `XR_USE_GRAPHICS_API_D3D12` before including the OpenXR platform header `openxr_platform.h`, in all portions of your library or application that include it.

### Swapchain Image Resource State

When an application acquires a swapchain image by calling `xrAcquireSwapchainImage` in a session create using `XrGraphicsBindingD3D12KHR`, the OpenXR runtime **must** guarantee that:

- The color rendering target image has a resource state match with `D3D12_RESOURCE_STATE_RENDER_TARGET`
- The depth rendering target image has a resource state match with `D3D12_RESOURCE_STATE_DEPTH_WRITE`
- The `ID3D12CommandQueue` specified in `XrGraphicsBindingD3D12KHR` can write to the image.

When an application releases a swapchain image by calling `xrReleaseSwapchainImage`, in a session create using `XrGraphicsBindingD3D12KHR`, the OpenXR runtime **must** interpret the image as:

- Having a resource state match with `D3D12_RESOURCE_STATE_RENDER_TARGET` if the image is a color rendering target
- Having a resource state match with `D3D12_RESOURCE_STATE_DEPTH_WRITE` if the image is a depth rendering target
- Being available for read/write on the `ID3D12CommandQueue` specified in `XrGraphicsBindingD3D12KHR`.

The application is responsible for transitioning the swapchain image back to the resource state and queue availability that the OpenXR runtime requires. If the image is not in a resource state match with the above specifications the runtime **may** exhibit undefined behavior.

All `XrSwapchainUsageFlags` values passed in a session created using `XrGraphicsBindingD3D12KHR` **must** be interpreted as follows by the runtime, so that the returned swapchain images used by the application may be used as if they were created with the corresponding D3D12_BIND_FLAG flags and heap type. The runtime **may** set additional resource flags but **must** not restrict usage.

<table>
<thead>
<tr>
<th><code>XrSwapchainUsageFlagBits</code></th>
<th>Corresponding D3D12 resource flag bits</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_COLOR_ATTACHMENT_BIT</code></td>
<td><code>D3D12_RESOURCE_FLAG_ALLOW_RENDER_TARGET</code></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT</code></td>
<td><code>D3D12_RESOURCE_FLAG_ALLOW_DEPTH_STENCIL</code></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_UNORDERED_ACCESS_BIT</code></td>
<td><code>D3D12_RESOURCE_FLAG_ALLOW_UNORDERED_ACCESS</code></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_TRANSFER_SRC_BIT</code></td>
<td>ignored</td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_TRANSFER_DST_BIT</code></td>
<td>ignored</td>
</tr>
<tr>
<td><strong>XrSwapchainUsageFlagBits</strong></td>
<td><strong>Corresponding D3D12 resource flag bits</strong></td>
</tr>
<tr>
<td>-----------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_SAMPLED_BIT <strong>omitted</strong></td>
<td>D3D12_RESOURCE_FLAG_DENY_SHADER_RESOURCE</td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_MUTABLE_FORMAT_BIT</td>
<td><strong>ignored</strong></td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_KHR (Added by XR_KHR_swapchain_usage_input_attachment_bit and only available when that extension is enabled)</td>
<td><strong>ignored</strong></td>
</tr>
</tbody>
</table>

All D3D12 swapchain textures are created with D3D12_HEAP_TYPE_DEFAULT usage.

New Object Types

New Flag Types

New Enum Constants

**XrStructureType** enumeration is extended with:

- XR_TYPE_GRAPHICS_REQUIREMENTS_D3D12_KHR
- XR_TYPE_GRAPHICS_BINDING_D3D12_KHR
- XR_TYPE_SWAPCHAIN_IMAGE_D3D12_KHR

New Enums

New Structures

The following structures are provided to supply supporting runtimes the necessary information required to work with the D3D12 API executing on certain operating systems.

The **XrGraphicsBindingD3D12KHR** structure is defined as:

```c
typedef struct XrGraphicsBindingD3D12KHR {
    XrStructureType        type;
    const void*            next;
    ID3D12Device*          device;
    ID3D12CommandQueue*    queue;
} XrGraphicsBindingD3D12KHR;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **device** is a pointer to a valid ID3D12Device to use.
- **queue** is a pointer to a valid ID3D12CommandQueue to use.

When creating a D3D12-backed XrSession, the application will provide a pointer to an XrGraphicsBindingD3D12KHR in the XrSessionCreateInfo::next field of structure passed to xrCreateSession. The D3D12 device specified in XrGraphicsBindingD3D12KHR::device must be created in accordance with the requirements retrieved through xrGetD3D12GraphicsRequirementsKHR, otherwise xrCreateSession must return XR_ERROR_GRAPHICS_DEVICE_INVALID.

Valid Usage (Implicit)

- The XR_KHR_D3D12_enable extension must be enabled prior to using XrGraphicsBindingD3D12KHR
- **type** must be XR_TYPE_GRAPHICS_BINDING_D3D12_KHR
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **device** must be a pointer to an ID3D12Device value
- **queue** must be a pointer to an ID3D12CommandQueue value

The XrSwapchainImageD3D12KHR structure is defined as:

```c
typedef struct XrSwapchainImageD3D12KHR {
    XrStructureType type;
    void* next;
    ID3D12Resource* texture;
} XrSwapchainImageD3D12KHR;
```
Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `texture` is a pointer to a valid `ID3D12Texture2D` to use.

If a given session was created with `XrGraphicsBindingD3D12KHR`, the following conditions **must** apply.

- Calls to `xrEnumerateSwapchainImages` on an `XrSwapchain` in that session **must** return an array of `XrSwapchainImageD3D12KHR` structures.
- Whenever an OpenXR function accepts an `XrSwapchainImageBaseHeader` pointer as a parameter in that session, the runtime **must** also accept a pointer to an `XrSwapchainImageD3D12KHR`.

The OpenXR runtime **must** interpret the top-left corner of the swapchain image as the coordinate origin unless specified otherwise by extension functionality.

The OpenXR runtime **must** interpret the swapchain images in a clip space of positive Y pointing up, near Z plane at 0, and far Z plane at 1.

Valid Usage (Implicit)

- The `XR_KHR_D3D12_enable` extension **must** be enabled prior to using `XrSwapchainImageD3D12KHR`
- `type` **must** be `XR_TYPE_SWAPCHAIN_IMAGE_D3D12_KHR`
- `next` **must** be `NULL` or a valid pointer to the `next` structure in a structure chain
- `texture` **must** be a pointer to an `ID3D12Resource` value

The `XrGraphicsRequirementsD3D12KHR` structure is defined as:

```c
typedef struct XrGraphicsRequirementsD3D12KHR {
    XrStructureType type;
    void* next;
    LUID adapterLuid;
    D3D_FEATURE_LEVEL minFeatureLevel;
} XrGraphicsRequirementsD3D12KHR;
```
Member Descriptions

• **type** is the XRStructureType of this structure.

• **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

• **adapterLuid** identifies what graphics device needs to be used.

• **minFeatureLevel** is the minimum feature level that the D3D12 device must be initialized with.

**XrGraphicsRequirementsD3D12KHR** is populated by **xrGetD3D12GraphicsRequirementsKHR**.

Valid Usage (Implicit)

• The **XR_KHR_D3D12_enable** extension must be enabled prior to using **XrGraphicsRequirementsD3D12KHR**

• **type** must be **XR_TYPE_GRAPHICS_REQUIREMENTS_D3D12_KHR**

• **next** must be NULL or a valid pointer to the next structure in a structure chain

• **adapterLuid** must be a valid LUID value

• **minFeatureLevel** must be a valid D3D_FEATURE_LEVEL value

New Functions

Some computer systems may have multiple graphics devices, each of which may have independent external display outputs. XR systems that connect to such graphics devices are typically connected to a single device. Applications need to know what graphics device the XR system is connected to so that they can use that graphics device to generate XR images.

To retrieve the D3D12 feature level and graphics device for an instance and system, call:

```c
XrResult xrGetD3D12GraphicsRequirementsKHR(
    XrInstance instance,
    XrSystemId systemId,
    XrGraphicsRequirementsD3D12KHR* graphicsRequirements);
```
Parameter Descriptions

- **instance** is an XrInstance handle previously created with `xrCreateInstance`.
- **systemId** is an XrSystemId handle for the system which will be used to create a session.
- **graphicsRequirements** is the XrGraphicsRequirementsD3D12KHR output structure.

The `xrGetD3D12GraphicsRequirementsKHR` function identifies to the application what graphics device (Windows LUID) needs to be used and the minimum feature level to use. The runtime **must** return XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING (XR_ERROR_VALIDATION_FAILURE **may** be returned due to legacy behavior) on calls to `xrCreateSession` if `xrGetD3D12GraphicsRequirementsKHR` has not been called for the same **instance** and **systemId**. The LUID and feature level that `xrGetD3D12GraphicsRequirementsKHR` returns **must** be used to create the ID3D12Device that the application passes to `xrCreateSession` in the XrGraphicsBindingD3D12KHR.

Valid Usage (Implicit)

- The **XR_KHR_D3D12_enable** extension **must** be enabled prior to calling `xrGetD3D12GraphicsRequirementsKHR`
- **instance** **must** be a valid XrInstance handle
- **graphicsRequirements** **must** be a pointer to an XrGraphicsRequirementsD3D12KHR structure

Return Codes

**Success**

- XR_SUCCESS

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SYSTEM_INVALID

Issues

Version History
• Revision 1, 2018-05-07 (Mark Young)
  ◦ Initial draft

• Revision 2, 2018-06-21 (Bryce Hutchings)
  ◦ Split XR_KHR_D3D_enable into XR_KHR_D3D12_enable
  ◦ Rename and expand xrGetD3DGraphicsDeviceKHR functionality to xrGetD3D12GraphicsRequirementsKHR

• Revision 3, 2018-11-15 (Paul Pedriana)
  ◦ Specified the swapchain texture coordinate origin.

• Revision 4, 2018-11-16 (Minmin Gong)
  ◦ Specified Y direction and Z range in clip space

• Revision 5, 2019-01-29 (Dan Ginsburg)
  ◦ Added swapchain image resource state details.

• Revision 6, 2020-03-18 (Minmin Gong)
  ◦ Specified depth swapchain image resource state.

• Revision 7, 2020-08-06 (Bryce Hutchings)
  ◦ Added new XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING error code

• Revision 8, 2021-09-09 (Bryce Hutchings)
  ◦ Document mapping for XrSwapchainUsageFlags

• Revision 9, 2021-12-28 (Matthieu Bucchianeri)
  ◦ Added missing XR_ERROR_GRAPHICS_DEVICE_INVALID error condition

12.14. XR_KHR_loader_init

Name String
  XR_KHR_loader_init

Extension Type
  Instance extension

Registered Extension Number
  89

Revision
  1

Extension and Version Dependencies
  • Requires OpenXR 1.0
Overview

On some platforms, before loading can occur the loader must be initialized with platform-specific parameters. Unlike other extensions, the presence of this extension is signaled by a successful call to `xrGetInstanceProcAddr` to retrieve the function pointer for `xrInitializeLoaderKHR` using a null instance handle. If this extension is supported, its use may be required on some platforms and the use of the `xrInitializeLoaderKHR` function must precede other OpenXR calls except `xrGetInstanceProcAddr`. This function exists as part of the loader library that the application is using.

New Object Types

New Flag Types

New Enum Constants

New Enums

New Structures

The `XrLoaderInitInfoBaseHeaderKHR` structure is defined as:

```c
typedef struct XrLoaderInitInfoBaseHeaderKHR {
    XrStructureType type;
    const void* next;
} XrLoaderInitInfoBaseHeaderKHR;
```

Member Descriptions

- `type` is the `XrStructureType` of this structure. This base structure itself has no associated `XrStructureType` value.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
Valid Usage (Implicit)

• The `XR_KHR_loader_init` extension must be enabled prior to using `XrLoaderInitInfoBaseHeaderKHR`

• `type` must be `XR_TYPE_LOADER_INIT_INFO_ANDROID_KHR`

• `next` must be `NULL` or a valid pointer to the next structure in a structure chain

New Functions

To initialize an OpenXR loader with platform or implementation-specific parameters, call:

```c
XrResult xrInitializeLoaderKHR(
    const XrLoaderInitInfoBaseHeaderKHR* loaderInitInfo);
```

Parameter Descriptions

• `loaderInitInfo` is a pointer to an `XrLoaderInitInfoBaseHeaderKHR` structure, which is a polymorphic type defined by other platform- or implementation-specific extensions.

Issues

Version History

• Revision 1, 2020-05-07 (Cass Everitt)
  ◦ Initial draft

12.15. XR_KHR_loader_init_android

Name String

`XR_KHR_loader_init_android`

Extension Type

Instance extension

Registered Extension Number

90

Revision

1
Extension and Version Dependencies

- Requires OpenXR 1.0
- Requires XR_KHR_loader_init

Last Modified Date

2020-05-07

IP Status

No known IP claims.

Contributors

Cass Everitt, Facebook

Overview

On Android, some loader implementations need the application to provide additional information on initialization. This extension defines the parameters needed by such implementations. If this is available on a given implementation, an application must make use of it.

On implementations where use of this is required, the following condition must apply:

- Whenever an OpenXR function accepts an XrLoaderInitInfoBaseHeaderKHR pointer, the runtime (and loader) must also accept a pointer to an XrLoaderInitInfoAndroidKHR.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_LOADER_INIT_INFO_ANDROID_KHR

New Enums

New Structures

The XrLoaderInitInfoAndroidKHR structure is defined as:
typedef struct XrLoaderInitInfoAndroidKHR {
    XrStructureType    type;
    const void*        next;
    void*              applicationVM;
    void*              applicationContext;
} XrLoaderInitInfoAndroidKHR;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **applicationVM** is a pointer to the JNI's opaque JavaVM structure, cast to a void pointer.
- **applicationContext** is a JNI reference to an android.content.Context associated with the application, cast to a void pointer.

Valid Usage (Implicit)

- The XR_KHR_loader_init_android extension must be enabled prior to using XrLoaderInitInfoAndroidKHR
- **type** must be XR_TYPE_LOADER_INIT_INFO_ANDROID_KHR
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **applicationVM** must be a pointer value
- **applicationContext** must be a pointer value

New Functions

Issues

Version History

- Revision 1, 2020-05-07 (Cass Everitt)
  - Initial draft

12.16. XR_KHR_opengl_enable

Name String

XR_KHR_opengl_enable
**Extension Type**

Instance extension

**Registered Extension Number**

24

**Revision**

10

**Extension and Version Dependencies**

- Requires OpenXR 1.0

**Last Modified Date**

2019-07-02

**IP Status**

No known IP claims.

**Contributors**

Mark Young, LunarG
Bryce Hutchings, Microsoft
Paul Pedriana, Oculus
Minmin Gong, Microsoft
Robert Menzel, NVIDIA
Jakob Bornecrantz, Collabora
Paulo Gomes, Samsung Electronics

**Overview**

This extension enables the use of the OpenGL graphics API in an OpenXR runtime. Without this extension, the OpenXR runtime may not be able to provide any OpenGL swapchain images.

This extension provides the mechanisms necessary for an application to generate a valid `XrGraphicsBindingOpenGL_KHR` structure in order to create an OpenGL-based `XrSession`. Note that during this process the application is responsible for creating an OpenGL context to be used for rendering. The runtime however will provide the OpenGL textures to render into in the form of a swapchain.

This extension provides mechanisms for the application to interact with images acquired by calling `xrEnumerateSwapchainImages`.

In order to expose the structures, types, and functions of this extension, the application must define `XR_USE_GRAPHICS_API_OPENGL`, as well as an appropriate window system define supported by this extension, before including the OpenXR platform header `openxr_platform.h`, in all portions of the library or application that include it. The window system defines currently supported by this extension are:
• XR_USE_PLATFORM_WIN32
• XR_USE_PLATFORM_XLIB
• XR_USE_PLATFORM_XCB
• XR_USE_PLATFORM_WAYLAND

Note that a runtime implementation of this extension is only required to support the structs introduced by this extension which belong to the platform it is running on.

Note that the OpenGL context given to the call `xrCreateSession` must not be bound in another thread when calling the functions: `xrCreateSession`, `xrDestroySession`, `xrBeginFrame`, `xrEndFrame`, `xrCreateSwapchain`, `xrDestroySwapchain`, `xrEnumerateSwapchainImages`, `xrAcquireSwapchainImage`, `xrWaitSwapchainImage` and `xrReleaseSwapchainImage`. It **may** be bound in the thread calling those functions. The runtime **must** not access the context from any other function. In particular the application must be able to call `xrWaitFrame` from a different thread than the rendering thread.

**Swapchain Flag Bits**

All `XrSwapchainUsageFlags` valid values passed in a session created using `XrGraphicsBindingOpenGLWin32KHR`, `XrGraphicsBindingOpenGLXlibKHR`, `XrGraphicsBindingOpenGLXcbKHR` or `XrGraphicsBindingOpenGLWaylandKHR` **should** be ignored as there is no mapping to OpenGL texture settings.

Note

In such a session, a runtime **may** use a supporting graphics API, such as Vulkan, to allocate images that are intended to alias with OpenGL textures, and be part of an `XrSwapchain`. A runtime which allocates the texture with a different graphics API **may** need to enable several usage flags on the underlying native texture resource to ensure compatibility with OpenGL.

**New Object Types**

**New Flag Types**

**New Enum Constants**

`XrStructureType` enumeration is extended with:

- `XR_TYPE_GRAPHICS_REQUIREMENTS_OPENGL_KHR`
- `XR_TYPE_GRAPHICS_BINDING_OPENGL_WIN32_KHR`
- `XR_TYPE_GRAPHICS_BINDING_OPENGL_XLIB_KHR`
- `XR_TYPE_GRAPHICS_BINDING_OPENGL_XCB_KHR`
- `XR_TYPE_GRAPHICS_BINDING_OPENGL_WAYLAND_KHR`
- `XR_TYPE_SWAPCHAIN_IMAGE_OPENGL_KHR`
New Enums

New Structures

The following structures are provided to supply supporting runtimes the necessary information required to work with the OpenGL API executing on certain operating systems.

These structures are only available when the corresponding XR_USE_PLATFORM_ macro is defined before including openxr_platform.h.

The XrGraphicsBindingOpenGLWin32KHR structure is defined as:

```c
typedef struct XrGraphicsBindingOpenGLWin32KHR {
    XrStructureType type;
    const void* next;
    HDC hDC;
    HGLRC hGLRC;
} XrGraphicsBindingOpenGLWin32KHR;
```

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **hDC** is a valid Windows HW device context handle.
- **hGLRC** is a valid Windows OpenGL rendering context handle.

When creating an OpenGL-backed XrSession on Microsoft Windows, the application will provide a pointer to an XrGraphicsBindingOpenGLWin32KHR in the next chain of the XrSessionCreateInfo. As no standardized way exists for OpenGL to create the graphics context on a specific GPU, the runtime must assume that the application uses the operating systems default GPU. If the GPU used by the runtime does not match the GPU on which the OpenGL context of the application got created, xrCreateSession must return XR_ERROR_GRAPHICS_DEVICE_INVALID.

The required window system configuration define to expose this structure type is XR_USE_PLATFORM_WIN32.
Valid Usage (Implicit)

- The `XR_KHR_opengl_enable` extension must be enabled prior to using `XrGraphicsBindingOpenGLWin32KHR`.
- `type` must be `XR_TYPE_GRAPHICS_BINDING_OPENGL_WIN32_KHR`.
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain.
- `hDC` must be a valid `HDC` value.
- `hGLRC` must be a valid `HGLRC` value.

The `XrGraphicsBindingOpenGLXlibKHR` structure is defined as:

```c
typedef struct XrGraphicsBindingOpenGLXlibKHR {
    XrStructureType type;
    const void* next;
    Display* xDisplay;
    uint32_t visualid;
    GLXFBConfig glxFBConfig;
    GLXDrawable glxDrawable;
    GLXContext glxContext;
} XrGraphicsBindingOpenGLXlibKHR;
```

Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `xDisplay` is a valid X11 `Display`.
- `visualid` is a valid X11 visual identifier.
- `glxFBConfig` is a valid X11 OpenGL GLX `GLXFBConfig`.
- `glxDrawable` is a valid X11 OpenGL GLX `GLXDrawable`.
- `glxContext` is a valid X11 OpenGL GLX `GLXContext`.

When creating an OpenGL-backed `XrSession` on any Linux/Unix platform that utilizes X11 and GLX, via the Xlib library, the application will provide a pointer to an `XrGraphicsBindingOpenGLXlibKHR` in the `next` chain of the `XrSessionCreateInfo`.

The required window system configuration define to expose this structure type is

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Valid Usage (Implicit)

- The XR_KHR_opengl_enable extension must be enabled prior to using XrGraphicsBindingOpenGLXlibKHR
- type must be XR_TYPE_GRAPHICS_BINDING_OPENGL_XLIB_KHR
- next must be NULL or a valid pointer to the next structure in a structure chain
- xDisplay must be a pointer to a Display value
- glxFBConfig must be a valid GLXFBConfig value
- glxDrawable must be a valid GLXDrawable value
- glxContext must be a valid GLXContext value

The XrGraphicsBindingOpenGLXcbKHR structure is defined as:

typedef struct XrGraphicsBindingOpenGLXcbKHR {
    XrStructureType       type;
    const void*           next;
    xcb_connection_t*     connection;
    uint32_t              screenNumber;
    xcb_glx_fbconfig_t    fbconfigid;
    xcb_visualid_t        visualid;
    xcb_glx_drawable_t    glxDrawable;
    xcb_glx_context_t     glxContext;
} XrGraphicsBindingOpenGLXcbKHR;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **connection** is a valid `xcb_connection_t`.
- **screenNumber** is an index indicating which screen should be used for rendering.
- **fbconfigid** is a valid XCB OpenGL GLX `xcb_glx_fbconfig_t`.
- **visualid** is a valid XCB OpenGL GLX `xcb_visualid_t`.
- **glxDrawable** is a valid XCB OpenGL GLX `xcb_glx_drawable_t`.
- **glxContext** is a valid XCB OpenGL GLX `xcb_glx_context_t`.

When creating an OpenGL-backed `XrSession` on any Linux/Unix platform that utilizes X11 and GLX, via the Xlib library, the application will provide a pointer to an `XrGraphicsBindingOpenGLXcbKHR` in the **next** chain of the `XrSessionCreateInfo`.

The required window system configuration define to expose this structure type is `XR_USE_PLATFORM_XCB`.

Valid Usage (Implicit)

- The `XR_KHR_opengl_enable` extension must be enabled prior to using `XrGraphicsBindingOpenGLXcbKHR`.
- **type** must be `XR_TYPE_GRAPHICS_BINDING_OPENGL_XCB_KHR`.
- **next** must be NULL or a valid pointer to the next structure in a structure chain.
- **connection** must be a pointer to an `xcb_connection_t` value.
- **fbconfigid** must be a valid `xcb_glx_fbconfig_t` value.
- **visualid** must be a valid `xcb_visualid_t` value.
- **glxDrawable** must be a valid `xcb_glx_drawable_t` value.
- **glxContext** must be a valid `xcb_glx_context_t` value.

The `XrGraphicsBindingOpenGLWaylandKHR` structure is defined as:
typedef struct XrGraphicsBindingOpenGLWaylandKHR {
    XrStructureType       type;
    const void*           next;
    struct wl_display*    display;
} XrGraphicsBindingOpenGLWaylandKHR;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **display** is a valid Wayland wl_display.

When creating an OpenGL-backed XrSession on any Linux/Unix platform that utilizes the Wayland protocol with its compositor, the application will provide a pointer to an XrGraphicsBindingOpenGLWaylandKHR in the next chain of the XrSessionCreateInfo.

The required window system configuration define to expose this structure type is XR_USE_PLATFORM_WAYLAND.

**Valid Usage (Implicit)**

- The XR_KHR_opengl_enable extension must be enabled prior to using XrGraphicsBindingOpenGLWaylandKHR
- **type** must be XR_TYPE_GRAPHICS_BINDING_OPENGL_WAYLAND_KHR
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **display** must be a pointer to a wl_display value

The XrSwapchainImageOpenGLKHR structure is defined as:

typedef struct XrSwapchainImageOpenGLKHR {
    XrStructureType type;
    void*           next;
    uint32_t        image;
} XrSwapchainImageOpenGLKHR;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **image** is the OpenGL texture handle associated with this swapchain image.

If a given session was created with a XrGraphicsBindingOpenGLKHR, the following conditions **must** apply.

- Calls to xrEnumerateSwapchainImages on an XrSwapchain in that session **must** return an array of XrSwapchainImageOpenGLKHR structures.
- Whenever an OpenXR function accepts an XrSwapchainImageBaseHeader pointer as a parameter in that session, the runtime **must** also accept a pointer to an XrSwapchainImageOpenGLKHR.

The OpenXR runtime **must** interpret the bottom-left corner of the swapchain image as the coordinate origin unless specified otherwise by extension functionality.

The OpenXR runtime **must** interpret the swapchain images in a clip space of positive Y pointing up, near Z plane at -1, and far Z plane at 1.

Valid Usage (Implicit)

- The XR_KHR_opengl_enable extension **must** be enabled prior to using XrSwapchainImageOpenGLKHR
- **type** **must** be XR_TYPE_SWAPCHAIN_IMAGE_OPENGL_KHR
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain

The XrGraphicsRequirementsOpenGLKHR structure is defined as:

typedef struct XrGraphicsRequirementsOpenGLKHR {
    XrStructureType    type;
    void*              next;
    XrVersion          minApiVersionSupported;
    XrVersion          maxApiVersionSupported;
} XrGraphicsRequirementsOpenGLKHR;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **minApiVersionSupported** is the minimum version of OpenGL that the runtime supports. Uses XR_MAKE_VERSION on major and minor API version, ignoring any patch version component.
- **maxApiVersionSupported** is the maximum version of OpenGL that the runtime has been tested on and is known to support. Newer OpenGL versions might work if they are compatible. Uses XR_MAKE_VERSION on major and minor API version, ignoring any patch version component.

XrGraphicsRequirementsOpenGLKHR is populated by xrGetOpenGLGraphicsRequirementsKHR with the runtime's OpenGL API version requirements.

Valid Usage (Implicit)

- The XR_KHR_opengl_enable extension must be enabled prior to using XrGraphicsRequirementsOpenGLKHR
- **type** must be XR_TYPE_GRAPHICS_REQUIREMENTS_OPENGL_KHR
- **next** must be NULL or a valid pointer to the next structure in a structure chain

New Functions

To query OpenGL API version requirements for an instance and system, call:

```c
XrResult xrGetOpenGLGraphicsRequirementsKHR(
    XrInstance instance,
    XrSystemId systemId,
    XrGraphicsRequirementsOpenGLKHR* graphicsRequirements);
```

Parameter Descriptions

- **instance** is an XrInstance handle previously created with xrCreateInstance.
- **systemId** is an XrSystemId handle for the system which will be used to create a session.
- **graphicsRequirements** is the XrGraphicsRequirementsOpenGLKHR output structure.

The xrGetOpenGLGraphicsRequirementsKHR function identifies to the application the minimum
OpenGL version requirement and the highest known tested OpenGL version. The runtime must return XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING (XR_ERROR_VALIDATION_FAILURE may be returned due to legacy behavior) on calls to xrCreateSession if xrGetOpenGLGraphicsRequirementsKHR has not been called for the same instance and systemId.

Valid Usage (Implicit)

- The XR_KHR_opengl_enable extension must be enabled prior to calling xrGetOpenGLGraphicsRequirementsKHR
- instance must be a valid XrInstance handle
- graphicsRequirements must be a pointer to an XrGraphicsRequirementsOpenGLKHR structure

Return Codes

Success

- XR_SUCCESS

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SYSTEM_INVALID

Issues

Version History

- Revision 1, 2018-05-07 (Mark Young)
  ◦ Initial draft
- Revision 2, 2018-06-21 (Bryce Hutchings)
  ◦ Add new xrGetOpenGLGraphicsRequirementsKHR
- Revision 3, 2018-11-15 (Paul Pedriana)
  ◦ Specified the swapchain texture coordinate origin.
- Revision 4, 2018-11-16 (Minmin Gong)
  ◦ Specified Y direction and Z range in clip space
12.17. XR_KHR_opengl_es_enable

Name String

XR_KHR_opengl_es_enable

Extension Type

Instance extension

Registered Extension Number

25

Revision

8

Extension and Version Dependencies

• Requires OpenXR 1.0

Last Modified Date

2019-07-12

IP Status

No known IP claims.

Contributors

Mark Young, LunarG
Bryce Hutchings, Microsoft
Paul Pedriana, Oculus
Overview

This extension must be provided by runtimes supporting applications using OpenGL ES APIs for rendering. OpenGL ES applications need this extension to obtain compatible swapchain images which the runtime is required to supply. The runtime needs the following OpenGL ES objects from the application in order to interact properly with the OpenGL ES driver: EGLDisplay, EGLConfig and EGLContext.

These are passed from the application to the runtime in a XrGraphicsBindingOpenGLESAndroidKHR structure when creating the XrSession. Although not restricted to Android, the OpenGL ES extension is currently tailored for Android.

Note that the application is responsible for creating the required OpenGL ES objects, including an OpenGL ES context to be used for rendering.

This extension also provides mechanisms for the application to interact with images acquired by calling xrEnumerateSwapchainImages.

In order to expose the structures, types, and functions of this extension, the application source code must define XR_USE_GRAPHICS_API_OPENGL_ES, as well as an appropriate window system define, before including the OpenXR platform header openxr_platform.h, in all portions of your library or application that include it. The only window system define currently supported by this extension is:

- XR_USE_PLATFORM_ANDROID

Swapchain Flag Bits

All XrSwapchainUsageFlags valid values passed in a session created using XrGraphicsBindingOpenGLESAndroidKHR should be ignored as there is no mapping to OpenGL ES texture settings.

Note

In such a session, a runtime may use a supporting graphics API, such as Vulkan, to allocate images that are intended to alias with OpenGLES textures, and be part of an XrSwapchain. A runtime which allocates the texture with a different graphics API may need to enable several usage flags on the underlying native texture resource to ensure compatibility with OpenGL ES.
New Enum Constants

**XrStructureType** enumeration is extended with:

- `XR_TYPE_GRAPHICS_REQUIREMENTS_OPENGL_ES_KHR`
- `XR_TYPE_GRAPHICS_BINDING_OPENGL_ES_ANDROID_KHR`
- `XR_TYPE_SWAPCHAIN_IMAGE_OPENGL_ES_KHR`

New Enums

New Structures

The following structures are provided to supply supporting runtimes the necessary information required to work with the OpenGL ES API executing on certain operating systems.

These structures are only available when the corresponding `XR_USE_PLATFORM_` macro is defined before including `openxr_platform.h`.

The **XrGraphicsBindingOpenGLESAndroidKHR** structure is defined as:

```c
typedef struct XrGraphicsBindingOpenGLESAndroidKHR {
    XrStructureType    type;
    const void*        next;
    EGLDisplay         display;
    EGLConfig          config;
    EGLContext         context;
} XrGraphicsBindingOpenGLESAndroidKHR;
```

**Member Descriptions**

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `display` is a valid Android OpenGL ES `EGLDisplay`.
- `config` is a valid Android OpenGL ES `EGLConfig`.
- `context` is a valid Android OpenGL ES `EGLContext`.

When creating an OpenGL ES-backed **XrSession** on Android, the application will provide a pointer to an **XrGraphicsBindingOpenGLESAndroidKHR** structure in the `next` chain of the **XrSessionCreateInfo**.

The required window system configuration define to expose this structure type is
Valid Usage (Implicit)

- The `XR_KHR_opengl_es_enable` extension must be enabled prior to using `XrGraphicsBindingOpenGLESAndroidKHR`
- `type` must be `XR_TYPE_GRAPHICS_BINDING_OPENGL_ESANDROID_KHR`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `display` must be a valid `EGLDisplay` value
- `config` must be a valid `EGLConfig` value
- `context` must be a valid `EGLContext` value

The `XrSwapchainImageOpenGLESKHR` structure is defined as:

```c
typedef struct XrSwapchainImageOpenGLESKHR {
    XrStructureType    type;
    void*              next;
    uint32_t           image;
} XrSwapchainImageOpenGLESKHR;
```

Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `image` is an index indicating the current OpenGL ES swapchain image to use.

If a given session was created with a `XrGraphicsBindingOpenGLESKHR`, the following conditions must apply.

- Calls to `xrEnumerateSwapchainImages` on an `XrSwapchain` in that session must return an array of `XrSwapchainImageOpenGLESKHR` structures.
- Whenever an OpenXR function accepts an `XrSwapchainImageBaseHeader` pointer as a parameter in that session, the runtime must also accept a pointer to an `XrSwapchainImageOpenGLESKHR` structure.

The OpenXR runtime must interpret the bottom-left corner of the swapchain image as the coordinate origin unless specified otherwise by extension functionality.
The OpenXR runtime must interpret the swapchain images in a clip space of positive Y pointing up, near Z plane at -1, and far Z plane at 1.

### Valid Usage (Implicit)

- The `XR_KHR_opengl_es_enable` extension must be enabled prior to using `XrSwapchainImageOpenGLESKHR`
- `type` must be `XR_TYPE_SWAPCHAIN_IMAGE_OPENGL_ES_KHR`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain

The `XrGraphicsRequirementsOpenGLESKHR` structure is defined as:

```c
typedef struct XrGraphicsRequirementsOpenGLESKHR {
    XrStructureType    type;
    void*              next;
    XrVersion          minApiVersionSupported;
    XrVersion          maxApiVersionSupported;
} XrGraphicsRequirementsOpenGLESKHR;
```

### Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `minApiVersionSupported` is the minimum version of OpenGL ES that the runtime supports. Uses `XR_MAKE_VERSION` on major and minor API version, ignoring any patch version component.
- `maxApiVersionSupported` is the maximum version of OpenGL ES that the runtime has been tested on and is known to support. Newer OpenGL ES versions might work if they are compatible. Uses `XR_MAKE_VERSION` on major and minor API version, ignoring any patch version component.

`XrGraphicsRequirementsOpenGLESKHR` is populated by `xrGetOpenGLESGraphicsRequirementsKHR` with the runtime’s OpenGL ES API version requirements.
Valid Usage (Implicit)

- The XR_KHR_opengl_es_enable extension must be enabled prior to using XrGraphicsRequirementsOpenGLESKHR
- type must be XR_TYPE_GRAPHICS_REQUIREMENTS_OPENGL_ES_KHR
- next must be NULL or a valid pointer to the next structure in a structure chain

New Functions

To query OpenGL ES API version requirements for an instance and system, call:

```c
XrResult xrGetOpenGLESGraphicsRequirementsKHR(
    XrInstance instance,
    XrSystemId systemId,
    XrGraphicsRequirementsOpenGLESKHR* graphicsRequirements);
```

Parameter Descriptions

- instance is an XrInstance handle previously created with xrCreateInstance.
- systemId is an XrSystemId handle for the system which will be used to create a session.
- graphicsRequirements is the XrGraphicsRequirementsOpenGLESKHR output structure.

The xrGetOpenGLESGraphicsRequirementsKHR function identifies to the application the minimum OpenGL ES version requirement and the highest known tested OpenGL ES version. The runtime must return XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING (XR_ERROR_VALIDATION_FAILURE may be returned due to legacy behavior) on calls to xrCreateSession if xrGetOpenGLESGraphicsRequirementsKHR has not been called for the same instance and systemId.

Valid Usage (Implicit)

- The XR_KHR_opengl_es_enable extension must be enabled prior to calling xrGetOpenGLESGraphicsRequirementsKHR
- instance must be a valid XrInstance handle
- graphicsRequirements must be a pointer to an XrGraphicsRequirementsOpenGLESKHR structure
Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SYSTEM_INVALID

Issues

Version History

- Revision 1, 2018-05-07 (Mark Young)
  - Initial draft
- Revision 2, 2018-06-21 (Bryce Hutchings)
  - Add new xrGetOpenGLESGraphicsRequirementsKHR
- Revision 3, 2018-11-15 (Paul Pedriana)
  - Specified the swapchain texture coordinate origin.
- Revision 4, 2018-11-16 (Minmin Gong)
  - Specified Y direction and Z range in clip space
- Revision 5, 2019-01-25 (Robert Menzel)
  - Description updated
- Revision 6, 2019-07-12 (Martin Renschler)
  - Description updated
- Revision 7, 2020-08-06 (Bryce Hutchings)
  - Added new XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING error code
- Revision 8, 2021-08-27 (Paulo F. Gomes)
  - Document handling of XrSwapchainUsageFlags
12.18. XR_KHR_swapchain_usage_input_attachment_bit

Name String
XR_KHR_swapchain_usage_input_attachment_bit

Extension Type
Instance extension

Registered Extension Number
166

Revision
3

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2021-05-11

IP Status
No known IP claims.

Contributors
Jakob Bornecrantz, Collabora
Ryan Pavlik, Collabora

Overview
This extension enables an application to specify that swapchain images should be created in a way so that they can be used as input attachments. At the time of writing this bit only affects Vulkan swapchains.

New Object Types

New Flag Types

New Enum Constants

XrSwapchainUsageFlagBits enumeration is extended with:

• XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_KHR - indicates that the image format may be used as an input attachment.

New Enums
New Structures

New Functions

Issues

Version History

• Revision 1, 2020-07-23 (Jakob Bornecrantz)
  ◦ Initial draft
• Revision 2, 2020-07-24 (Jakob Bornecrantz)
  ◦ Added note about only affecting Vulkan
  ◦ Changed from MNDX to MND
• Revision 3, 2021-05-11 (Ryan Pavlik)
  ◦ Updated for promotion from MND to KHR

12.19. XR_KHR_visibility_mask

Name String

XR_KHR_visibility_mask

Extension Type

Instance extension

Registered Extension Number

32

Revision

2

Extension and Version Dependencies

• Requires OpenXR 1.0

Last Modified Date

2018-07-05

IP Status

No known IP claims.

Contributors

Paul Pedriana, Oculus
Alex Turner, Microsoft
Overview

This extension supports the providing of a per-view drawing mask for applications. The primary purpose of this is to enable performance improvements that result from avoiding drawing on areas that aren’t visible to the user. A common occurrence in head-mounted VR hardware is that the optical system’s frustum doesn’t intersect precisely with the rectangular display it is viewing. As a result, it may be that there are parts of the display that aren’t visible to the user, such as the corners of the display. In such cases it would be unnecessary for the application to draw into those parts.

New Object Types

New Flag Types

New Enum Constants

New Enums

XrVisibilityMaskTypeKHR identifies the different types of mask specification that is supported. The application can request a view mask in any of the formats identified by these types.

code

typedef enum XrVisibilityMaskTypeKHR {
    XR_VISIBILITY_MASK_TYPE_HIDDEN_TRIANGLE_MESH_KHR = 1,
    XR_VISIBILITY_MASK_TYPE_VISIBLE_TRIANGLE_MESH_KHR = 2,
    XR_VISIBILITY_MASK_TYPE_LINE_LOOP_KHR = 3,
    XR_VISIBILITY_MASK_TYPE_MAX_ENUM_KHR = 0x7FFFFFFF
} XrVisibilityMaskTypeKHR;

Enumerant Descriptions

- **XR_VISIBILITY_MASK_TYPE_HIDDEN_TRIANGLE_MESH_KHR** refers to a two dimensional triangle mesh on the view surface which should not be drawn to by the application. `XrVisibilityMaskKHR` refers to a set of triangles identified by vertices and vertex indices. The index count will thus be a multiple of three. The triangle vertices will be returned in counter-clockwise order as viewed from the user perspective.

- **XR_VISIBILITY_MASK_TYPE_VISIBLE_TRIANGLE_MESH_KHR** refers to a two dimensional triangle mesh on the view surface which should be drawn to by the application. `XrVisibilityMaskKHR` refers to a set of triangles identified by vertices and vertex indices. The index count will thus be a multiple of three. The triangle vertices will be returned in counter-clockwise order as viewed from the user perspective.

- **XR_VISIBILITY_MASK_TYPE_LINE_LOOP_KHR** refers to a single multi-segmented line loop on the view surface which encompasses the view area which should be drawn by the application. It is the border that exists between the visible and hidden meshes identified by `XR_VISIBILITY_MASK_TYPE_HIDDEN_TRIANGLE_MESH_KHR` and `XR_VISIBILITY_MASK_TYPE_VISIBLE_TRIANGLE_MESH_KHR`. The line is counter-clockwise, contiguous, and non-self crossing, with the last point implicitly connecting to the first point. There is one vertex per point, the index count will equal the vertex count, and the indices will refer to the vertices.

New Structures

The `XrVisibilityMaskKHR` structure is an input/output struct which specifies the view mask.

typedef struct XrVisibilityMaskKHR {
    XrStructureType type;
    void* next;
    uint32_t vertexCapacityInput;
    uint32_t vertexCountOutput;
    XrVector2f* vertices;
    uint32_t indexCapacityInput;
    uint32_t indexCountOutput;
    uint32_t* indices;
} XrVisibilityMaskKHR;
**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **vertexCapacityInput** is the capacity of the vertices array, or 0 to indicate a request to retrieve the required capacity.
- **vertexCountOutput** is filled in by the runtime with the count of vertices written or the required capacity in the case that vertexCapacityInput or indexCapacityInput is insufficient.
- **vertices** is an array of vertices filled in by the runtime that specifies mask coordinates in the z=-1 plane of the rendered view—i.e. one meter in front of the view. When rendering the mask for use in a projection layer, these vertices must be transformed by the application’s projection matrix used for the respective XrCompositionLayerProjectionView.
- **indexCapacityInput** is the capacity of the indices array, or 0 to indicate a request to retrieve the required capacity.
- **indexCountOutput** is filled in by the runtime with the count of indices written or the required capacity in the case that vertexCapacityInput or indexCapacityInput is insufficient.
- **indices** is an array of indices filled in by the runtime, specifying the indices of the mask geometry in the vertices array.

**Valid Usage (Implicit)**

- The XR_KHR_visibility_mask extension must be enabled prior to using XrVisibilityMaskKHR
- **type** must be XR_TYPE_VISIBILITY_MASK_KHR
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- If vertexCapacityInput is not 0, vertices must be a pointer to an array of vertexCapacityInput XrVector2f structures
- If indexCapacityInput is not 0, indices must be a pointer to an array of indexCapacityInput uint32_t values

The XrEventDataVisibilityMaskChangedKHR structure specifies an event which indicates that a given view mask has changed. The application should respond to the event by calling xrGetVisibilityMaskKHR to retrieve the updated mask. This event is per-view, so if the masks for multiple views in a configuration change then multiple instances of this event will be sent to the application, one per view.
typedef struct XrEventDataVisibilityMaskChangedKHR {
    XrStructureType            type;
    const void*                next;
    XrSession                  session;
    XrViewConfigurationType    viewConfigurationType;
    uint32_t                   viewIndex;
} XrEventDataVisibilityMaskChangedKHR;

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **session** is the `XrSession` for which the view mask has changed.
- **viewConfigurationType** is the view configuration whose mask has changed.
- **viewIndex** is the individual view within the view configuration to which the change refers.

**Valid Usage (Implicit)**

- The `XR_KHR_visibility_mask` extension **must** be enabled prior to using `XrEventDataVisibilityMaskChangedKHR`
- **type** **must** be `XR_TYPE_EVENT_DATA_VISIBILITY_MASK_CHANGED_KHR`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **session** **must** be a valid `XrSession` handle
- **viewConfigurationType** **must** be a valid `XrViewConfigurationType` value

**New Functions**

The `xrGetVisibilityMaskKHR` function is defined as:

```c
XrResult xrGetVisibilityMaskKHR(
    XrSession                                   session,
    XrViewConfigurationType                     viewConfigurationType,
    uint32_t                                    viewIndex,
    XrVisibilityMaskTypeKHR                     visibilityMaskType,
    XrVisibilityMaskKHR*                        visibilityMask);
```
**Parameter Descriptions**

- **session** is an XrSession handle previously created with `xrCreateSession`.
- **viewConfigurationType** is the view configuration from which to retrieve mask information.
- **viewIndex** is the individual view within the view configuration from which to retrieve mask information.
- **visibilityMaskType** is the type of visibility mask requested.
- **visibilityMask** is an input/output struct which specifies the view mask.

```
xrGetVisibilityMaskKHR retrieves the view mask for a given view. This function follows the two-call idiom for filling multiple buffers in a struct. Specifically, if either `vertexCapacityInput` or `indexCapacityInput` is 0, the runtime must respond as if both fields were set to 0, returning the vertex count and index count through `vertexCountOutput` or `indexCountOutput` respectively. If a view mask for the specified view isn't available, the returned vertex and index counts must be 0.
```

**Valid Usage (Implicit)**

- The **XR_KHR_visibility_mask** extension must be enabled prior to calling `xrGetVisibilityMaskKHR`.
- **session** must be a valid XrSession handle
- **viewConfigurationType** must be a valid XrViewConfigurationType value
- **visibilityMaskType** must be a valid XrVisibilityMaskTypeKHR value
- **visibilityMask** must be a pointer to an XrVisibilityMaskKHR structure
## Return Codes

### Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

### Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_SIZE_INSUFFICIENT`
- `XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED`

## Issues

## Version History

- Revision 1, 2018-07-05 (Paul Pedriana)
  - Initial version.
- Revision 2, 2019-07-15 (Alex Turner)
  - Adjust two-call idiom usage.

### 12.20. XR_KHR_vulkan_enable

#### Name String

```
XR_KHR_vulkan_enable
```

#### Extension Type

Instance extension

#### Registered Extension Number

26

#### Revision

8
Overview

This extension enables the use of the Vulkan graphics API in an OpenXR runtime. Without this extension, the OpenXR runtime may not be able to use any Vulkan swapchain images.

This extension provides the mechanisms necessary for an application to generate a valid XrGraphicsBindingVulkanKHR structure in order to create a Vulkan-based XrSession. Note that during this process the application is responsible for creating all the required Vulkan objects.

This extension also provides mechanisms for the application to interact with images acquired by calling xrEnumerateSwapchainImages.

In order to expose the structures, types, and functions of this extension, you must define XR_USE_GRAPHICS_API_VULKAN before including the OpenXR platform header openxr_platform.h, in all portions of your library or application that include it.

Initialization

Some of the requirements for creating a valid XrGraphicsBindingVulkanKHR include correct initialization of a VkInstance, VkPhysicalDevice, and VkDevice.

A runtime may require that the VkInstance be initialized to a specific Vulkan API version. Additionally, the runtime may require a set of instance extensions to be enabled in the VkInstance. These requirements can be queried by the application using xrGetVulkanGraphicsRequirementsKHR and xrGetVulkanInstanceExtensionsKHR, respectively.

Similarly, the runtime may require the VkDevice to have a set of device extensions enabled, which can
be queried using \texttt{xrGetVulkanDeviceExtensionsKHR}.

In order to satisfy the \texttt{VkPhysicalDevice} requirements, the application can query \texttt{xrGetVulkanGraphicsDeviceKHR} to identify the correct \texttt{VkPhysicalDevice}.

Populating an \texttt{XrGraphicsBindingVulkanKHR} with a \texttt{VkInstance}, \texttt{VkDevice}, or \texttt{VkPhysicalDevice} that does not meet the requirements outlined by this extension \textit{may} result in undefined behavior by the OpenXR runtime.

The API version, instance extension, device extension and physical device requirements only apply to the \texttt{VkInstance}, \texttt{VkDevice}, and \texttt{VkPhysicalDevice} objects which the application wishes to associate with an \texttt{XrGraphicsBindingVulkanKHR}.

**Concurrency**

Vulkan requires that concurrent access to a \texttt{VkQueue} from multiple threads be externally synchronized. Therefore, OpenXR functions that may access the \texttt{VkQueue} specified in the \texttt{XrGraphicsBindingVulkanKHR} must also be externally synchronized.

The list of OpenXR functions where the OpenXR runtime \textit{may} access the \texttt{VkQueue} are:

- \texttt{xrBeginFrame}
- \texttt{xrEndFrame}
- \texttt{xrAcquireSwapchainImage}
- \texttt{xrReleaseSwapchainImage}

The runtime \textbf{must} not access the \texttt{VkQueue} in any OpenXR function that is not listed above or in an extension definition.

**Swapchain Image Layout**

When an application acquires a swapchain image by calling \texttt{xrAcquireSwapchainImage} in a session created using \texttt{XrGraphicsBindingVulkanKHR}, the OpenXR runtime \textbf{must} guarantee that:

- The image has a memory layout compatible with \texttt{VK_IMAGE_LAYOUT_COLOR_ATTACHMENT_OPTIMAL} for color images, or \texttt{VK_IMAGE_LAYOUT_DEPTH_STENCIL_ATTACHMENT_OPTIMAL} for depth images.
- The \texttt{VkQueue} specified in \texttt{XrGraphicsBindingVulkanKHR} has ownership of the image.

When an application releases a swapchain image by calling \texttt{xrReleaseSwapchainImage}, in a session created using \texttt{XrGraphicsBindingVulkanKHR}, the OpenXR runtime \textbf{must} interpret the image as:

- Having a memory layout compatible with \texttt{VK_IMAGE_LAYOUT_COLOR_ATTACHMENT_OPTIMAL} for color images, or \texttt{VK_IMAGE_LAYOUT_DEPTH_STENCIL_ATTACHMENT_OPTIMAL} for depth images.
- Being owned by the \texttt{VkQueue} specified in \texttt{XrGraphicsBindingVulkanKHR}.

The application is responsible for transitioning the swapchain image back to the image layout and
queue ownership that the OpenXR runtime requires. If the image is not in a layout compatible with the above specifications the runtime may exhibit undefined behavior.

**Swapchain Flag Bits**

All `XrSwapchainUsageFlags` values passed in a session created using `XrGraphicsBindingVulkanKHR` must be interpreted as follows by the runtime, so that the returned swapchain images used by the application may be used as if they were created with at least the specified `VkImageUsageFlagBits` or `VkImageCreateFlagBits` set.

<table>
<thead>
<tr>
<th><code>XrSwapchainUsageFlagBits</code></th>
<th>Corresponding Vulkan flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_COLOR_ATTACHMENT_BIT</code></td>
<td><code>VK_IMAGE_USAGE_COLOR_ATTACHMENT_BIT</code></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT</code></td>
<td><code>VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT</code></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_UNORDERED_ACCESS_BIT</code></td>
<td><code>VK_IMAGE_USAGE_STORAGE_BIT</code></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_TRANSFER_SRC_BIT</code></td>
<td><code>VK_IMAGE_USAGE_TRANSFER_SRC_BIT</code></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_TRANSFER_DST_BIT</code></td>
<td><code>VK_IMAGE_USAGE_TRANSFER_DST_BIT</code></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_SAMPLED_BIT</code></td>
<td><code>VK_IMAGE_USAGE_SAMPLED_BIT</code></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_MUTABLE_FORMAT_BIT</code></td>
<td><code>VK_IMAGE_CREATE_MUTABLE_FORMAT_BIT</code></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_KHR</code></td>
<td><code>VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT</code></td>
</tr>
<tr>
<td>(Added by <code>XR_KHR_swapchain_usage_input_attachment_bit</code> and only available when that extension is enabled)</td>
<td></td>
</tr>
<tr>
<td><code>XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_MND</code></td>
<td><code>VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT</code></td>
</tr>
<tr>
<td>(Added by the now deprecated <code>XR_MND_swapchain_usage_input_attachment_bit</code> extension and only available when that extension is enabled)</td>
<td></td>
</tr>
</tbody>
</table>

**New Object Types**

**New Flag Types**

**New Enum Constants**

`XrStructureType` enumeration is extended with:

- `XR_TYPE_GRAPHICS_REQUIREMENTS_VULKAN_KHR`
- `XR_TYPE_GRAPHICS_BINDING_VULKAN_KHR`
- `XR_TYPE_SWAPCHAIN_IMAGE_VULKAN_KHR`

**New Enums**

**New Structures**
The following structures are provided to supply supporting runtimes the necessary information required to work with the Vulkan API executing on certain operating systems.

The `XrGraphicsBindingVulkanKHR` structure is defined as:

```c
typedef struct XrGraphicsBindingVulkanKHR {
    XrStructureType     type;
    const void*         next;
    VkInstance          instance;
    VkPhysicalDevice    physicalDevice;
    VkDevice            device;
    uint32_t            queueFamilyIndex;
    uint32_t            queueIndex;
} XrGraphicsBindingVulkanKHR;
```

**Member Descriptions**

- *type* is the `XrStructureType` of this structure.
- *next* is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- *instance* is a valid Vulkan `VkInstance`.
- *physicalDevice* is a valid Vulkan `VkPhysicalDevice`.
- *device* is a valid Vulkan `VkDevice`.
- *queueFamilyIndex* is a valid queue family index on `device`.
- *queueIndex* is a valid queue index on `device` to be used for synchronization.

When creating a Vulkan-backed `XrSession`, the application will provide a pointer to an `XrGraphicsBindingVulkanKHR` in the *next* chain of the `XrSessionCreateInfo`. 
Valid Usage

- **instance must** have enabled a Vulkan API version in the range specified by `XrGraphicsBindingVulkanKHR`
- **instance must** have enabled all the instance extensions specified by `xrGetVulkanInstanceExtensionsKHR`
- **physicalDevice VkPhysicalDevice must** match the device specified by `xrGetVulkanGraphicsDeviceKHR`
- **device must** have enabled all the device extensions specified by `xrGetVulkanDeviceExtensionsKHR`

Valid Usage (Implicit)

- The `XR_KHR_vulkan_enable` extension **must** be enabled prior to using `XrGraphicsBindingVulkanKHR`
- **type must** be `XR_TYPE_GRAPHICS_BINDING_VULKAN_KHR`
- **next must** be `NULL` or a valid pointer to the next structure in a structure chain
- **instance must** be a valid `VkInstance` value
- **physicalDevice must** be a valid `VkPhysicalDevice` value
- **device must** be a valid `VkDevice` value

The `XrSwapchainImageVulkanKHR` structure is defined as:

```c
typedef struct XrSwapchainImageVulkanKHR {
    XrStructureType    type;
    void*              next;
    VkImage            image;
} XrSwapchainImageVulkanKHR;
```

Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **image** is a valid Vulkan `VkImage` to use.
If a given session was created with XrGraphicsBindingVulkanKHR, the following conditions must apply.

- Calls to xrEnumerateSwapchainImages on an XrSwapchain in that session must return an array of XrSwapchainImageVulkanKHR structures.
- Whenever an OpenXR function accepts an XrSwapchainImageBaseHeader pointer as a parameter in that session, the runtime must also accept a pointer to an XrSwapchainImageVulkanKHR.

The OpenXR runtime must interpret the top-left corner of the swapchain image as the coordinate origin unless specified otherwise by extension functionality.

The OpenXR runtime must interpret the swapchain images in a clip space of positive Y pointing down, near Z plane at 0, and far Z plane at 1.

Valid Usage (Implicit)

- The XR_KHR_vulkan_enable extension must be enabled prior to using XrSwapchainImageVulkanKHR
- type must be XR_TYPE_SWAPCHAIN_IMAGE_VULKAN_KHR
- next must be NULL or a valid pointer to the next structure in a structure chain. See also: XrSwapchainImageFoveationVulkanFB
- image must be a valid VkImage value

The XrGraphicsRequirementsVulkanKHR structure is defined as:

```c
typedef struct XrGraphicsRequirementsVulkanKHR {
    XrStructureType type;
    void* next;
    XrVersion minApiVersionSupported;
    XrVersion maxApiVersionSupported;
} XrGraphicsRequirementsVulkanKHR;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **minApiVersionSupported** is the minimum Vulkan Instance API version that the runtime supports. Uses XR_MAKE_VERSION on major and minor API version, ignoring any patch version component.
- **maxApiVersionSupported** is the maximum Vulkan Instance API version that the runtime has been tested on and is known to support. Newer Vulkan Instance API versions might work if they are compatible. Uses XR_MAKE_VERSION on major and minor API version, ignoring any patch version component.

XrGraphicsRequirementsVulkanKHR is populated by xrGetVulkanGraphicsRequirementsKHR with the runtime's Vulkan API version requirements.

Valid Usage (Implicit)

- The XR_KHR_vulkan_enable extension must be enabled prior to using XrGraphicsRequirementsVulkanKHR
- **type** must be XR_TYPE_GRAPHICS_REQUIREMENTS_VULKAN_KHR
- **next** must be NULL or a valid pointer to the next structure in a structure chain

New Functions

To query Vulkan API version requirements, call:

```c
XrResult xrGetVulkanGraphicsRequirementsKHR(  
    XrInstance instance,  
    XrSystemId systemId,  
    XrGraphicsRequirementsVulkanKHR* graphicsRequirements);
```
Parameter Descriptions

- **instance** is an `XrInstance` handle previously created with `xrCreateInstance`.
- **systemId** is an `XrSystemId` handle for the system which will be used to create a session.
- **graphicsRequirements** is the `XrGraphicsRequirementsVulkanKHR` output structure.

The `xrGetVulkanGraphicsRequirementsKHR` function identifies to the application the minimum Vulkan version requirement and the highest known tested Vulkan version. The runtime **must** return `XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING` (`XR_ERROR_VALIDATION_FAILURE` may be returned due to legacy behavior) on calls to `xrCreateSession` if `xrGetVulkanGraphicsRequirementsKHR` has not been called for the same `instance` and `systemId`.

Valid Usage (Implicit)

- The `XR_KHR_vulkan_enable` extension **must** be enabled prior to calling `xrGetVulkanGraphicsRequirementsKHR`
- **instance** must be a valid `XrInstance` handle
- **graphicsRequirements** must be a pointer to an `XrGraphicsRequirementsVulkanKHR` structure

Return Codes

**Success**
- `XR_SUCCESS`

**Failure**
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SYSTEM_INVALID`

Some computer systems may have multiple graphics devices, each of which may have independent external display outputs. XR systems that connect to such graphics devices are typically connected to a single device. Applications need to know what graphics device the XR system is connected to so that they can use that graphics device to generate XR images.

To identify what graphics device needs to be used for an instance and system, call:
XrResult xrGetVulkanGraphicsDeviceKHR(
    XrInstance instance,
    XrSystemId systemId,
    VkInstance vkInstance,
    VkPhysicalDevice* vkPhysicalDevice);

Parameter Descriptions

- **instance** is an XrInstance handle previously created with xrCreateInstance.
- **systemId** is an XrSystemId handle for the system which will be used to create a session.
- **vkInstance** is a valid Vulkan VkInstance.
- **vkPhysicalDevice** is a pointer to a VkPhysicalDevice value to populate.

xrGetVulkanGraphicsDeviceKHR function identifies to the application what graphics device (Vulkan VkPhysicalDevice) needs to be used. xrGetVulkanGraphicsDeviceKHR **must** be called prior to calling xrCreateSession, and the VkPhysicalDevice that xrGetVulkanGraphicsDeviceKHR returns should be passed to xrCreateSession in the XrGraphicsBindingVulkanKHR.

Valid Usage (Implicit)

- The **XR_KHR_vulkan_enable** extension **must** be enabled prior to calling xrGetVulkanGraphicsDeviceKHR
- **instance** **must** be a valid XrInstance handle
- **vkInstance** **must** be a valid VkInstance value
- **vkPhysicalDevice** **must** be a pointer to a VkPhysicalDevice value
Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SYSTEM_INVALID

XrResult xrGetVulkanInstanceExtensionsKHR(
    XrInstance instance,
    XrSystemId systemId,
    uint32_t bufferCapacityInput,
    uint32_t* bufferCountOutput,
    char* buffer);

Parameter Descriptions

- **instance** is an XrInstance handle previously created with xrCreateInstance.
- **systemId** is an XrSystemId handle for the system which will be used to create a session.
- **bufferCapacityInput** is the capacity of the buffer, or 0 to indicate a request to retrieve the required capacity.
- **bufferCountOutput** is a pointer to the count of characters written (including terminating \0), or a pointer to the required capacity in the case that bufferCapacityInput is insufficient.
- **buffer** is a pointer to an array of characters, but can be NULL if bufferCapacityInput is 0. The format of the output is a single space (ASCII 0x20) delimited string of extension names.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required buffer size.
Valid Usage (Implicit)

- The `XR_KHR_vulkan_enable` extension must be enabled prior to calling `xrGetVulkanInstanceExtensionsKHR`
- `instance` must be a valid `XrInstance` handle
- `bufferCountOutput` must be a pointer to a `uint32_t` value
- If `bufferCapacityInput` is not 0, `buffer` must be a pointer to an array of `bufferCapacityInput` char values

Return Codes

Success

- `XR_SUCCESS`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SIZE_INSUFFICIENT`
- `XR_ERROR_SYSTEM_INVALID`
Parameter Descriptions

- **instance** is an XrInstance handle previously created with xrCreateInstance.
- **systemId** is an XrSystemId handle for the system which will be used to create a session.
- **bufferCapacityInput** is the capacity of the buffer, or 0 to indicate a request to retrieve the required capacity.
- **bufferCountOutput** is a pointer to the count of characters written (including terminating \0), or a pointer to the required capacity in the case that bufferCapacityInput is insufficient.
- **buffer** is a pointer to an array of characters, but can be NULL if bufferCapacityInput is 0. The format of the output is a single space (ASCII 0x20) delimited string of extension names.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required buffer size.

Valid Usage (Implicit)

- The XR_KHR_vulkan_enable extension must be enabled prior to calling xrGetVulkanDeviceExtensionsKHR
- **instance** must be a valid XrInstance handle
- **bufferCountOutput** must be a pointer to a uint32_t value
- If bufferCapacityInput is not 0, buffer must be a pointer to an array of bufferCapacityInput char values

Return Codes

**Success**

- XR_SUCCESS

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_SYSTEM_INVALID
Issues

Version History

- Revision 1, 2018-05-07 (Mark Young)
  ◦ Initial draft
- Revision 2, 2018-06-21 (Bryce Hutchings)
  ◦ Replace session parameter with instance and systemId parameters.
  ◦ Move xrGetVulkanDeviceExtensionsKHR, xrGetVulkanInstanceExtensionsKHR and xrGetVulkanGraphicsDeviceKHR functions into this extension
  ◦ Add new XrGraphicsRequirementsVulkanKHR function.
- Revision 3, 2018-11-15 (Paul Pedriana)
  ◦ Specified the swapchain texture coordinate origin.
- Revision 4, 2018-11-16 (Minmin Gong)
  ◦ Specified Y direction and Z range in clip space
- Revision 5, 2019-01-24 (Robert Menzel)
  ◦ Description updated
- Revision 6, 2019-01-25 (Andres Rodriguez)
  ◦ Reword sections of the spec to shift requirements on to the runtime instead of the app
- Revision 7, 2020-08-06 (Bryce Hutchings)
  ◦ Added new XR_ERROR_GRAPHICS_REQUIREMENTS_CALL MISSING error code
- Revision 8, 2021-01-21 (Ryan Pavlik)
  ◦ Document mapping for XrSwapchainUsageFlags

12.21. XR_KHR_vulkan_enable2

Name String

XR_KHR_vulkan_enable2

Extension Type

Instance extension

Registered Extension Number

91

Revision

2
12.21.1. Overview

This extension enables the use of the Vulkan graphics API in an OpenXR runtime. Without this extension, the OpenXR runtime may not be able to use any Vulkan swapchain images.

This extension provides the mechanisms necessary for an application to generate a valid XrGraphicsBindingVulkan2KHR structure in order to create a Vulkan-based XrSession.

This extension also provides mechanisms for the application to interact with images acquired by calling xrEnumerateSwapchainImages.

In order to expose the structures, types, and functions of this extension, you must define XR_USE_GRAPHICS_API_VULKAN before including the OpenXR platform header openxr_platform.h, in all portions of your library or application that include it.

Note

This extension is intended as an alternative to XR_KHR_vulkan_enable, and does not depend on it.

12.21.2. Initialization

When operating in Vulkan mode, the OpenXR runtime and the application will share the Vulkan queue described in the XrGraphicsBindingVulkan2KHR structure. This section of the document describes the mechanisms this extension exposes to ensure the shared Vulkan queue is compatible with the runtime and the application’s requirements.
Vulkan Version Requirements

First, a compatible Vulkan version **must** be agreed upon. To query the runtime’s Vulkan API version requirements an application will call:

```c
XrResult xrGetVulkanGraphicsRequirements2KHR(
    XrInstance instance,
    XrSystemId systemId,
    XrGraphicsRequirementsVulkanKHR* graphicsRequirements);
```

The `xrGetVulkanGraphicsRequirements2KHR` function identifies to the application the runtime’s minimum Vulkan version requirement and the highest known tested Vulkan version. `xrGetVulkanGraphicsRequirements2KHR` **must** be called prior to calling `xrCreateSession`. The runtime **must** return `XR_ERROR_GRAPHICS_REQUIREMENTS_CALL_MISSING` on calls to `xrCreateSession` if `xrGetVulkanGraphicsRequirements2KHR` has not been called for the same `instance` and `systemId`.

### Parameter Descriptions

- **instance** is an `XrInstance` handle previously created with `xrCreateInstance`.
- **systemId** is an `XrSystemId` handle for the system which will be used to create a session.
- **graphicsRequirements** is the `XrGraphicsRequirementsVulkan2KHR` output structure.

### Valid Usage (Implicit)

- The `XR_KHR_vulkan_enable2` extension **must** be enabled prior to calling `xrGetVulkanGraphicsRequirements2KHR`
- **instance** **must** be a valid `XrInstance` handle
- **graphicsRequirements** **must** be a pointer to an `XrGraphicsRequirementsVulkanKHR` structure
**Return Codes**

**Success**

- XR_SUCCESS

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SYSTEM_INVALID

The **XrGraphicsRequirementsVulkan2KHR** structure populated by **xrGetVulkanGraphicsRequirements2KHR** is defined as:

```c
// XrGraphicsRequirementsVulkan2KHR is an alias for XrGraphicsRequirementsVulkanKHR
typedef struct XrGraphicsRequirementsVulkanKHR {
    XrStructureType type;
    void* next;
    XrVersion minApiVersionSupported;
    XrVersion maxApiVersionSupported;
} XrGraphicsRequirementsVulkanKHR;

typedef XrGraphicsRequirementsVulkanKHR XrGraphicsRequirementsVulkan2KHR;
```

**Member Descriptions**

- **type** is the **XrStructureType** of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **minApiVersionSupported** is the minimum version of Vulkan that the runtime supports. Uses **XR_MAKE_VERSION** on major and minor API version, ignoring any patch version component.
- **maxApiVersionSupported** is the maximum version of Vulkan that the runtime has been tested on and is known to support. Newer Vulkan versions might work if they are compatible. Uses **XR_MAKE_VERSION** on major and minor API version, ignoring any patch version component.
Valid Usage (Implicit)

- The `XR_KHR_vulkan_enable2` extension must be enabled prior to using `XrGraphicsRequirementsVulkan2KHR`.

- Note: `XrGraphicsRequirementsVulkan2KHR` is an alias for `XrGraphicsRequirementsVulkanKHR`, so implicit valid usage for `XrGraphicsRequirementsVulkanKHR` has been replicated below.

- `type` must be `XR_TYPE_GRAPHICS_REQUIREMENTS_VULKAN_KHR`.

- `next` must be `NULL` or a valid pointer to the next structure in a structure chain.

Vulkan Instance Creation

Second, a compatible `VkInstance` must be created. The `xrCreateVulkanInstanceKHR` entry point is a wrapper around `vkCreateInstance` intended for this purpose. When called, the runtime must aggregate the requirements specified by the application with its own requirements and forward the `VkInstance` creation request to the `vkCreateInstance` function pointer returned by `PFNGetInstanceProcAddr`.

```c
XrResult xrCreateVulkanInstanceKHR(
    XrInstance instance,
    const XrVulkanInstanceCreateInfoKHR* createInfo,
    VkInstance* vulkanInstance,
    VkResult* vulkanResult);
```

Parameter Descriptions

- `instance` is an `XrInstance` handle previously created with `xrCreateInstance`.

- `createInfo` extensible input struct of type `XrVulkanInstanceCreateInfoKHR`.

- `vulkanInstance` points to a `VkInstance` handle to populate with the new Vulkan instance.

- `vulkanResult` points to a `VkResult` to populate with the result of the `vkCreateInstance` operation as returned by `PFNGetInstanceProcAddr`.

Valid Usage (Implicit)

- The XR_KHR_vulkan_enable2 extension must be enabled prior to calling xrCreateVulkanInstanceKHR
- instance must be a valid XrInstance handle
- createInfo must be a pointer to a valid XrVulkanInstanceCreateInfoKHR structure
- vulkanInstance must be a pointer to a VkInstance value
- vulkanResult must be a pointer to a VkResult value

Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_SYSTEM_INVALID

The XrVulkanInstanceCreateInfoKHR structure contains the input parameters to xrCreateVulkanInstanceKHR.

typedef struct XrVulkanInstanceCreateInfoKHR {
    XrStructureType type;
    const void* next;
    XrSystemId systemId;
    XrVulkanInstanceCreateFlagsKHR createFlags;
    PFN_vkGetInstanceProcAddr pfnGet InstanceProcAddr;
    const VkInstanceCreateInfo* vulkanCreateInfo;
    const VkAllocationCallbacks* vulkanAllocator;
} XrVulkanInstanceCreateInfoKHR;
Member Descriptions

- **systemId** is an XrSystemId handle for the system which will be used to create a session.
- **PFNGetInstanceProcAddr** is a function pointer to vkGetInstanceProcAddr or a compatible entry point.
- **vulkanCreateInfo** is the VkInstanceCreateInfo as specified by Vulkan.
- **vulkanAllocator** is the VkAllocationCallbacks as specified by Vulkan.

Valid Usage (Implicit)

- The **XR_KHR_vulkan_enable2** extension must be enabled prior to using XrVulkanInstanceCreateInfoKHR
- **type** must be XR_TYPE_VULKAN_INSTANCE_CREATE_INFO_KHR
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **createFlags** must be 0
- **PFNGetInstanceProcAddr** must be a valid PFN_vkGetInstanceProcAddr value
- **vulkanCreateInfo** must be a pointer to a valid VkInstanceCreateInfo value
- If **vulkanAllocator** is not NULL, **vulkanAllocator** must be a pointer to a valid VkAllocationCallbacks value

```c
typedef XrFlags64 XrVulkanInstanceCreateFlagsKHR;
```

Physical Device Selection

Third, a **VkPhysicalDevice** must be chosen. Some computer systems may have multiple graphics devices, each of which may have independent external display outputs. The runtime must report a **VkPhysicalDevice** that is compatible with the OpenXR implementation when xrGetVulkanGraphicsDevice2KHR is invoked. The application will use this **VkPhysicalDevice** to interact with the OpenXR runtime.
XrResult xrGetVulkanGraphicsDevice2KHR(
    XrInstance                                  instance,
    const XrVulkanGraphicsDeviceGetInfoKHR*     getInfo,
    VkPhysicalDevice*                           vulkanPhysicalDevice);

Parameter Descriptions

- **instance** is an *XrInstance* handle previously created with *xrCreateInstance*.
- **getInfo** extensible input struct of type *XrVulkanGraphicsDeviceGetInfoKHR*
- **vulkanPhysicalDevice** is a pointer to a *VkPhysicalDevice* handle to populate.

Valid Usage (Implicit)

- The *XR_KHR_vulkan_enable2* extension **must** be enabled prior to calling *xrGetVulkanGraphicsDevice2KHR*
- **instance** **must** be a valid *XrInstance* handle
- **getInfo** **must** be a pointer to a valid *XrVulkanGraphicsDeviceGetInfoKHR* structure
- **vulkanPhysicalDevice** **must** be a pointer to a *VkPhysicalDevice* value

Return Codes

**Success**
- *XR_SUCCESS*

**Failure**
- *XR_ERROR_FUNCTION_UNSUPPORTED*
- *XR_ERROR_VALIDATION_FAILURE*
- *XR_ERROR_RUNTIME_FAILURE*
- *XR_ERROR_HANDLE_INVALID*
- *XR_ERROR_INSTANCE_LOST*
- *XR_ERROR_SYSTEM_INVALID*

The *XrVulkanGraphicsDeviceGetInfoKHR* structure contains the input parameters to *xrCreateVulkanInstanceKHR*. 

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typedef struct XrVulkanGraphicsDeviceGetInfoKHR {
    XrStructureType    type;
    const void*        next;
    XrSystemId         systemId;
    VkInstance         vulkanInstance;
} XrVulkanGraphicsDeviceGetInfoKHR;

Member Descriptions

- `systemId` is an `XrSystemId` handle for the system which will be used to create a session.
- `vulkanInstance` is a valid Vulkan `VkInstance`.

Valid Usage (Implicit)

- The `XR_KHR_vulkan_enable2` extension must be enabled prior to using `XrVulkanGraphicsDeviceGetInfoKHR`
- `type` must be `XR_TYPE_VULKAN_GRAPHICS_DEVICE_GET_INFO_KHR`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `vulkanInstance` must be a valid `VkInstance` value

Vulkan Device Creation

Fourth, a compatible `VkDevice` must be created. The `xrCreateVulkanDeviceKHR` entry point is a wrapper around `vkCreateDevice` intended for this purpose. When called, the runtime must aggregate the requirements specified by the application with its own requirements and forward the `VkDevice` creation request to the `vkCreateDevice` function pointer returned by `pfnGetInstanceProcAddr`.

```c
XrResult xrCreateVulkanDeviceKHR(
    XrInstance                                  instance,
    const XrVulkanDeviceCreateInfoKHR*          createInfo,
    VkDevice*                                   vulkanDevice,
    VkResult*                                   vulkanResult);
```
Parameter Descriptions

- **instance** is an `XrInstance` handle previously created with `xrCreateInstance`.
- **createInfo** extensible input struct of type `XrCreateVulkanDeviceCreateInfoKHR`.
- **vulkanDevice** points to a `VkDevice` handle to populate with the new Vulkan device.
- **vulkanResult** points to a `VkResult` to populate with the result of the `vkCreateDevice` operation as returned by `PFNGetInstanceProcAddr`.

Valid Usage (Implicit)

- The `XR_KHR_vulkan_enable2` extension **must** be enabled prior to calling `xrCreateVulkanDeviceKHR`.
- **instance** **must** be a valid `XrInstance` handle.
- **createInfo** **must** be a pointer to a valid `XrVulkanDeviceCreateInfoKHR` structure.
- **vulkanDevice** **must** be a pointer to a `VkDevice` value.
- **vulkanResult** **must** be a pointer to a `VkResult` value.

Return Codes

**Success**
- `XR_SUCCESS`

**Failure**
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_LIMIT_REACHED`
- `XR_ERROR_SYSTEM_INVALID`

The `XrVulkanDeviceCreateInfoKHR` structure contains the input parameters to `xrCreateVulkanDeviceKHR`. 
typedef struct XrVulkanDeviceCreateInfoKHR {
    XrStructureType type;
    const void* next;
    XrSystemId systemId;
    XrVulkanDeviceCreateFlagsKHR createFlags;
    PFN_vkGetInstanceProcAddr pfnGetInstanceProcAddr;
    VkPhysicalDevice vulkanPhysicalDevice;
    const VkDeviceCreateInfo* vulkanCreateInfo;
    const VkAllocationCallbacks* vulkanAllocator;
} XrVulkanDeviceCreateInfoKHR;

Member Descriptions

• systemId is an XrSystemId handle for the system which will be used to create a session.
• pfnGetInstanceProcAddr is a function pointer to vkGetInstanceProcAddr or a compatible entry point.
• VulkanPhysicalDevice must match xrGetVulkanGraphicsDeviceKHR.
• VulkanCreateInfo is the VkDeviceCreateInfo as specified by Vulkan.
• VulkanAllocator is the VkAllocationCallbacks as specified by Vulkan.

Valid Usage (Implicit)

• The XR_KHR_vulkan_enable2 extension must be enabled prior to using XrVulkanDeviceCreateInfoKHR
• type must be XR_TYPE_VULKAN_DEVICE_CREATE_INFO_KHR
• next must be NULL or a valid pointer to the next structure in a structure chain
• createFlags must be 0
• pfnGetInstanceProcAddr must be a valid PFN_vkGetInstanceProcAddr value
• VulkanPhysicalDevice must be a valid VkPhysicalDevice value
• VulkanCreateInfo must be a pointer to a valid VkDeviceCreateInfo value
• If VulkanAllocator is not NULL, VulkanAllocator must be a pointer to a valid VkAllocationCallbacks value

typedef XrFlags64 XrVulkanDeviceCreateFlagsKHR;
If the `vulkanPhysicalDevice` parameter does not match the output of `xrGetVulkanGraphicsDeviceKHR`, then the runtime must return `XR_ERROR_HANDLE_INVALID`.

**Queue Selection**

Last, the application selects a `VkQueue` from the `VkDevice` that has the `VK_QUEUE_GRAPHICS_BIT` set.

*Note*

The runtime may schedule work on the `VkQueue` specified in the binding, or it may schedule work on any hardware queue in a foreign logical device.

**Vulkan Graphics Binding**

When creating a Vulkan-backed `XrSession`, the application will chain a pointer to an `XrGraphicsBindingVulkan2KHR` to the `XrSessionCreateInfo` parameter of `xrCreateSession`. With the data collected in the previous sections, the application now has all the necessary information to populate an `XrGraphicsBindingVulkan2KHR` structure for session creation.

```c
// XrGraphicsBindingVulkan2KHR is an alias for XrGraphicsBindingVulkanKHR
typedef struct XrGraphicsBindingVulkanKHR {
    XrStructureType     type;
    const void*         next;
    VkInstance          instance;
    VkPhysicalDevice    physicalDevice;
    VkDevice            device;
    uint32_t            queueFamilyIndex;
    uint32_t            queueIndex;
} XrGraphicsBindingVulkanKHR;

typedef XrGraphicsBindingVulkanKHR XrGraphicsBindingVulkan2KHR;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **instance** is a valid Vulkan VkInstance.
- **physicalDevice** is a valid Vulkan VkPhysicalDevice.
- **device** is a valid Vulkan VkDevice.
- **queueFamilyIndex** is a valid queue family index on device.
- **queueIndex** is a valid queue index on device to be used for synchronization.

Valid Usage

- **instance** must have enabled a Vulkan API version in the range specified by xrGetVulkanGraphicsRequirements2KHR
- **instance** must have been created using xrCreateVulkanInstanceKHR
- **physicalDevice** VkPhysicalDevice must match the device specified by xrGetVulkanGraphicsDevice2KHR
- **device** must have been created using xrCreateVulkanDeviceKHR

Valid Usage (Implicit)

- The XR_KHR_vulkan_enable2 extension must be enabled prior to using XrGraphicsBindingVulkan2KHR
- **Note:** XrGraphicsBindingVulkan2KHR is an alias for XrGraphicsBindingVulkanKHR, so implicit valid usage for XrGraphicsBindingVulkanKHR has been replicated below.
  - **type** must be XR_TYPE_GRAPHICS_BINDING_VULKAN_KHR
  - **next** must be NULL or a valid pointer to the next structure in a structure chain
  - **instance** must be a valid VkInstance value
  - **physicalDevice** must be a valid VkPhysicalDevice value
  - **device** must be a valid VkDevice value

Populating an XrGraphicsBindingVulkan2KHR structure with a member that does not meet the requirements outlined by this extension may result in undefined behavior by the OpenXR runtime.

The requirements outlined in this extension only apply to the VkInstance, VkDevice, VkPhysicalDevice
and VkQueue objects which the application wishes to associate with an XrGraphicsBindingVulkan2KHR.

12.21.3. Concurrency

Vulkan requires that concurrent access to a VkQueue from multiple threads be externally synchronized. Therefore, OpenXR functions that may access the VkQueue specified in the XrGraphicsBindingVulkan2KHR must also be externally synchronized by the OpenXR application.

The list of OpenXR functions where the OpenXR runtime may access the VkQueue are:

- xrBeginFrame
- xrEndFrame
- xrAcquireSwapchainImage
- xrReleaseSwapchainImage

The runtime must not access the VkQueue in any OpenXR function that is not listed above or in an extension definition.

Failure by the application to synchronize access to VkQueue may result in undefined behavior in the OpenXR runtime.

12.21.4. Swapchain Interactions

Swapchain Images

When an application interacts with XrSwapchainImageBaseHeader structures in a Vulkan-backed XrSession, the application can interpret these to be XrSwapchainImageVulkan2KHR structures. These are defined as:

```c
// XrSwapchainImageVulkan2KHR is an alias for XrSwapchainImageVulkanKHR
typedef struct XrSwapchainImageVulkanKHR {
    XrStructureType    type;
    void*              next;
    VkImage            image;
} XrSwapchainImageVulkanKHR;

typedef XrSwapchainImageVulkanKHR XrSwapchainImageVulkan2KHR;
```
**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **image** is a valid Vulkan VkImage to use.

If a given session was created with XrGraphicsBindingVulkan2KHR, the following conditions must apply.

- Calls to xrEnumerateSwapchainImages on an XrSwapchain in that session must return an array of XrSwapchainImageVulkan2KHR structures.
- Whenever an OpenXR function accepts an XrSwapchainImageBaseHeader pointer as a parameter in that session, the runtime must also accept a pointer to an XrSwapchainImageVulkan2KHR.

The OpenXR runtime must interpret the top-left corner of the swapchain image as the coordinate origin unless specified otherwise by extension functionality.

The OpenXR runtime must interpret the swapchain images in a clip space of positive Y pointing down, near Z plane at 0, and far Z plane at 1.

**Valid Usage (Implicit)**

- The XR_KHR_vulkan_enable2 extension must be enabled prior to using XrSwapchainImageVulkan2KHR.
- **Note:** XrSwapchainImageVulkan2KHR is an alias for XrSwapchainImageVulkanKHR, so implicit valid usage for XrSwapchainImageVulkanKHR has been replicated below.

- **type** must be XR_TYPE_SWAPCHAIN_IMAGE_VULKAN_KHR
- **next** must be NULL or a valid pointer to the next structure in a structure chain. See also: XrSwapchainImageFoveationVulkanFB
- **image** must be a valid VkImage value

**Swapchain Image Layout**

When an application acquires a swapchain image by calling xrAcquireSwapchainImage in a session created using XrGraphicsBindingVulkan2KHR, the OpenXR runtime must guarantee that:

- The image has a memory binding compatible with VK_IMAGE_LAYOUT_COLOR_ATTACHMENT_OPTIMAL for color images, or VK_IMAGE_LAYOUT_DEPTH_STENCIL_ATTACHMENT_OPTIMAL for depth images.
- The VkQueue specified in XrGraphicsBindingVulkan2KHR has ownership of the image.
When an application releases a swapchain image by calling `xrReleaseSwapchainImage`, in a session created using `XrGraphicsBindingVulkan2KHR`, the OpenXR runtime must interpret the image as:

- Having a memory layout compatible with `VK_IMAGE_LAYOUT_COLOR_ATTACHMENT_OPTIMAL` for color images, or `VK_IMAGE_LAYOUT_DEPTH_STENCIL_ATTACHMENT_OPTIMAL` for depth images.
- Being owned by the `VkQueue` specified in `XrGraphicsBindingVulkan2KHR`.
- Being referenced by command buffers submitted to the `VkQueue` specified in `XrGraphicsBindingVulkan2KHR` which have not yet completed execution.

The application is responsible for transitioning the swapchain image back to the image layout and queue ownership that the OpenXR runtime requires. If the image is not in a layout compatible with the above specifications the runtime may exhibit undefined behavior.

**Swapchain Flag Bits**

All `XrSwapchainUsageFlags` values passed in a session created using `XrGraphicsBindingVulkan2KHR` must be interpreted as follows by the runtime, so that the returned swapchain images used by the application may be used as if they were created with at least the specified `VkImageUsageFlagBits` or `VkImageCreateFlagBits` set.

<table>
<thead>
<tr>
<th><code>XrSwapchainUsageFlagBits</code></th>
<th>Corresponding Vulkan flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_SWAPCHAIN_USAGE_COLOR_ATTACHMENT_BIT</td>
<td>VK_IMAGE_USAGE_COLOR_ATTACHMENT_BIT</td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT</td>
<td>VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT</td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_UNORDERED_ACCESS_BIT</td>
<td>VK_IMAGE_USAGE_STORAGE_BIT</td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_TRANSFER_SRC_BIT</td>
<td>VK_IMAGE_USAGE_TRANSFER_SRC_BIT</td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_TRANSFER_DST_BIT</td>
<td>VK_IMAGE_USAGE_TRANSFER_DST_BIT</td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_SAMPLED_BIT</td>
<td>VK_IMAGE_USAGE_SAMPLED_BIT</td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_MUTABLE_FORMAT_BIT</td>
<td>VK_IMAGE_CREATE_MUTABLE_FORMAT_BIT</td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_KHR (Added by XR_KHR_swapchain_usage_input_attachment_bit and only available when that extension is enabled)</td>
<td>VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT</td>
</tr>
<tr>
<td>XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_MND (Added by the now deprecated XR_MND_swapchain_usage_input_attachment_bit extension and only available when that extension is enabled)</td>
<td>VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT</td>
</tr>
</tbody>
</table>

**12.21.5. Appendix**
Questions

1. Should the `xrCreateVulkanDeviceKHR` and `xrCreateVulkanInstanceKHR` functions have an output parameter that returns the combined list of parameters used to create the Vulkan device(instance)?

   ◦ No. If the application is interested in capturing this data it can set the `PFNGetInstanceProcAddr` parameter to a local callback that captures the relevant information.

Quick Reference

New Enum Constants

`XrStructureType` enumeration is extended with:

- `XR_TYPE_GRAPHICS_REQUIREMENTS_VULKAN2_KHR` (alias of `XR_TYPE_GRAPHICS_REQUIREMENTS_VULKAN_KHR`)
- `XR_TYPE_GRAPHICS_BINDING_VULKAN2_KHR` (alias of `XR_TYPE_GRAPHICS_BINDING_VULKAN_KHR`)
- `XR_TYPE_SWAPCHAIN_IMAGE_VULKAN2_KHR` (alias of `XR_TYPE_SWAPCHAIN_IMAGE_VULKAN_KHR`)

New Structures

- `XrVulkanInstanceCreateInfoKHR`
- `XrVulkanDeviceCreateInfoKHR`
- `XrVulkanGraphicsDeviceGetInfoKHR`
- `XrGraphicsBindingVulkan2KHR` (alias of `XrGraphicsBindingVulkanKHR`)
- `XrSwapchainImageVulkan2KHR` (alias of `XrSwapchainImageVulkanKHR`)
- `XrGraphicsRequirementsVulkan2KHR` (alias of `XrGraphicsRequirementsVulkanKHR`)

New Functions

- `xrCreateVulkanInstanceKHR`
- `xrCreateVulkanDeviceKHR`
- `xrGetVulkanGraphicsDevice2KHR`
- `xrGetVulkanGraphicsRequirements2KHR`

Version History

- Revision 1, 2020-05-04 (Andres Rodriguez)
  ◦ Initial draft
- Revision 2, 2021-01-21 (Ryan Pavlik)
  ◦ Document mapping for `XrSwapchainUsageFlags`
12.22. XR_KHR_vulkan_swapchain_format_list

Name String

XR_KHR_vulkan_swapchain_format_list

Extension Type

Instance extension

Registered Extension Number

15

Revision

4

Extension and Version Dependencies

• Requires OpenXR 1.0

• Requires XR_KHR_vulkan_enable

Last Modified Date

2020-01-01

IP Status

No known IP claims.

Contributors

Paul Pedriana, Oculus

Dan Ginsburg, Valve

Overview

Vulkan has the VK_KHR_image_format_list extension which allows applications to tell the vkCreateImage function which formats the application intends to use when VK_IMAGE_CREATE_MUTABLE_FORMAT_BIT is specified. This OpenXR extension exposes that Vulkan extension to OpenXR applications. In the same way that a Vulkan-based application can pass a VkImageFormatListCreateInfo struct to the vkCreateImage function, an OpenXR application can pass an identically configured XrVulkanSwapchainFormatListCreateInfoKHR structure to xrCreateSwapchain.

Applications using this extension to specify more than one swapchain format must create OpenXR swapchains with the XR_SWAPCHAIN_USAGE_MUTABLE_FORMAT_BIT bit set.

Runtimes implementing this extension must support the XR_KHR_vulkan_enable or the XR_KHR_vulkan_enable2 extension. When XR_KHR_vulkan_enable is used, the runtime must add VK_KHR_image_format_list to the list of extensions enabled in xrCreateVulkanDeviceKHR.

New Object Types
New Flag Types

New Enum Constants

`XrStructureType` enumeration is extended with:

```
XR_TYPE_VULKAN_SWAPCHAIN_FORMAT_LIST_CREATE_INFO_KHR
```

New Enums

New Structures

```c
typedef struct XrVulkanSwapchainFormatListCreateInfoKHR {
    XrStructureType    type;
    const void*        next;
    uint32_t           viewFormatCount;
    const VkFormat*    viewFormats;
} XrVulkanSwapchainFormatListCreateInfoKHR;
```

**Member Descriptions**

- **`type`** is the `XrStructureType` of this structure.
- **`next`** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **`viewFormatCount`** is the number of view formats passed in `viewFormats`.
- **`viewFormats`** is an array of `VkFormat`.

**Valid Usage (Implicit)**

- The `XR_KHR_vulkan_swapchain_format_list` extension **must** be enabled prior to using `XrVulkanSwapchainFormatListCreateInfoKHR`
- **`type`** must be `XR_TYPE_VULKAN_SWAPCHAIN_FORMAT_LIST_CREATE_INFO_KHR`
- **`next`** must be `NULL` or a valid pointer to the next structure in a structure chain
- If `viewFormatCount` is not `0`, `viewFormats` **must** be a pointer to an array of `viewFormatCount` valid `VkFormat` values

New Functions
Issues

Version History

• Revision 1, 2017-09-13 (Paul Pedriana)
  ◦ Initial proposal.
• Revision 2, 2018-06-21 (Bryce Hutchings)
  ◦ Update reference of `XR_KHR_vulkan_extension_requirements` to `XR_KHR_vulkan_enable`
• Revision 3, 2020-01-01 (Andres Rodriguez)
  ◦ Update for `XR_KHR_vulkan_enable2`
• Revision 4, 2021-01-21 (Ryan Pavlik)
  ◦ Fix reference to the mutable-format bit in Vulkan.

12.23.
XR_KHR_win32_convert_performance_counter_time

Name String
XR_KHR_win32_convert_performance_counter_time

Extension Type
Instance extension

Registered Extension Number
36

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2019-01-24

IP Status
No known IP claims.

Contributors
Paul Pedriana, Oculus
Bryce Hutchings, Microsoft

Overview
This extension provides two functions for converting between the Windows performance counter (QPC) time stamps and \texttt{XrTime}. The \texttt{xrConvertWin32PerformanceCounterToTimeKHR} function converts from Windows performance counter time stamps to \texttt{XrTime}, while the \texttt{xrConvertTimeToWin32PerformanceCounterKHR} function converts \texttt{XrTime} to Windows performance counter time stamps. The primary use case for this functionality is to be able to synchronize events between the local system and the OpenXR system.

\section*{New Object Types}

\section*{New Flag Types}

\section*{New Enum Constants}

\section*{New Enums}

\section*{New Structures}

\section*{New Functions}

To convert from a Windows performance counter time stamp to \texttt{XrTime}, call:

\begin{verbatim}
XrResult xrConvertWin32PerformanceCounterToTimeKHR(
    XrInstance instance, 
    const LARGE_INTEGER* performanceCounter, 
    XrTime* time);
\end{verbatim}

\section*{Parameter Descriptions}

- \texttt{instance} is an \texttt{XrInstance} handle previously created with \texttt{xrCreateInstance}.
- \texttt{performanceCounter} is a time returned by \texttt{QueryPerformanceCounter}.
- \texttt{time} is the resulting \texttt{XrTime} that is equivalent to the \texttt{performanceCounter}.

The \texttt{xrConvertWin32PerformanceCounterToTimeKHR} function converts a time stamp obtained by the \texttt{QueryPerformanceCounter} Windows function to the equivalent \texttt{XrTime}.

If the output \texttt{time} cannot represent the input \texttt{performanceCounter}, the runtime \textbf{must} return \texttt{XR_ERROR_TIME_INVALID}.
Valid Usage (Implicit)

- The \texttt{XR_KHR_win32_convert_performance_counter_time} extension \textbf{must} be enabled prior to calling \texttt{xrConvertWin32PerformanceCounterToTimeKHR}
- \texttt{instance} \textbf{must} be a valid \texttt{XrInstance} handle
- \texttt{performanceCounter} \textbf{must} be a pointer to a valid \texttt{LARGE_INTEGER} value
- \texttt{time} \textbf{must} be a pointer to an \texttt{XrTime} value

Return Codes

**Success**
- \texttt{XR_SUCCESS}

**Failure**
- \texttt{XR_ERROR_FUNCTION_UNSUPPORTED}
- \texttt{XR_ERROR_VALIDATION_FAILURE}
- \texttt{XR_ERROR_RUNTIME_FAILURE}
- \texttt{XR_ERROR_HANDLE_INVALID}
- \texttt{XR_ERROR_INSTANCE_LOST}
- \texttt{XR_ERROR_TIME_INVALID}

To convert from \texttt{XrTime} to a Windows performance counter time stamp, call:

\begin{verbatim}
XrResult xrConvertTimeToWin32PerformanceCounterKHR(
    XrInstance instance,
    XrTime time,
    LARGE_INTEGER* performanceCounter);
\end{verbatim}

Parameter Descriptions

- \texttt{instance} is an \texttt{XrInstance} handle previously created with \texttt{xrCreateInstance}.
- \texttt{time} is an \texttt{XrTime}.
- \texttt{performanceCounter} is the resulting Windows performance counter time stamp that is equivalent to the \texttt{time}. 
The `xrConvertTimeToWin32PerformanceCounterKHR` function converts an `XrTime` to time as if generated by the `QueryPerformanceCounter` Windows function.

If the output `performanceCounter` cannot represent the input `time`, the runtime must return `XR_ERROR_TIME_INVALID`.

### Valid Usage (Implicit)

- The `XR_KHR_win32_convert_performance_counter_time` extension must be enabled prior to calling `xrConvertTimeToWin32PerformanceCounterKHR`.
- `instance` must be a valid `XrInstance` handle.
- `performanceCounter` must be a pointer to a `LARGE_INTEGER` value.

### Return Codes

**Success**

- `XR_SUCCESS`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_TIME_INVALID`

### Issues

**Version History**

- Revision 1, 2019-01-24 (Paul Pedriana)
  - Initial draft

### 12.24. XR_EXT_conformance_automation

**Name String**

`XR_EXT_conformance_automation`

**Extension Type**

Instance extension
Overview

The XR_EXT_conformance_automation allows conformance test and runtime developers to provide hints to the underlying runtime as to what input the test is expecting. This enables runtime authors to automate the testing of their runtime conformance. This is useful for achieving rapidly iterative runtime development whilst maintaining conformance for runtime releases.

This extension provides the following capabilities:

- The ability to toggle the active state of an input device.
- The ability to set the state of an input device button or other input component.
- The ability to set the location of the input device.

Applications may call these functions at any time. The runtime must do its best to honor the request of applications calling these functions, however it does not guarantee that any state change will be reflected immediately, at all, or with the exact value that was requested. Applications are thus advised to wait for the state change to be observable and to not assume that the value they requested will be the value observed. If any of the functions of this extension are called, control over input must be removed from the physical hardware of the system.
Warning

This extension is **not** intended for use by non-conformance-test applications. A runtime **may** require a runtime-specified configuration such as a "developer mode" to be enabled before reporting support for this extension or providing a non-stub implementation of it.

**Do not** use this functionality in a non-conformance-test application!

New Object Types
New Flag Types
New Enum Constants
New Enums
New Structures
New Functions

```c
XrResult xrSetInputDeviceActiveEXT(
    XrSession session,
    XrPath interactionProfile,
    XrPath topLevelPath,
    XrBool32 isActive);
```

Parameter Descriptions

- **session** is the `XrSession` to set the input device state in.
- **interactionProfile** is the path representing the interaction profile of the input device (e.g. `/interaction_profiles/khr/simple_controller`).
- **topLevelPath** is the path representing the input device (e.g. `/user/hand/left`).
- **isActive** is the requested activation state of the input device.

Valid Usage

- **session must** be a valid session handle.
- **topLevelPath must** be a valid top level path.
Valid Usage (Implicit)

• The `XR_EXT_conformance_automation` extension must be enabled prior to calling `xrSetInputDeviceActiveEXT`.
• `session` must be a valid `XrSession` handle.

Return Codes

Success

• `XR_SUCCESS`
• `XR_SESSION_LOSS_PENDING`

Failure

• `XR_ERROR_FUNCTION_UNSUPPORTED`
• `XR_ERROR_VALIDATION_FAILURE`
• `XR_ERROR_HANDLE_INVALID`
• `XR_ERROR_INSTANCE_LOST`
• `XR_ERROR_SESSION_LOST`
• `XR_ERROR_PATH_UNSUPPORTED`
• `XR_ERROR_PATH_INVALID`

```
XrResult xrSetInputDeviceStateBoolEXT(
    XrSession session,
    XrPath topLevelPath,
    XrPath inputSourcePath,
    XrBool32 state);
```

Parameter Descriptions

• `session` is the `XrSession` to set the input device state in.
• `topLevelPath` is the path representing the input device (e.g. `/user/hand/left`).
• `inputSourcePath` is the full path of the input component for which we wish to set the state for (e.g. `/user/hand/left/input/select/click`).
• `state` is the requested boolean state of the input device.
Valid Usage

- `session` **must** be a valid session handle.
- `topLevelPath` **must** be a valid top level path.
- `inputSourcePath` **must** be a valid input source path.

Valid Usage (Implicit)

- The `XR_EXT_conformance_automation` extension **must** be enabled prior to calling `xrSetInputDeviceStateBoolEXT`
- `session` **must** be a valid `XrSession` handle

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_PATH_INVALID`

```cpp
XrResult xrSetInputDeviceStateFloatEXT(
    XrSession session,
    XrPath topLevelPath,
    XrPath inputSourcePath,
    float state);
```
Parameter Descriptions

- **session** is the XrSession to set the input device state in.
- **topLevelPath** is the path representing the input device (e.g. /user/\hand/\left).
- **inputSourcePath** is the full path of the input component for which we wish to set the state for (e.g. /user/\hand/\left/input/trigger/value).
- **state** is the requested float state of the input device.

Valid Usage

- **session** must be a valid session handle.
- **topLevelPath** must be a valid top level path.
- **inputSourcePath** must be a valid input source path.

Valid Usage (Implicit)

- The XR_EXT_conformance_automation extension must be enabled prior to calling xrSetInputDeviceStateFloatEXT
- **session** must be a valid XrSession handle

Return Codes

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_PATH_INVALID
XrResult xrSetInputDeviceStateVector2fEXT(
    XrSession session,
    XrPath topLevelPath,
    XrPath inputSourcePath,
    XrVector2f state);

**Parameter Descriptions**

- **session** is the XrSession to set the input device state in.
- **topLevelPath** is the path representing the input device (e.g. /user/hand/left).
- **inputSourcePath** is the full path of the input component for which we wish to set the state for (e.g. /user/hand/left/input/thumbstick).
- **state** is the requested two-dimensional state of the input device.

**Valid Usage**

- **session** must be a valid session handle.
- **topLevelPath** must be a valid top level path.
- **inputSourcePath** must be a valid input source path.

**Valid Usage (Implicit)**

- The XR_EXT_conformance_automation extension must be enabled prior to calling xrSetInputDeviceStateVector2fEXT
- **session** must be a valid XrSession handle
Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_PATH_INVALID

XrResult xrSetInputDeviceLocationEXT(
    XrSession session,
    XrPath topLevelPath,
    XrPath inputSourcePath,
    XrSpace space,
    XrPosef pose);

Parameter Descriptions

- session is the XrSession to set the input device state in.
- topLevelPath is the path representing the input device (e.g. /user/hand/left).
- inputSourcePath is the full path of the input component for which we wish to set the pose for (e.g. /user/hand/left/input/grip/pose).
- pose is the requested pose state of the input device.
Valid Usage

• session must be a valid session handle.
• topLevelPath must be a valid top level path.
• inputSourcePath must be a valid input source path.

Valid Usage (Implicit)

• The XR_EXT_conformance_automation extension must be enabled prior to calling xrSetInputDeviceLocationEXT
• session must be a valid XrSession handle
• space must be a valid XrSpace handle
• space must have been created, allocated, or retrieved from session

Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_POSE_INVALID
• XR_ERROR_PATH_UNSUPPORTED
• XR_ERROR_PATH_INVALID

New Function Pointers

Issues

None

Version History

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12.25. XR_EXT_debug_utils

Name String
XR_EXT_debug_utils

Extension Type
Instance extension

Registered Extension Number
20

Revision
4

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2021-04-14

IP Status
No known IP claims.

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Overview

Due to the nature of the OpenXR interface, there is very little error information available to the developer and application. By using the XR_EXT_debug_utils extension, developers can obtain more information. When combined with validation layers, even more detailed feedback on the application’s use of OpenXR will be provided.

This extension provides the following capabilities:
• The ability to create a debug messenger which will pass along debug messages to an application supplied callback.
• The ability to identify specific OpenXR handles using a name to improve tracking.

12.25.1. Object Debug Annotation

It can be useful for an application to provide its own content relative to a specific OpenXR handle.

Object Naming

xrSetDebugUtilsObjectNameEXT allows application developers to associate user-defined information with OpenXR handles.

This is useful when paired with the callback that you register when creating an XrDebugUtilsMessengerEXT object. When properly used, debug messages will contain not only the corresponding object handle, but the associated object name as well.

An application can change the name associated with an object simply by calling xrSetDebugUtilsObjectNameEXT again with a new string. If the objectName member of the XrDebugUtilsObjectNameInfoEXT structure is an empty string, then any previously set name is removed.

12.25.2. Debug Messengers

OpenXR allows an application to register arbitrary number of callbacks with all the OpenXR components wishing to report debug information. Some callbacks can log the information to a file, others can cause a debug break point or any other behavior defined by the application. A primary producer of callback messages are the validation layers. If the extension is enabled, an application can register callbacks even when no validation layers are enabled. The OpenXR loader, other layers, and runtimes may also produce callback messages.

The debug messenger will provide detailed feedback on the application’s use of OpenXR when events of interest occur. When an event of interest does occur, the debug messenger will submit a debug message to the debug callback that was provided during its creation. Additionally, the debug messenger is responsible with filtering out debug messages that the callback isn’t interested in and will only provide desired debug messages.

12.25.3. Debug Message Categorization

Messages that are triggered by the debug messenger are categorized by their message type and severity. Additionally, each message has a string value identifying its messageId. These 3 bits of information can be used to filter out messages so you only receive reports on the messages you desire. In fact, during debug messenger creation, the severity and type flag values are provided to indicate what messages should be allowed to trigger the user’s callback.
**Message Type**

The message type indicates the general category the message falls under. Currently we have the following message types:

*Table 4. XR_EXT_debug_utils Message Type Flag Descriptions*

<table>
<thead>
<tr>
<th>Enum</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_DEBUG_UTILS_MESSAGE_TYPE_GENERAL_BIT_EXT</td>
<td>Specifies a general purpose event type. This is typically a non-validation, non-performance event.</td>
</tr>
<tr>
<td>XR_DEBUG_UTILS_MESSAGE_TYPE_VALIDATION_BIT_EXT</td>
<td>Specifies an event caused during a validation against the OpenXR specification that may indicate invalid OpenXR usage.</td>
</tr>
<tr>
<td>XR_DEBUG_UTILS_MESSAGE_TYPE_PERFORMANCE_BIT_EXT</td>
<td>Specifies a potentially non-optimal use of OpenXR.</td>
</tr>
<tr>
<td>XR_DEBUG_UTILS_MESSAGE_TYPE_CONFORMANCE_BIT_EXT</td>
<td>Specifies a non-conformant OpenXR result. This is typically caused by a layer or runtime returning non-conformant data.</td>
</tr>
</tbody>
</table>

A message may correspond to more than one type. For example, if a validation warning also could impact performance, then the message might be identified with both the XR_DEBUG_UTILS_MESSAGE_TYPE_VALIDATION_BIT_EXT and XR_DEBUG_UTILS_MESSAGE_TYPE_PERFORMANCE_BIT_EXT flag bits.

**Message Severity**

The severity of a message is a flag that indicates how important the message is using standard logging naming. The severity flag bit values are shown in the following table.

*Table 5. XR_EXT_debug_utils Message Severity Flag Descriptions*

<table>
<thead>
<tr>
<th>Enum</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_DEBUG_UTILS_MESSAGE_SEVERITY_VERBOSE_BIT_EXT</td>
<td>Specifies the most verbose output indicating all diagnostic messages from the OpenXR loader, layers, and drivers should be captured.</td>
</tr>
<tr>
<td>XR_DEBUG_UTILS_MESSAGE_SEVERITY_INFO_BIT_EXT</td>
<td>Specifies an informational message such as resource details that might be handy when debugging an application.</td>
</tr>
<tr>
<td>Enum</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>XR_DEBUG_UTILS_MESSAGE_SEVERITY_WARNING_BIT_EXT</td>
<td>Specifies use of OpenXR that could be an application bug. Such cases <strong>may</strong> not be immediately harmful, such as providing too many swapchain images. Other cases <strong>may</strong> point to behavior that is almost certainly bad when unintended, such as using a swapchain image whose memory has not been filled. In general, if you see a warning but you know that the behavior is intended/desired, then simply ignore the warning.</td>
</tr>
<tr>
<td>XR_DEBUG_UTILS_MESSAGE_SEVERITY_ERROR_BIT_EXT</td>
<td>Specifies an error that <strong>may</strong> cause undefined behavior, including an application crash.</td>
</tr>
</tbody>
</table>

**Note**

The values of `XrDebugUtilsMessageSeverityFlagBitsEXT` are sorted based on severity. The higher the flag value, the more severe the message. This allows for simple boolean operation comparisons when looking at `XrDebugUtilsMessageSeverityFlagBitsEXT` values.

**Message IDs**

The `XrDebugUtilsMessengerCallbackDataEXT` structure contains a `messageId` that may be a string identifying the message ID for the triggering debug message. This may be blank, or it may simply contain the name of an OpenXR component (like "OpenXR Loader"). However, when certain API layers or runtimes are used, especially the OpenXR core_validation API layer, then this value is intended to uniquely identify the message generated. If a certain warning/error message constantly fires, a user can simply look at the unique ID in their callback handler and manually filter it out.

For validation layers, this `messageId` value actually can be used to find the section of the OpenXR specification that the layer believes to have been violated. See the core_validation API Layer documentation for more information on how this can be done.

### 12.25.4. Session Labels

All OpenXR work is performed inside of an `XrSession`. There are times that it helps to label areas in your OpenXR session to allow easier debugging. This can be especially true if your application creates more than one session. There are two kinds of labels provided in this extension:

- Region labels
- Individual labels

To begin identifying a region using a debug label inside a session, you may use the `xrSessionBeginDebugUtilsLabelRegionEXT` function. Calls to `xrSessionBeginDebugUtilsLabelRegionEXT`
may be nested allowing you to identify smaller and smaller labeled regions within your code. Using this, you can build a “call-stack” of sorts with labels since any logging callback will contain the list of all active session label regions.

To end the last session label region that was begun, you **must** call `xrSessionEndDebugUtilsLabelRegionEXT`. Each `xrSessionBeginDebugUtilsLabelRegionEXT` **must** have a matching `xrSessionEndDebugUtilsLabelRegionEXT`. All of a session’s label region’s **must** be closed by the `xrDestroySession` function is called for the given `XrSession`.

An individual debug label may be inserted at any time using `xrSessionInsertDebugUtilsLabelEXT`. The `xrSessionInsertDebugUtilsLabelEXT` is used to indicate a particular location within the execution of the application’s session functions. The next call to `xrSessionInsertDebugUtilsLabelEXT`, `xrSessionBeginDebugUtilsLabelRegionEXT`, or `xrSessionEndDebugUtilsLabelRegionEXT` overrides this value.

**New Object Types**

```c
XR_DEFINE_HANDLE(XrDebugUtilsMessengerEXT)
```

`XrDebugUtilsMessengerEXT` represents a callback function and associated filters registered with the runtime.

**New Flag Types**

```c
typedef XrFlags64 XrDebugUtilsMessageSeverityFlagsEXT;
```

```c
// Flag bits for XrDebugUtilsMessageSeverityFlagsEXT
static const XrDebugUtilsMessageSeverityFlagsEXT
  XR_DEBUG_UTILS_MESSAGE_SEVERITY_VERBOSE_BIT_EXT = 0x00000001;
static const XrDebugUtilsMessageSeverityFlagsEXT
  XR_DEBUG_UTILS_MESSAGE_SEVERITY_INFO_BIT_EXT = 0x00000010;
static const XrDebugUtilsMessageSeverityFlagsEXT
  XR_DEBUG_UTILS_MESSAGE_SEVERITY_WARNING_BIT_EXT = 0x00000100;
static const XrDebugUtilsMessageSeverityFlagsEXT
  XR_DEBUG_UTILS_MESSAGE_SEVERITY_ERROR_BIT_EXT = 0x00001000;
```
typedef XrFlags64 XrDebugUtilsMessageTypeFlagsEXT;

// Flag bits for XrDebugUtilsMessageTypeFlagsEXT
static const XrDebugUtilsMessageTypeFlagsEXT XR_DEBUG_UTILS_MESSAGE_TYPE_GENERAL_BIT_EXT = 0x00000001;
static const XrDebugUtilsMessageTypeFlagsEXT XR_DEBUG_UTILS_MESSAGE_TYPE_VALIDATION_BIT_EXT = 0x00000002;
static const XrDebugUtilsMessageTypeFlagsEXT XR_DEBUG_UTILS_MESSAGE_TYPE_PERFORMANCE_BIT_EXT = 0x00000004;
static const XrDebugUtilsMessageTypeFlagsEXT XR_DEBUG_UTILS_MESSAGE_TYPE_CONFORMANCE_BIT_EXT = 0x00000008;

New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_DEBUG_UTILS_OBJECT_NAME_INFO_EXT
- XR_TYPE_DEBUG_UTILS_MESSENGER_CALLBACK_DATA_EXT
- XR_TYPE_DEBUG_UTILS_MESSENGER_CREATE_INFO_EXT
- XR_TYPE_DEBUG_UTILS_LABEL_EXT

New Enums

New Structures

typedef struct XrDebugUtilsObjectNameInfoEXT {
    XrStructureType type;
    const void* next;
    XrObjectType objectType;
    uint64_t objectHandle;
    const char* objectName;
} XrDebugUtilsObjectNameInfoEXT;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **objectType** is an `XrObjectType` specifying the type of the object to be named.
- **objectHandle** is the object to be named.
- **objectName** is a `NULL` terminated UTF-8 string specifying the name to apply to `objectHandle`.

Valid Usage

- If `objectType` is `XR_OBJECT_TYPE_UNKNOWN`, `objectHandle` must not be `XR_NULL_HANDLE`.
- If `objectType` is not `XR_OBJECT_TYPE_UNKNOWN`, `objectHandle` must be `XR_NULL_HANDLE` or an OpenXR handle of the type associated with `objectType`.

Valid Usage (Implicit)

- The `XR_EXT_debug_utils` extension must be enabled prior to using `XrDebugUtilsObjectNameInfoEXT`.
- **type** must be `XR_TYPE_DEBUG_UTILS_OBJECT_NAME_INFO_EXT`.
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain.
- **objectType** must be a valid `XrObjectType` value.
- If `objectName` is not `NULL`, `objectName` must be a null-terminated UTF-8 string.

typedef struct XrDebugUtilsLabelEXT {
    XrStructureType type;
    const void* next;
    const char* labelName;
} XrDebugUtilsLabelEXT;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **labelName** is a NULL terminated UTF-8 string specifying the label name.

Valid Usage (Implicit)

- The XR_EXT_debug_utils extension **must** be enabled prior to using XrDebugUtilsLabelEXT
- **type** **must** be XR_TYPE_DEBUG_UTILS_LABEL_EXT
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain
- **labelName** **must** be a null-terminated UTF-8 string

typedef struct XrDebugUtilsMessengerCallbackDataEXT {
    XrStructureType                   type;
    const void*                       next;
    const char*                       messageId;
    const char*                       functionName;
    const char*                       message;
    uint32_t                          objectCount;
    XrDebugUtilsObjectNameInfoEXT*    objects;
    uint32_t                          sessionLabelCount;
    XrDebugUtilsLabelEXT*             sessionLabels;
} XrDebugUtilsMessengerCallbackDataEXT;
Member Descriptions

- **type** is the XrStructureType of this structure.

- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

- **messageId** is a NULL terminated string that identifies the message in a unique way. If the callback is triggered by a validation layer, this string corresponds the Valid Usage ID (VUID) that can be used to jump to the appropriate location in the OpenXR specification. This value may be NULL if no unique message identifier is associated with the message.

- **functionName** is a NULL terminated string that identifies the OpenXR function that was executing at the time the message callback was triggered. This value may be NULL in cases where it is difficult to determine the originating OpenXR function.

- **message** is a NULL terminated string detailing the trigger conditions.

- **objectCount** is a count of items contained in the **objects** array. This may be 0.

- **objects** is a pointer to an array of XrDebugUtilsObjectNameInfoEXT objects related to the detected issue. The array is roughly in order or importance, but the 0th element is always guaranteed to be the most important object for this message.

- **sessionLabelCount** is a count of items contained in the **sessionLabels** array. This may be 0.

- **sessionLabels** is a pointer to an array of XrDebugUtilsLabelEXT objects related to the detected issue. The array is roughly in order or importance, but the 0th element is always guaranteed to be the most important object for this message.

- **sessionLabels** is NULL or a pointer to an array of XrDebugUtilsLabelEXT active in the current XrSession at the time the callback was triggered. Refer to Session Labels for more information.

Valid Usage (Implicit)

- The XR_EXT_debug_utils extension must be enabled prior to using XrDebugUtilsMessengerCallbackDataEXT

- **type** must be XR_TYPE_DEBUG_UTILS_MESSENGER_CALLBACK_DATA_EXT

- **next** must be NULL or a valid pointer to the next structure in a structure chain

- **messageId** must be a null-terminated UTF-8 string

- **functionName** must be a null-terminated UTF-8 string

- **message** must be a null-terminated UTF-8 string

An XrDebugUtilsMessengerCallbackDataEXT is a messenger object that handles passing along debug messages to a provided debug callback.
This structure should only be considered valid during the lifetime of the triggered callback.

The labels listed inside sessionLabels are organized in time order, with the most recently generated label appearing first, and the oldest label appearing last.

```c
typedef struct XrDebugUtilsMessengerCreateInfoEXT {
    XrStructureType                         type;
    const void*                             next;
    XrDebugUtilsMessageSeverityFlagsEXT     messageSeverities;
    XrDebugUtilsMessageTypeFlagsEXT         messageTypes;
    PFN_xrDebugUtilsMessengerCallbackEXT    userCallback;
    void*                                   userData;
} XrDebugUtilsMessengerCreateInfoEXT;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **messageSeverities** is a bitmask of `XrDebugUtilsMessageSeverityFlagBitsEXT` specifying which severity of event(s) that will cause this callback to be called.
- **messageTypes** is a combination of `XrDebugUtilsMessageTypeFlagBitsEXT` specifying which type of event(s) will cause this callback to be called.
- **userCallback** is the application defined callback function to call.
- **userData** is arbitrary user data to be passed to the callback.

**Valid Usage**

- **userCallback** must be a valid `PFN_xrDebugUtilsMessengerCallbackEXT`
Valid Usage (Implicit)

- The `XR_EXT_debug_utils` extension must be enabled prior to using `XrDebugUtilsMessengerCreateInfoEXT`.
- `type` must be `XR_TYPE_DEBUG_UTILS_MESSENGER_CREATE_INFO_EXT`.
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain.
- `messageSeverities` must be a valid combination of `XrDebugUtilsMessageSeverityFlagBitsEXT` values.
- `messageSeverities` must not be `0`.
- `messageTypes` must be a valid combination of `XrDebugUtilsMessageTypeFlagBitsEXT` values.
- `messageTypes` must not be `0`.
- `userCallback` must be a valid `PFN_xrDebugUtilsMessengerCallbackEXT` value.

For each `XrDebugUtilsMessengerEXT` that is created the `XrDebugUtilsMessengerCreateInfoEXT::messageSeverities` and `XrDebugUtilsMessengerCreateInfoEXT::messageTypes` determine when that `XrDebugUtilsMessengerCreateInfoEXT::userCallback` is called. The process to determine if the user's `userCallback` is triggered when an event occurs is as follows:

- The runtime will perform a bitwise AND of the event's `XrDebugUtilsMessageSeverityFlagBitsEXT` with the `XrDebugUtilsMessengerCreateInfoEXT::messageSeverities` provided during creation of the `XrDebugUtilsMessengerEXT` object.
- If this results in `0`, the message is skipped.
- The runtime will perform bitwise AND of the event's `XrDebugUtilsMessageTypeFlagBitsEXT` with the `XrDebugUtilsMessengerCreateInfoEXT::messageTypes` provided during the creation of the `XrDebugUtilsMessengerEXT` object.
- If this results in `0`, the message is skipped.
- If the message of the current event is not skipped, the callback will be called with the message.

The callback will come directly from the component that detected the event, unless some other layer intercepts the calls for its own purposes (filter them in a different way, log to a system error log, etc.).

An application can receive multiple callbacks if multiple `XrDebugUtilsMessengerEXT` objects are created. A callback will always be executed in the same thread as the originating OpenXR call.

---

**Note**

A callback can be called from multiple threads simultaneously if the application is making OpenXR calls from multiple threads.

---

New Functions
XrResult xrSetDebugUtilsObjectNameEXT(
    XrInstance instance,
    const XrDebugUtilsObjectNameInfoEXT* nameInfo);

Parameter Descriptions

• instance is the XrInstance that the object was created under.
• nameInfo is a pointer to an instance of the XrDebugUtilsObjectNameInfoEXT structure specifying the parameters of the name to set on the object.

Valid Usage

• In the structure pointed to by nameInfo, XrDebugUtilsObjectNameInfoEXT::objectType must not be XR_OBJECT_TYPE_UNKNOWN
• In the structure pointed to by nameInfo, XrDebugUtilsObjectNameInfoEXT::objectHandle must not be XR_NULL_HANDLE

Valid Usage (Implicit)

• The XR_EXT_debug_utils extension must be enabled prior to calling xrSetDebugUtilsObjectNameEXT
• instance must be a valid XrInstance handle
• nameInfo must be a pointer to a valid XrDebugUtilsObjectNameInfoEXT structure

Thread Safety

• Access to the objectHandle member of the nameInfo parameter must be externally synchronized
Return Codes

Success

• XR_SUCCESS

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_OUT_OF_MEMORY

Applications may change the name associated with an object simply by calling `xrSetDebugUtilsObjectNameEXT` again with a new string. If `XrDebugUtilsObjectNameInfoEXT::objectName` is an empty string, then any previously set name is removed.

```c
XrResult xrCreateDebugUtilsMessengerEXT(
    XrInstance instance,
    const XrDebugUtilsMessengerCreateInfoEXT* createInfo,
    XrDebugUtilsMessengerEXT* messenger);
```

Parameter Descriptions

• `instance` is the instance the messenger will be used with.

• `createInfo` points to an `XrDebugUtilsMessengerCreateInfoEXT` structure, which contains the callback pointer as well as defines the conditions under which this messenger will trigger the callback.

• `messenger` is a pointer to which the created `XrDebugUtilsMessengerEXT` object is returned.
Valid Usage (Implicit)

- The `XR_EXT_debug_utils` extension must be enabled prior to calling `xrCreateDebugUtilsMessengerEXT`
- `instance` must be a valid `XrInstance` handle
- `createInfo` must be a pointer to a valid `XrDebugUtilsMessengerCreateInfoEXT` structure
- `messenger` must be a pointer to an `XrDebugUtilsMessengerEXT` handle

Thread Safety

- Access to `instance`, and any child handles, must be externally synchronized

Return Codes

Success

- `XR_SUCCESS`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_LIMIT_REACHED`

The application must ensure that `xrCreateDebugUtilsMessengerEXT` is not executed in parallel with any OpenXR function that is also called with `instance` or child of `instance`.

When an event of interest occurs a debug messenger calls its `createInfo->userCallback` with a debug message from the producer of the event. Additionally, the debug messenger must filter out any debug messages that the application's callback is not interested in based on `XrDebugUtilsMessengerCreateInfoEXT` flags, as described below.
XrResult xrDestroyDebugUtilsMessengerEXT(XrDebugUtilsMessengerEXT messenger);

Parameter Descriptions

- messenger the XrDebugUtilsMessengerEXT object to destroy. messenger is an externally synchronized object and must not be used on more than one thread at a time. This means that xrDestroyDebugUtilsMessengerEXT must not be called when a callback is active.

Valid Usage (Implicit)

- The XR_EXT_debug_utils extension must be enabled prior to calling xrDestroyDebugUtilsMessengerEXT
- messenger must be a valid XrDebugUtilsMessengerEXT handle

Thread Safety

- Access to messenger must be externally synchronized
- Access to the XrInstance used to create messenger, and all of its child handles must be externally synchronized

Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_HANDLE_INVALID

The application must ensure that xrDestroyDebugUtilsMessengerEXT is not executed in parallel with any OpenXR function that is also called with the instance or child of instance that it was created with.
XrResult xrSubmitDebugUtilsMessageEXT(
    XrInstance instance,
    XrDebugUtilsMessageSeverityFlagsEXT messageSeverity,
    XrDebugUtilsMessageTypeFlagsEXT messageTypes,
    const XrDebugUtilsMessengerCallbackDataEXT* callbackData);

Parameter Descriptions

• `instance` is the debug stream's `XrInstance`.

• `messageSeverity` is a single bit value of `XrDebugUtilsMessageSeverityFlagsEXT` severity of this event/message.

• `messageTypes` is an `XrDebugUtilsMessageTypeFlagsEXT` bitmask of `XrDebugUtilsMessageTypeFlagBitsEXT` specifying which types of event to identify this message with.

• `callbackData` contains all the callback related data in the `XrDebugUtilsMessengerCallbackDataEXT` structure.

Valid Usage

• For each structure in `objects` found in `callbackData`, the value of `XrDebugUtilsObjectNameInfoEXT::objectType` must not be `XR_OBJECT_TYPE_UNKNOWN`

Valid Usage (Implicit)

• The `XR_EXT_debug_utils` extension must be enabled prior to calling `xrSubmitDebugUtilsMessageEXT`

• `instance` must be a valid `XrInstance` handle

• `messageSeverity` must be a valid combination of `XrDebugUtilsMessageSeverityFlagBitsEXT` values

• `messageSeverity` must not be 0

• `messageTypes` must be a valid combination of `XrDebugUtilsMessageTypeFlagBitsEXT` values

• `messageTypes` must not be 0

• `callbackData` must be a pointer to a valid `XrDebugUtilsMessengerCallbackDataEXT` structure
Return Codes

Success
  • XR_SUCCESS

Failure
  • XR_ERROR_FUNCTION_UNSUPPORTED
  • XR_ERROR_VALIDATION_FAILURE
  • XR_ERROR_RUNTIME_FAILURE
  • XR_ERROR_HANDLE_INVALID
  • XR_ERROR_INSTANCE_LOST

The application can also produce a debug message, and submit it into the OpenXR messaging system.

The call will propagate through the layers and generate callback(s) as indicated by the message's flags. The parameters are passed on to the callback in addition to the userData value that was defined at the time the messenger was created.

XrResult xrSessionBeginDebugUtilsLabelRegionEXT(
  XrSession                                   session,
  const XrDebugUtilsLabelEXT*                 labelInfo);

Parameter Descriptions

• session is the XrSession that a label region should be associated with.

• labelInfo is the XrDebugUtilsLabelEXT containing the label information for the region that should be begun.

Valid Usage (Implicit)

• The XR_EXT_debug_utils extension must be enabled prior to calling xrSessionBeginDebugUtilsLabelRegionEXT

• session must be a valid XrSession handle

• labelInfo must be a pointer to a valid XrDebugUtilsLabelEXT structure
**Return Codes**

**Success**
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST

The `xrSessionBeginDebugUtilsLabelRegionEXT` function begins a label region within `session`.

```c
XrResult xrSessionEndDebugUtilsLabelRegionEXT(
    XrSession session);
```

**Parameter Descriptions**
- `session` is the `XrSession` that a label region should be associated with.

**Valid Usage**
- `xrSessionEndDebugUtilsLabelRegionEXT` **must** be called only after a matching `xrSessionBeginDebugUtilsLabelRegionEXT`.

**Valid Usage (Implicit)**
- The `XR_EXT_debug_utils` extension **must** be enabled prior to calling `xrSessionEndDebugUtilsLabelRegionEXT`
- `session` **must** be a valid `XrSession` handle
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST

This function ends the last label region begun with the `xrSessionBeginDebugUtilsLabelRegionEXT` function within the same `session`.

```c
XrResult xrSessionInsertDebugUtilsLabelEXT(
    XrSession session,
    const XrDebugUtilsLabelEXT* labelInfo);
```

Parameter Descriptions

- `session` is the `XrSession` that a label region should be associated with.
- `labelInfo` is the `XrDebugUtilsLabelEXT` containing the label information for the region that should be begun.

Valid Usage (Implicit)

- The `XR_EXT_debug_utils` extension must be enabled prior to calling `xrSessionInsertDebugUtilsLabelEXT`
- `session` must be a valid `XrSession` handle
- `labelInfo` must be a pointer to a valid `XrDebugUtilsLabelEXT` structure
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST

The `xrSessionInsertDebugUtilsLabelEXT` function inserts an individual label within session. The individual labels are useful for different reasons based on the type of debugging scenario. When used with something active like a profiler or debugger, it identifies a single point of time. When used with logging, the individual label identifies that a particular location has been passed at the point the log message is triggered. Because of this usage, individual labels only exist in a log until the next call to any of the label functions:

- `xrSessionBeginDebugUtilsLabelRegionEXT`
- `xrSessionEndDebugUtilsLabelRegionEXT`
- `xrSessionInsertDebugUtilsLabelEXT`

New Function Pointers

typedef XrBool32 (XRAPI_PTR *PFN_xrDebugUtilsMessengerCallbackEXT)(
    XrDebugUtilsMessageSeverityFlagsEXT messageSeverity,
    XrDebugUtilsMessageTypeFlagsEXT messageTypes,
    const XrDebugUtilsMessengerCallbackDataEXT* callbackData,
    void* userData);

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Parameter Descriptions

- `messageSeverity` indicates the single bit value of `XrDebugUtilsMessageSeverityFlagsEXT` that triggered this callback.
- `messageTypes` indicates the `XrDebugUtilsMessageTypeFlagsEXT` specifying which types of event triggered this callback.
- `callbackData` contains all the callback related data in the `XrDebugUtilsMessengerCallbackDataEXT` structure.
- `userData` is the user data provided when the `XrDebugUtilsMessengerEXT` was created.

The callback must not call `xrDestroyDebugUtilsMessengerEXT`.

The callback returns an `XrBool32` that indicates to the calling layer the application's desire to abort the call. A value of `XR_TRUE` indicates that the application wants to abort this call. If the application returns `XR_FALSE`, the function must not be aborted. Applications should always return `XR_FALSE` so that they see the same behavior with and without validation layers enabled.

If the application returns `XR_TRUE` from its callback and the OpenXR call being aborted returns an `XrResult`, the layer will return `XR_ERROR_VALIDATION_FAILURE`.

The object pointed to by `callbackData` (and any pointers in it recursively) must be valid during the lifetime of the triggered callback. It may become invalid afterwards.

**Examples**

**Example 1**

`XR_EXT_debug_utils` allows an application to register multiple callbacks with any OpenXR component wishing to report debug information. Some callbacks may log the information to a file, others may cause a debug break point or other application defined behavior. An application can register callbacks even when no validation layers are enabled, but they will only be called for loader and, if implemented, driver events.

To capture events that occur while creating or destroying an instance an application can link an `XrDebugUtilsMessengerCreateInfoEXT` structure to the next element of the `XrInstanceCreateInfo` structure given to `xrCreateInstance`. This callback is only valid for the duration of the `xrCreateInstance` and the `xrDestroyInstance` call. Use `xrCreateDebugUtilsMessengerEXT` to create persistent callback objects.

Example uses: Create three callback objects. One will log errors and warnings to the debug console using Windows `OutputDebugString`. The second will cause the debugger to break at that callback when an error happens and the third will log warnings to stdout.

```c
extern XrInstance instance; // previously initialized
```
// Must call extension functions through a function pointer:
PFN_xrCreateDebugUtilsMessengerEXT pfnCreateDebugUtilsMessengerEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrCreateDebugUtilsMessengerEXT",
reinterpret_cast<PFN_xrVoidFunction*>(
&pfnCreateDebugUtilsMessengerEXT)));

PFN_xrDestroyDebugUtilsMessengerEXT pfnDestroyDebugUtilsMessengerEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrDestroyDebugUtilsMessengerEXT",
reinterpret_cast<PFN_xrVoidFunction*>(
&pfnDestroyDebugUtilsMessengerEXT)));

XrDebugUtilsMessengerCreateInfoEXT callback1 = {
    XR_TYPE_DEBUG_UTILS_MESSENGER_CREATE_INFO_EXT,   // type
    NULL,                                            // next
    XR_DEBUG_UTILS_MESSAGE_SEVERITY_ERROR_BIT_EXT,   // messageSeverities
    XR_DEBUG_UTILS_MESSAGE_SEVERITY_WARNING_BIT_EXT, // messageSeverities
    XR_DEBUG_UTILS_MESSAGE_TYPE_GENERAL_BIT_EXT,     // messageTypes
    XR_DEBUG_UTILS_MESSAGE_TYPE_VALIDATION_BIT_EXT,  // messageTypes
    myOutputDebugString,  // userCallback
    NULL                  // userData
};
XrDebugUtilsMessengerEXT messenger1 = XR_NULL_HANDLE;
CHK_XR(pfnCreateDebugUtilsMessengerEXT(instance, &callback1, &messenger1));

callback1.messageSeverities = XR_DEBUG_UTILS_MESSAGE_SEVERITY_ERROR_BIT_EXT;
callback1.userCallback = myDebugBreak;
callback1.userData = NULL;
XrDebugUtilsMessengerEXT messenger2 = XR_NULL_HANDLE;
CHK_XR(pfnCreateDebugUtilsMessengerEXT(instance, &callback1, &messenger2));

XrDebugUtilsMessengerCreateInfoEXT callback3 = {
    XR_TYPE_DEBUG_UTILS_MESSENGER_CREATE_INFO_EXT,    // type
    NULL,                                             // next
    XR_DEBUG_UTILS_MESSAGE_SEVERITY_WARNING_BIT_EXT,  // messageSeverities
    XR_DEBUG_UTILS_MESSAGE_TYPE_GENERAL_BIT_EXT |     // messageTypes
    XR_DEBUG_UTILS_MESSAGE_TYPE_VALIDATION_BIT_EXT,  // messageTypes
    myStdOutLogger,  // userCallback
    NULL             // userData
};
XrDebugUtilsMessengerEXT messenger3 = XR_NULL_HANDLE;
CHK_XR(pfnCreateDebugUtilsMessengerEXT(instance, &callback3, &messenger3));

// ...

// Remove callbacks when cleaning up
pfnDestroyDebugUtilsMessengerEXT(messenger1);
pfnDestroyDebugUtilsMessengerEXT(messenger2);
Example 2

Associate a name with an **XrSpace**, for easier debugging in external tools or with validation layers that can print a friendly name when referring to objects in error messages.

```c
extern XrInstance instance;  // previously initialized
extern XrSpace space;        // previously initialized

// Must call extension functions through a function pointer:
PFN_xrSetDebugUtilsObjectNameEXT pfnSetDebugUtilsObjectNameEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrSetDebugUtilsObjectNameEXT",
    reinterpret_cast<PFN_xrVoidFunction*>(
        &pfnSetDebugUtilsObjectNameEXT)));

// Set a name on the space
const XrDebugUtilsObjectNameInfoEXT spaceNameInfo = {
    XR_TYPE_DEBUG_UTILS_OBJECT_NAME_INFO_EXT,  // type
    NULL,                                      // next
    XR_OBJECT_TYPE_SPACE,                      // objectType
    (uint64_t)space,                           // objectHandle
    "My Object-Specific Space",                // objectName
};

pfnSetDebugUtilsObjectNameEXT(instance, &spaceNameInfo);
```

// A subsequent error might print:
// Space "My Object-Specific Space" (0xc0dec0dedeadbeef) is used
// with an XrSession that is not it's parent.

Example 3

Labeling the workload with naming information so that any form of analysis can display a more usable visualization of where actions occur in the lifetime of a session.

```c
extern XrInstance instance;  // previously initialized
extern XrSession session;    // previously initialized

// Must call extension functions through a function pointer:
PFN_xrSessionBeginDebugUtilsLabelRegionEXT pfnSessionBeginDebugUtilsLabelRegionEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrSessionBeginDebugUtilsLabelRegionEXT",
    reinterpret_cast<PFN_xrVoidFunction*>(
        &pfnSessionBeginDebugUtilsLabelRegionEXT)));
```
PFN_xrSessionEndDebugUtilsLabelRegionEXT pfnSessionEndDebugUtilsLabelRegionEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrSessionEndDebugUtilsLabelRegionEXT",
  reinterpret_cast<PFN_xrVoidFunction*>(
    &pfnSessionEndDebugUtilsLabelRegionEXT)));

PFN_xrSessionInsertDebugUtilsLabelEXT pfnSessionInsertDebugUtilsLabelEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrSessionInsertDebugUtilsLabelEXT",
  reinterpret_cast<PFN_xrVoidFunction*>(
    &pfnSessionInsertDebugUtilsLabelEXT)));

XrSessionBeginInfo session_begin_info = {
  XR_TYPE_SESSION_BEGIN_INFO,
  nullptr,
  XR_VIEW_CONFIGURATION_TYPE_PRIMARY_STEREO
};
xrBeginSession(session, &session_begin_info);

const XrDebugUtilsLabelEXT session_active_region_label = {
  XR_TYPE_DEBUG_UTILS_LABEL_EXT,  // type
  NULL,                           // next
  "Session active",               // labelName
};

// Start an annotated region of calls under the 'Session Active' name
pfnSessionBeginDebugUtilsLabelRegionEXT(session, &session_active_region_label);

// Brackets added for clarity
{
  XrDebugUtilsLabelEXT individual_label = {
    XR_TYPE_DEBUG_UTILS_LABEL_EXT,  // type
    NULL,                           // next
    "WaitFrame",                    // labelName
  };

  const char wait_frame_label[] = "WaitFrame";
  individual_label.labelName = wait_frame_label;
  pfnSessionInsertDebugUtilsLabelEXT(session, &individual_label);
  XrFrameWaitInfo wait_frame_info; // initialization omitted for readability
  XrFrameState frame_state = {XR_TYPE_FRAME_STATE, nullptr};
  xrWaitFrame(session, &wait_frame_info, &frame_state);

  // Do stuff 1

  const XrDebugUtilsLabelEXT session_frame_region_label = {
    XR_TYPE_DEBUG_UTILS_LABEL_EXT,  // type
    NULL,                           // next
    "Session Frame 123",            // labelName
  };

  // Do stuff 2

  // Do stuff 3
}
In the above example, if an error occurred in the // Do stuff 1 section, then your debug utils callback would contain the following data in its sessionLabels array:

- [0] = individual_label with labelName = "WaitFrame"
- [1] = session_active_region_label with labelName = "Session active"

However, if an error occurred in the // Do stuff 2 section, then your debug utils callback would contain the following data in its sessionLabels array:

- [0] = individual_label with labelName = "BeginFrame"
- [1] = session_frame_region_label with labelName = "Session Frame 123"
- [2] = session_active_region_label with labelName = "Session active"
You’ll notice that “WaitFrame” is no longer available as soon as the next call to another function like `xrSessionBeginDebugUtilsLabelRegionEXT`.

**Issues**

None

**Version History**

- **Revision 1, 2018-02-19 (Mark Young / Karl Schultz)**
  - Initial draft, based on VK_EXT_debug_utils.
- **Revision 2, 2018-11-16 (Mark Young)**
  - Clean up some language based on changes going into the Vulkan VK_EXT_debug_utils extension by Peter Kraus (aka @krOoze).
  - Added session labels
- **Revision 3, 2019-07-19 (Ryan Pavlik)**
  - Update examples.
  - Improve formatting.
- **Revision 4, 2021-04-04 (Ryan Pavlik)**
  - Fix missing error code.
  - Improve formatting.

**12.26. XR_EXT_dpad_binding**

**Name String**

`XR_EXT_dpad_binding`

**Extension Type**

Instance extension

**Registered Extension Number**

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**Revision**

1

**Extension and Version Dependencies**

- Requires OpenXR 1.0
- Requires `XR_KHR_binding_modification`
Overview

This extension allows the application to bind one or more digital actions to a trackpad or thumbstick as though it were a dpad by defining additional component paths to suggest bindings for. The behavior of this dpad-like mapping may be customized using `XrInteractionProfileDpadBindingEXT`.

Applications **must** also enable the `XR_KHR_binding_modification` extension that this builds on top of.

New Component Paths

When this extension is enabled, a runtime **must** accept otherwise-valid suggested bindings that refer to the following component paths added to certain existing input source paths.

- For a given interaction profile,
  - For each **input source path** valid in that interaction profile that has identifier `trackpad` but without a component specified (i.e. `.../input/trackpad` or `.../input/trackpad_<location>`), a runtime **must** accept the following components appended to that path in a suggested binding:
    - `.../dpad_up`
    - `.../dpad_down`
    - `.../dpad_left`
    - `.../dpad_right`
    - `.../dpad_center`
  - For each **input source path** valid in that interaction profile that has identifier `thumbstick` but without a component specified (i.e. `.../input/thumbstick` or `.../input/thumbstick_<location>`), a runtime **must** accept the following components appended to that path in a suggested binding:
    - `.../dpad_up`
    - `.../dpad_down`
While a runtime may ignore accepted suggested bindings, and may use their contents as suggestions for automatic remapping when not obeying them, this extension defines interpretations the runtime must make in the case that a suggested binding using one of these paths is being obeyed.

An application can pass XrInteractionProfileDpadBindingEXT in the XrBindingModificationsKHR::bindingModifications array associated with a suggested binding to customize the behavior of this mapping in the case that suggested bindings are being obeyed, and to provide remapping hints in other cases. If no XrInteractionProfileDpadBindingEXT structure is present in XrBindingModificationsKHR::bindingModifications for a given action set and component-less input source path, the runtime must behave as if one were passed with the following values:

- forceThreshold = 0.5
- forceThresholdReleased = 0.4
- centerRegion = 0.5
- wedgeAngle = \( \frac{1}{2} \pi \)
- isSticky = XR_FALSE
- onHaptic = NULL
- offHaptic = NULL

For the purposes of description, the (-1, 1) ranges of the x and y components of trackpad and thumbstick inputs are depicted in this extension as if their scale were equal between axes. However, this is not required by this extension: while their numeric scale is treated as equal, their physical scale may not be.

Each of the component paths defined by this extension behave as boolean inputs. The center component \(.../dpad_center\) (only present when the path identifier is trackpad) must not be active at the same time as any other dpad component. For the other components, zero, one, or (depending on the wedgeAngle) two of them may be active at any time, though only adjacent components on a single logical dpad may be active simultaneously. For example, \(.../dpad_down\) and \(.../dpad_left\) are adjacent, and thus may be active simultaneously, while \(.../dpad_up\) and \(.../dpad_down\) are not adjacent and must not be active simultaneously.

### Note
If wedgeAngle > \( \frac{1}{2} \pi \), it is possible for two components referring to adjacent directions (excluding \(.../dpad_center\)) to be active at the same time, as the directional regions overlap. If wedgeAngle < \( \frac{1}{2} \pi \), there are wedges between directional regions that correspond to no dpad component.

The following components are defined by possibly-overlapping truncated wedges pointing away from 0, 0 in x, y input space, with their angular size of XrInteractionProfileDpadBindingEXT::wedgeAngle...
centered around the indicated direction.

- \(.../dpad\_up\): direction (0, 1)
- \(.../dpad\_down\): direction (0, -1)
- \(.../dpad\_left\): direction (-1, 0)
- \(.../dpad\_right\): direction (1, 0)

Typical values for \texttt{wedgeAngle} are \(\frac{\pi}{2}\) (or 90°) for regions that don't overlap or \(\frac{3\pi}{4}\) (or 135°) for regions are evenly divided between the exclusive region for one cardinal direction and the overlap with neighboring regions.

Each of these regions are truncated by an arc to exclude the area within a radius of \texttt{XrInteractionProfileDpadBindingEXT::centerRegion} away from 0, 0. When used with an input path with an identifier of \texttt{trackpad}, the area within this radius corresponds to the \(.../dpad\_center\) component. When used with an input path with an identifier of \texttt{thumbstick}, the area within this radius is a region where all dpad components \textbf{must} be inactive.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{wedge_angles.png}
\caption{Wedge Angles}
\end{figure}

\textbf{Behavior}

For both the \texttt{trackpad} and \texttt{thumbstick} input identifiers, there are conditions that \textbf{must} be true for any dpad component to report active. If these conditions are true, the selection of which component or components are active, if any, takes place.

- Activation of a dpad component when appended to an input path with identifier \texttt{trackpad} on the values of the \(.../x\) and \(.../y\) components, as well as on an overall activation state. If the overall state is inactive, the runtime \textbf{must} treat all corresponding dpad components as inactive.
  - If the component \(.../\texttt{click}\) is also valid for the trackpad, the overall activation state is equal to the value of the \(.../\texttt{click}\).
If the component \textit{click} is not valid for the trackpad, but the component \textit{force} is valid, the overall activation state depends on the value of that \textit{force} component, as well as the previous overall activation state for hysteresis. The \textit{force} component value hysteresis thresholds for overall activation are \texttt{XrInteractionProfileDpadBindingEXT::forceThreshold} and \texttt{forceThresholdReleased}. More explicitly:

- If the previous overall state was inactive, the current overall state \textbf{must} be active if and only if the value of the \textit{force} component is greater than or equal to \texttt{forceThreshold}.

- If the previous overall state was active, the current state \textbf{must} be inactive if and only if the value of the \textit{force} component is strictly less than \texttt{forceThresholdReleased}.

- Activation of a dpad component when appended to an input path with identifier \texttt{thumbstick} depends only on the value of the \textit{x} and \textit{y} components of that input.

  - If the \texttt{thumbstick x} and \texttt{y} values correspond to a deflection from center of less than \texttt{centerRegion}, all dpad components \textbf{must} be reported as inactive.

Hysteresis is desirable to avoid an unintentional, rapid toggling between the active and inactive state that can occur when the amount of force applied by the user is very close to the threshold at which the input is considered active. Hysteresis is optional, and is achieved through a difference between \texttt{forceThreshold} and \texttt{forceThresholdReleased}.

When \texttt{XrInteractionProfileDpadBindingEXT::isSticky} is \texttt{XR_FALSE}, and the above logic indicates that some dpad component is active, a runtime obeying suggested bindings \textbf{must} select which dpad components to report as active based solely on the current \texttt{x}, \texttt{y} values.

If \texttt{XrInteractionProfileDpadBindingEXT::isSticky} is \texttt{XR_TRUE}, the region(s) to be made active \textbf{must} be latched when the above logic begins to indicate that some dpad component is active, and the \texttt{x} and \texttt{y} values are within at least one region. The latched region(s) \textbf{must} continue to be reported as active until the activation logic indicates that all dpad components \textbf{must} be inactive. The latched region(s) remain active even if the input leaves that region or enters another region.

The runtime \textbf{must} latch the \texttt{x} and \texttt{y} values, and thus the region or regions (in the case of overlapping dpad component wedges), when the sticky activation toggle becomes true. The latched regions \textbf{must} continue to be true until the input returns to the center region (for a \texttt{thumbstick}) or is released (for a trackpad). In this way, sticky dpads maintain their selected region across touch/click transitions.
Examples for isSticky == XR_TRUE

- Trackpad example: If the user clicks a trackpad in the .../dpad_up region, then (while clicked) slides their finger to the .../dpad_down region, .../dpad_up will remain true.

- Thumbstick example: If the user presses up on the thumbstick and activates the .../dpad_up region, then slides the thumbstick around to the .../dpad_down region without crossing the centerRegion, .../dpad_up is the virtual input that will be true.

- Thumbstick example: If the user presses up on the thumbstick and activates the .../dpad_up region, then slides the thumbstick directly down and through the region specified by centerRegion to .../dpad_down. Initially .../dpad_up will activate. Then when the thumbstick enters the centerRegion it will deactivate. Finally, when entering the .../dpad_down region .../dpad_down will activate.

New Structures

The XrInteractionProfileDpadBindingEXT structure is defined as:

typedef struct XrInteractionProfileDpadBindingEXT {
  XrStructureType              type;
  const void*                  next;
  XrPath                       binding;
  XrActionSet                  actionSet;
  float                        forceThreshold;
  float                        forceThresholdReleased;
  float                        centerRegion;
  float                        wedgeAngle;
  XrBool32                     isSticky;
  const XrHapticBaseHeader*    onHaptic;
  const XrHapticBaseHeader*    offHaptic;
} XrInteractionProfileDpadBindingEXT;
Member Descriptions

- **type** is the XrStructureType of this structure.

- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

- **binding** is the input path used for the specified actions in the suggested binding list to be used as a dpad. E.g. path:/user/hand/right/input/thumbstick

- **actionSet** is the action set for which this dpad will be active. The implementation must use the parameters from this structure for any actions from this action set that are bound to one of the dpad subpaths for this input path.

- **forceThreshold** a number in the half-open range (0, 1] representing the force value threshold at or above which (≥) a dpad input will transition from inactive to active.

- **forceThresholdReleased** a number in the half-open range (0, 1] representing the force value threshold strictly below which (<) a dpad input will transition from active to inactive.

- **centerRegion** defines the center region of the thumbstick or trackpad. This is the radius, in the input value space, of a logically circular region in the center of the input, in the range (0, 1).

- **wedgeAngle** indicates the angle in radians of each direction region and is a value in the half-open range [0, π).

- **isSticky** indicates that the implementation will latch the first region that is activated and continue to indicate that the binding for that region is true until the user releases the input underlying the virtual dpad.

- **onHaptic** is the haptic output that the runtime must trigger when the binding changes from false to true. If this field is NULL, the runtime must not trigger any haptic output on the threshold. This field can point to any supported sub-type of XrHapticBaseHeader.

- **offHaptic** is the haptic output that the runtime must trigger when the binding changes from true to false. If this field is NULL, the runtime must not trigger any haptic output on the threshold. This field can point to any supported sub-type of XrHapticBaseHeader.

The XrInteractionProfileDpadBindingEXT structure is an input struct that defines how to use any two-axis input to provide dpad-like functionality to the application. The struct must be added for each input that should be treated as a dpad to the bindingModifications array of the XrBindingModificationsKHR structure (See XR_KHR_binding_modification extension).

Runtimes are free to ignore any of the fields when not obeying the bindings, but may use it for automatic rebindings of actions.

The implementation must return XR_ERROR_VALIDATION_FAILURE from xrSuggestInteractionProfileBindings if any of the following are true:

- **forceThreshold** or **forceThresholdReleased** are outside the half-open range (0, 1]
• forceThreshold < forceThresholdReleased
• centerRegion is outside the exclusive range (0, 1)
• wedgeAngle outside the half-open range [0, π)

If more than one XrInteractionProfileDpadBindingEXT is provided for the same input identifier, including top level path (e.g. /user/hand/left/input/thumbstick), and two or more of them specify the same actionset, the runtime must return XR_ERROR_VALIDATION_FAILURE. If the same input identifier, including top level path, is used for more than one action set, in addition to inputs being suppressed by higher priority action sets, haptic events from dpads are also suppressed.

For example, a Valve Index controller binding with a "Walking" action set can have a dpad on each of:

• left thumbstick
• right thumbstick
• left trackpad
• right trackpad

Another action set can also have a dpad active on each of those inputs, and they can have different settings. If both action sets are active, the higher priority one trumps the lower priority one, and the lower priority one is suppressed.

Valid Usage (Implicit)

• The XR_EXT_dpad_binding extension must be enabled prior to using XrInteractionProfileDpadBindingEXT
• type must be XR_TYPE_INTERACTION_PROFILE_DPAD_BINDING_EXT
• next must be NULL or a valid pointer to the next structure in a structure chain
• actionSet must be a valid XrActionSet handle
• If onHaptic is not NULL, onHaptic must be a pointer to a valid XrHapticBaseHeader-based structure. See also: XrHapticVibration
• If offHaptic is not NULL, offHaptic must be a pointer to a valid XrHapticBaseHeader-based structure. See also: XrHapticVibration

New Functions

Issues

• What if an interaction profile is added that contains a trackpad identifier, for which there is neither a .../click or a .../force component?
  ◦ Equivalent logic would apply to whatever component is available to distinguish action from inaction.
Is zero a valid wedge angle? Is π?

- Yes, though it is mostly useless, as it makes the directional regions empty in size and thus impossible to activate. The user could only activate .../dpad_center on a trackpad identifier. π is not a valid wedge angle because that would imply being able to activate three adjacent directions, of which two must be opposite. In practice, the sensors underlying these inputs make it effectively impossible to input an exact floating point value.

Example

The following sample code shows how to create dpad bindings using this extension.

```cpp
// Create dpad paths
XrPath pathThumbstick, pathDpadUp, pathDpadDown;
xrStringToPath( pInstance, "\user\hand\left\input\thumbstick\", &pathThumbstick);
xrStringToPath( pInstance, "\user\hand\left\input\thumbstick\dpad\up\", &pathDpadUp);
xrStringToPath( pInstance, "\user\hand\left\input\thumbstick\dpad\down\", &pathDpadDown);

// Set dpad binding modifiers
XrInteractionProfileDpadBindingEXT xrDpadModification {
    XR_TYPE_INTERACTION_PROFILE_DPAD_BINDING_EXT);
    xrDpadModification.actionSet = xrActionSet_Main;
    xrDpadModification.binding = pathThumbstick;
    xrDpadModification.centerRegion = 0.25f;
    xrDpadModification.wedgeAngle = 2.0f;
} // A gap between these next two members creates hysteresis, to avoid rapid toggling
    xrDpadModification.forceThreshold = 0.8f;
    xrDpadModification.forceThresholdReleased = 0.2f;

// Add dpad binding modifiers to binding modifications vector
std::vector<XrInteractionProfileDpadBindingEXT> vBindingModifs;
vBindingModifs.push_back( xrDpadModification );

std::vector<XrBindingModificationBaseHeaderKHR*> vBindingModifsBase;
for ( XrInteractionProfileDpadBindingEXT &modif : vBindingModifs )
{
    vBindingModifsBase.push_back( reinterpret_cast<XrBindingModificationBaseHeaderKHR*>( &modif ) );
}

XrBindingModificationsKHR xrBindingModifications { XR_TYPE_BINDING_MODIFICATIONS_KHR };
xrBindingModifications.bindingModifications = vBindingModifsBase.data();
xrBindingModifications.bindingModificationCount = ( uint32_t )vBindingModifsBase.size();
```
// Set dpad input path as suggested binding for an action
XrActionSuggestedBinding xrActionBindingTeleport, xrActionBindingMenu;

xrActionBindingTeleport.action = xrAction_Teleport;
xrActionBindingTeleport.binding = pathDpadUp;

xrActionBindingMenu.action = xrAction_Menu;
xrActionBindingMenu.binding = pathDpadDown;

std::vector< XrActionSuggestedBinding > vActionBindings;
vActionBindings.push_back( xrActionBindingTeleport );
vActionBindings.push_back( xrActionBindingMenu );

// Create interaction profile/controller path
XrPath xrInteractionProfilePath;
xrStringToPath( pInstance, "/interaction_profiles/valve/index_controller", &xrInteractionProfilePath );

// Set suggested binding to interaction profile
XrInteractionProfileSuggestedBinding xrInteractionProfileSuggestedBinding {
    XR_TYPE_INTERACTION_PROFILE_SUGGESTED_BINDING
};
xrInteractionProfileSuggestedBinding.interactionProfile = xrInteractionProfilePath;
xrInteractionProfileSuggestedBinding.suggestedBindings = vActionBindings.data();
xrInteractionProfileSuggestedBinding.countSuggestedBindings = ( uint32_t )vActionBindings.size();

// Set binding modifications to interaction profile's suggested binding
xrInteractionProfileSuggestedBinding.next = &xrBindingModifications;

// Finally, suggest interaction profile bindings to runtime
xrSuggestInteractionProfileBindings( pInstance, &xrInteractionProfileSuggestedBinding );

Version History

- Revision 1, 2022-02-18 (Rune Berg)
  - Initial extension description

12.27. XR_EXT_eye_gaze_interaction

Name String
XR_EXT_eye_gaze_interaction

Extension Type
Instance extension
Overview

This extension provides an XrPath for getting eye gaze input from an eye tracker to enable eye gaze interactions.

The intended use for this extension is to provide:

- system properties to inform if eye gaze interaction is supported by the current device.
- an XrPath for real time eye tracking that exposes an accurate and precise eye gaze pose to be used to enable eye gaze interactions.
- a structure XrEyeGazeSampleTimeEXT that allows for an application to retrieve more information regarding the eye tracking samples.

With these building blocks, an application can discover if the XR runtime has access to an eye tracker, bind the eye gaze pose to the action system, determine if the eye tracker is actively tracking the users eye gaze, and use the eye gaze pose as an input signal to build eye gaze interactions.

12.27.1. Eye tracker

An eye tracker is a sensory device that tracks eyes and accurately maps what the user is looking at. The
main purpose of this extension is to provide accurate and precise eye gaze for the application.

Eye tracking data can be sensitive personal information and is closely linked to personal privacy and integrity. It is strongly recommended that applications that store or transfer eye tracking data always ask the user for active and specific acceptance to do so.

If a runtime supports a permission system to control application access to the eye tracker, then the runtime **must** set the `isActive` field to `XR_FALSE` on the supplied `XrActionStatePose` structure, and **must** clear `XR_SPACE_LOCATION_POSITION_TRACKED_BIT`, `XR_SPACE_LOCATION_POSITION_VALID_BIT`, `XR_SPACE_LOCATION_ORIENTATION_TRACKED_BIT` and `XR_SPACE_LOCATION_ORIENTATION_VALID_BIT` when locating using the tracked space until the application has been allowed access to the eye tracker. When the application access has been allowed, the runtime **may** set `isActive` on the supplied `XrActionStatePose` structure to `XR_TRUE` and **may** set `XR_SPACE_LOCATION_POSITION_TRACKED_BIT`, `XR_SPACE_LOCATION_POSITION_VALID_BIT` `XR_SPACE_LOCATION_ORIENTATION_TRACKED_BIT` and `XR_SPACE_LOCATION_ORIENTATION_VALID_BIT` when locating using the tracked space.

### 12.27.2. Device enumeration

When the eye gaze input extension is enabled an application **may** pass in a `XrSystemEyeGazeInteractionPropertiesEXT` structure in next chain structure when calling `xrGetSystemProperties` to acquire information about the connected eye tracker.

The runtime **must** populate the `XrSystemEyeGazeInteractionPropertiesEXT` structure with the relevant information to the `XrSystemProperties` returned by the `xrGetSystemProperties` call.

```c
typedef struct XrSystemEyeGazeInteractionPropertiesEXT {
    XrStructureType    type;
    void*              next;
    XrBool32           supportsEyeGazeInteraction;
} XrSystemEyeGazeInteractionPropertiesEXT;
```

#### Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **supportsEyeGazeInteraction** the runtime **must** set this value to `XR_TRUE` when eye gaze sufficient for use cases such as aiming or targeting is supported by the current device, otherwise the runtime **must** set this to `XR_FALSE`. 
### Valid Usage (Implicit)

- The `XR_EXT_eye_gaze_interaction` extension **must** be enabled prior to using `XrSystemEyeGazeInteractionPropertiesEXT`
- The `type` **must** be `XR_TYPE_SYSTEM_EYE_GAZE_INTERACTION_PROPERTIES_EXT`
- The `next` **must** be `NULL` or a valid pointer to the `next` structure in a `structure chain`

### 12.27.3. Eye gaze input

This extension exposes a new interaction profile path `/interaction_profiles/ext/eye_gaze_interaction` that is valid for the user path

- `/user/eyes_ext`

for supported input source

- `.../input/gaze_ext/pose`

The eye gaze pose is natively oriented with +Y up, +X to the right, and -Z forward and not gravity-aligned, similar to the `XR_REFERENCE_SPACE_TYPE_VIEW`. The eye gaze pose may originate from a point positioned between the user's eyes. At any point of time both the position and direction of the eye pose is tracked or untracked. This means that the runtime **must** set both `XR_SPACE_LOCATION_POSITION_TRACKED_BIT` and `XR_SPACE_LOCATION_ORIENTATION_TRACKED_BIT` or clear both `XR_SPACE_LOCATION_POSITION_TRACKED_BIT` and `XR_SPACE_LOCATION_ORIENTATION_TRACKED_BIT`.

One particularity for eye trackers compared to most other spatial input is that the runtime may not have the capability to predict or interpolate eye gaze poses. Runtimes that cannot predict or interpolate eye gaze poses **must** clamp the gaze pose requested in the `xrLocateSpace` call to the value nearest to `time` requested in the call. To allow for an application to reason about high accuracy eye tracking, the application **can** chain in an `XrEyeGazeSampleTimeEXT` to the next pointer of the `XrSpaceLocation` structure passed into the `xrLocateSpace` call. The runtime **must** set `time` in the `XrEyeGazeSampleTimeEXT` structure to the clamped, predicted or interpolated time. The application **should** inspect the `time` field to understand when in time the pose is expressed. The `time` field may be in the future if a runtime can predict gaze poses. The runtime **must** set the `time` field to 0 if the sample time is not available.

When the runtime provides a nominal eye gaze pose, the `XR_SPACE_LOCATION_POSITION_TRACKED_BIT` **must** be set if the eye otherwise has a fully-tracked pose relative to the other space. A runtime **can** provide a sub-nominal eye-gaze pose but **must** then clear the `XR_SPACE_LOCATION_POSITION_TRACKED_BIT`. An application can expect that a nominal eye gaze pose can be used for use cases such as aiming or targeting, while a sub-nominal eye gaze pose has degraded performance and should not be relied on for all input scenarios. Applications should be very careful when using sub-nominal eye gaze pose, since the behavior can vary considerably for different users and manufacturers, and some manufacturers **may** not provide sub-nominal eye gaze pose at all.
With current technology, some eye trackers may need to undergo an explicit calibration routine to provide a nominal accurate and precise eye gaze pose. If the eye tracker is in an uncalibrated state when the first call to xrSyncActions is made with an eye gaze action enabled, then the runtime should request eye tracker calibration from the user if it has not yet been requested.

```c
typedef struct XrEyeGazeSampleTimeEXT {
    XrStructureType    type;
    void*              next;
    XrTime             time;
} XrEyeGazeSampleTimeEXT;
```

### Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **time** is when in time the eye gaze pose is expressed.

### Valid Usage (Implicit)

- The XR_EXT_eye_gaze_interaction extension must be enabled prior to using XrEyeGazeSampleTimeEXT
- **type** must be XR_TYPE_EYE_GAZE_SAMPLE_TIME_EXT
- **next** must be NULL or a valid pointer to the next structure in a structure chain

### 12.27.4. Sample code

The following example code shows how to bind the eye pose to the action system.

```c
extern XrInstance instance;
extern XrSession session;
extern XrPosef pose_identity;

// Create action set
XrActionSetCreateInfo actionSetInfo{XR_TYPE_ACTION_SET_CREATE_INFO};
strcpy(actionSetInfo.actionSetName, "gameplay");
strcpy(actionSetInfo.localizedActionSetName, "Gameplay");
actionSetInfo.priority = 0;
```
XrActionSet gameplayActionSet;
CHK_XR(xrCreateActionSet(instance, &actionSetInfo, &gameplayActionSet));

// Create user intent action
XrActionCreateInfo actionInfo{XR_TYPE_ACTION_CREATE_INFO};
strcpy(actionInfo.actionName, "user_intent" outra ele tipo de preço de venda);
actionInfo.actionType = XR_ACTION_TYPE_POSE_INPUT;
strcpy(actionInfo.localizedActionName, "User Intent");   // Create user intent action
XrAction userIntentAction;
CHK_XR(xrCreateAction(gameplayActionSet, &actionInfo, &userIntentAction));

// Create suggested bindings
XrPath eyeGazeInteractionProfilePath;
CHK_XR(xrStringToPath(instance, "/interaction_profiles/ext/eye_gaze_interaction",
&eyeGazeInteractionProfilePath));

XrPath gazePosePath;
CHK_XR(xrStringToPath(instance, "/user/eyes_ext/input/gaze_ext/pose", &gazePosePath));

XrActionSuggestedBinding bindings;
bindings.action = userIntentAction;
bindings.binding = gazePosePath;

XrInteractionProfileSuggestedBinding
suggestedBindings{XR_TYPE_INTERACTION_PROFILE_SUGGESTED_BINDING};
suggestedBindings.interactionProfile = eyeGazeInteractionProfilePath;
suggestedBindings.suggestedBindings = &bindings;
suggestedBindings.countSuggestedBindings = 1;
CHK_XR(xrSuggestInteractionProfileBindings(instance, &suggestedBindings));

XrSessionActionSetsAttachInfo attachInfo{XR_TYPE_SESSION_ACTION_SETS_ATTACH_INFO};
attachInfo.countActionSets = 1;
attachInfo.actionSets = &gameplayActionSet;
CHK_XR(xrAttachSessionActionSets(session, &attachInfo));

XrActionSpaceCreateInfo createActionSpaceInfo{XR_TYPE_ACTION_SPACE_CREATE_INFO};
createActionSpaceInfo.action = userIntentAction;
createActionSpaceInfo.poseInActionSpace = pose_identity;
XrSpace gazeActionSpace;
CHK_XR(xrCreateActionSpace(session, &createActionSpaceInfo, &gazeActionSpace));

XrReferenceSpaceCreateInfo createReferenceSpaceInfo{XR_TYPE_REFERENCE_SPACE_CREATE_INFO};
createReferenceSpaceInfo.referenceSpaceType = XR_REFERENCE_SPACE_TYPE_LOCAL;
createReferenceSpaceInfo.poseInReferenceSpace = pose_identity;
XrSpace localReferenceSpace;
CHK_XR(xrCreateReferenceSpace(session, &createReferenceSpaceInfo, &localReferenceSpace));

while(true)
{ 
  XrActiveActionSet activeActionSet{gameplayActionSet, XR_NULL_PATH};
  XrTime time;

  XrActionsSyncInfo syncInfo{XR_TYPE_ACTIONS_SYNC_INFO};
  syncInfo.countActiveActionSets = 1;
  syncInfo.activeActionSets = &activeActionSet;
  CHK_XR(xrSyncActions(session, &syncInfo));

  XrActionStatePose actionStatePose{XR_TYPE_ACTION_STATE_POSE};
  XrActionStateGetInfo getActionStateInfo{XR_TYPE_ACTION_STATE_GET_INFO};
  getActionStateInfo.action = userIntentAction;
  CHK_XR(xrGetActionStatePose(session, &getActionStateInfo, &actionStatePose));

  if(actionStatePose.isActive){
    XrEyeGazeSampleTimeEXT eyeGazeSampleTime{XR_TYPE_EYE_GAZE_SAMPLE_TIME_EXT};
    XrSpaceLocation gazeLocation{XR_TYPE_SPACE_LOCATION, &eyeGazeSampleTime};
    CHK_XR(xrLocateSpace(gazeActionSpace, localReferenceSpace, time, &gazeLocation));
  }

  // Do things
}

Version History

• Revision 1, 2020-02-20 (Denny Rönngren)
  ◦ Initial version
• Revision 2, 2022-05-27 (Bryce Hutchings)
  ◦ Remove error-prone XrEyeGazeSampleTimeEXT validation requirement

12.28. XR_EXT_hand_joints_motion_range

Name String
  XR_EXT_hand_joints_motion_range

Extension Type
  Instance extension

Registered Extension Number
  81

Revision
  1
Extension and Version Dependencies

- Requires OpenXR 1.0
- Requires XR_EXT_hand_tracking

Last Modified Date

2021-04-15

IP Status

No known IP claims.

Contributors

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Overview

This extension augments the XR_EXT_hand_tracking extension to enable applications to request that the XrHandJointLocationsEXT returned by xrLocateHandJointsEXT should return hand joint locations conforming to a range of motion specified by the application.

The application must enable the XR_EXT_hand_tracking extension in order to use this extension.

New Object Types

New Flag Types

New Enum Constants

New Enums

The XrHandJointsMotionRangeEXT describes the hand joints' range of motion returned by xrLocateHandJointsEXT.

Runtimes must support both XR_HAND_JOINTS_MOTION_RANGE_CONFORMING_TO_CONTROLLER_EXT and XR_HAND_JOINTS_MOTION_RANGE_UNOBSTRUCTED_EXT for each controller interaction profile that supports hand joint data.

```c
typedef enum XrHandJointsMotionRangeEXT {
    XR_HAND_JOINTS_MOTION_RANGE_UNOBSTRUCTED_EXT = 1,
    XR_HAND_JOINTS_MOTION_RANGE_CONFORMING_TO_CONTROLLER_EXT = 2,
    XR_HAND_JOINTS_MOTION_RANGE_MAX_ENUM_EXT = 0x7FFFFFFF
} XrHandJointsMotionRangeEXT;
```
Enumerant Descriptions

• **XR_HAND_JOINTS_MOTION_RANGE_UNOBSTRUCTED_EXT** This option refers to the range of motion of a human hand, without any obstructions. Input systems that obstruct the movement of the user's hand (e.g.: a held controller preventing the user from making a fist) or have only limited ability to track finger positions **must** use the information available to them to emulate an unobstructed range of motion.

• **XR_HAND_JOINTS_MOTION_RANGE_CONFORMING_TO_CONTROLLER_EXT** This option refers to the range of motion of the hand joints taking into account any physical limits imposed by the controller itself. This will tend to be the most accurate pose compared to the user's actual hand pose, but might not allow a closed fist for example.

  ◦ If the current interaction profile represents a controller, or other device that obstructs the hand, the implementation **must** return joint locations conforming to the shape of that device. If the current interaction profile is being emulated by a different physical controller, the implementation **may** return joint locations conforming to the shape of either the current interaction profile or the actual physical controller.

  ◦ If the current interaction profile does not represent a controller, the implementation **must** return joint locations based on the unobstructed joint locations.

New Structures

The **XrHandJointsMotionRangeInfoEXT** is a structure that an application **can** chain in **XrHandJointsLocateInfoEXT** to request the joint motion range specified by the **handJointsMotionRange** field.

Runtimes **must** return the appropriate joint locations depending on the **handJointsMotionRange** field and the currently active interaction profile.

typedef struct XrHandJointsMotionRangeInfoEXT {
    XrStructureType                   type;
    const void*                       next;
    XrHandJointsMotionRangeEXT        handJointsMotionRange;
} XrHandJointsMotionRangeInfoEXT;
**Member Descriptions**

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `handJointsMotionRange` is an `XrHandJointsMotionRangeEXT` that defines the hand joint range of motion the application wants.

**Valid Usage (Implicit)**

- The `XR_EXT_hand_joints_motion_range` extension **must** be enabled prior to using `XrHandJointsMotionRangeInfoEXT`.
- `type` **must** be `XR_TYPE_HAND_JOINTS_MOTION_RANGE_INFO_EXT`.
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain.
- `handJointsMotionRange` **must** be a valid `XrHandJointsMotionRangeEXT` value.

**New Functions**

**Issues**

**Version History**

- Revision 1, 2021-04-15 (Rune Berg)
  - Initial extension description

**12.29. XR_EXT_hand_tracking**

**Name String**

`XR_EXT_hand_tracking`

**Extension Type**

Instance extension

**Registered Extension Number**

52

**Revision**

4
12.29.1. Overview

This extension enables applications to locate the individual joints of hand tracking inputs. It enables applications to render hands in XR experiences and interact with virtual objects using hand joints.

12.29.2. Inspect system capability

An application can inspect whether the system is capable of hand tracking input by extending the XrSystemProperties with XrSystemHandTrackingPropertiesEXT structure when calling xrGetSystemProperties.
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **supportsHandTracking** is an XrBool32, indicating if current system is capable of hand tracking input.

Valid Usage (Implicit)

- The XR_EXT_hand_tracking extension must be enabled prior to using XrSystemHandTrackingPropertiesEXT
- **type** must be XR_TYPE_SYSTEM_HAND_TRACKING_PROPERTIES_EXT
- **next** must be NULL or a valid pointer to the next structure in a structure chain

If a runtime returns XR_FALSE for supportsHandTracking, the runtime must return XR_ERROR_FEATURE_UNSUPPORTED from xrCreateHandTrackerEXT.

12.29.3. Create a hand tracker handle

The XrHandTrackerEXT handle represents the resources for hand tracking of the specific hand.

```c
XR_DEFINE_HANDLE(XrHandTrackerEXT)
```

An application creates separate XrHandTrackerEXT handles for left and right hands. This handle can be used to locate hand joints using xrLocateHandJointsEXT function.

A hand tracker provides joint locations with an unobstructed range of motion of an empty human hand.

**Note**

This behavior can be modified by the XR_EXT_hand_joints_motion_range extension

An application can create an XrHandTrackerEXT handle using xrCreateHandTrackerEXT function.
XrResult xrCreateHandTrackerEXT(
    XrSession session,
    const XrHandTrackerCreateInfoEXT* createInfo,
    XrHandTrackerEXT* handTracker);

Parameter Descriptions

- **session** is an XrSession in which the hand tracker will be active.
- **createInfo** is the XrHandTrackerCreateInfoEXT used to specify the hand tracker.
- **handTracker** is the returned XrHandTrackerEXT handle.

Valid Usage (Implicit)

- The XR_EXT_hand_tracking extension **must** be enabled prior to calling xrCreateHandTrackerEXT
- **session** **must** be a valid XrSession handle
- **createInfo** **must** be a pointer to a valid XrHandTrackerCreateInfoEXT structure
- **handTracker** **must** be a pointer to an XrHandTrackerEXT handle
Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_FEATURE_UNSUPPORTED

If the system does not support hand tracking, runtime must return XR_ERROR_FEATURE_UNSUPPORTED from xrCreateHandTrackerEXT. In this case, the runtime must return XR_FALSE for supportsHandTracking in XrSystemHandTrackingPropertiesEXT when the function xrGetSystemProperties is called, so that the application can avoid creating a hand tracker.

The XrHandTrackerCreateInfoEXT structure describes the information to create an XrHandTrackerEXT handle.

```c
typedef struct XrHandTrackerCreateInfoEXT {
    XrStructureType type;
    const void* next;
    XrHandEXT hand;
    XrHandJointSetEXT handJointSet;
} XrHandTrackerCreateInfoEXT;
```
Member Descriptions

- **type** is the *XrStructureType* of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **hand** is an *XrHandEXT* which describes which hand the tracker is tracking.
- **handJointSet** is an *XrHandJointSetEXT* describe the set of hand joints to retrieve.

Valid Usage (Implicit)

- The *XR_EXT_hand_tracking* extension must be enabled prior to using *XrHandTrackerCreateInfoEXT*
- **type** must be *XR_TYPE_HAND_TRACKER_CREATE_INFO_EXT*
- **next** must be NULL or a valid pointer to the next structure in a structure chain. See also: *XrHandPoseTypeInfoMSFT*
- **hand** must be a valid *XrHandEXT* value
- **handJointSet** must be a valid *XrHandJointSetEXT* value

The *XrHandEXT* describes which hand the *XrHandTrackerEXT* is tracking.

typedef enum XrHandEXT {
    XR_HAND_LEFT_EXT = 1,
    XR_HAND_RIGHT_EXT = 2,
    XR_HAND_MAX_ENUM_EXT = 0x7FFFFFFF
} XrHandEXT;

Enumerant Descriptions

- **XR_HAND_LEFT_EXT** specifies the hand tracker will be tracking the user's left hand.
- **XR_HAND_RIGHT_EXT** specifies the hand tracker will be tracking the user's right hand.

The *XrHandJointSetEXT* enum describes the set of hand joints to track when creating an *XrHandTrackerEXT*. 
typedef enum XrHandJointSetEXT {
    XR_HAND_JOINT_SET_DEFAULT_EXT = 0,
    XR_HAND_JOINT_SET_HAND_WITH_FOREARM_ULTRALEAP = 1000149000,
    XR_HAND_JOINT_SET_MAX_ENUM_EXT = 0x7FFFFFFF
} XrHandJointSetEXT;

**Enumerant Descriptions**

- **XR_HAND_JOINT_SET_DEFAULT_EXT** indicates that the created XrHandTrackerEXT tracks the set of hand joints described by XrHandJointEXT enum, i.e. the xrLocateHandJointsEXT function returns an array of joint locations with the count of XR_HAND_JOINT_COUNT_EXT and can be indexed using XrHandJointEXT.

**xrDestroyHandTrackerEXT** function releases the handTracker and the underlying resources when finished with hand tracking experiences.

```c
XrResult xrDestroyHandTrackerEXT(
    XrHandTrackerEXT                            handTracker);
```

**Parameter Descriptions**

- **handTracker** is an XrHandTrackerEXT previously created by xrCreateHandTrackerEXT.

**Valid Usage (Implicit)**

- The XR_EXT_hand_tracking extension must be enabled prior to calling xrDestroyHandTrackerEXT
- **handTracker** must be a valid XrHandTrackerEXT handle

**Thread Safety**

- Access to handTracker, and any child handles, must be externally synchronized
Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_HANDLE_INVALID

12.29.4. Locate hand joints

The `xrLocateHandJointsEXT` function locates an array of hand joints to a base space at given time.

```c
XrResult xrLocateHandJointsEXT(
    XrHandTrackerEXT handTracker,
    const XrHandJointsLocateInfoEXT* locateInfo,
    XrHandJointLocationsEXT* locations);
```

Parameter Descriptions

- `handTracker` is an `XrHandTrackerEXT` previously created by `xrCreateHandTrackerEXT`.
- `locateInfo` is a pointer to `XrHandJointsLocateInfoEXT` describing information to locate hand joints.
- `locations` is a pointer to `XrHandJointLocationsEXT` receiving the returned hand joint locations.

Valid Usage (Implicit)

- The `XR_EXT_hand_tracking` extension must be enabled prior to calling `xrLocateHandJointsEXT`
- `handTracker` must be a valid `XrHandTrackerEXT` handle
- `locateInfo` must be a pointer to a valid `XrHandJointsLocateInfoEXT` structure
- `locations` must be a pointer to an `XrHandJointLocationsEXT` structure
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_TIME_INVALID

The XrHandJointsLocateInfoEXT structure describes the information to locate hand joints.

typedef struct XrHandJointsLocateInfoEXT {
    XrStructureType type;
    const void* next;
    XrSpace baseSpace;
    XrTime time;
} XrHandJointsLocateInfoEXT;

Member Descriptions

- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- baseSpace is an XrSpace within which the returned hand joint locations will be represented.
- time is an XrTime at which to locate the hand joints.
Valid Usage (Implicit)

- The `XR_EXT_hand_tracking` extension must be enabled prior to using `XrHandJointsLocateInfoEXT`
- `type` must be `XR_TYPE_HAND_JOINTS_LOCATE_INFO_EXT`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrHandJointsMotionRangeInfoEXT`
- `baseSpace` must be a valid `XrSpace` handle

`XrHandJointLocationsEXT` structure returns the state of the hand joint locations.

typedef struct XrHandJointLocationsEXT {
    XrStructureType            type;
    void*                      next;
    XrBool32                   isActive;
    uint32_t                   jointCount;
    XrHandJointLocationEXT*    jointLocations;
} XrHandJointLocationsEXT;

Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain, such as `XrHandJointVelocitiesEXT`.
- `isActive` is an `XrBool32` indicating if the hand tracker is actively tracking.
- `jointCount` is a `uint32_t` describing the count of elements in `jointLocations` array.
- `jointLocations` is an array of `XrHandJointLocationEXT` receiving the returned hand joint locations.

The application must allocate the memory for the output array `jointLocations` that can contain at least `jointCount` of `XrHandJointLocationEXT`.

The application must set `jointCount` as described by the `XrHandJointSetEXT` when creating the `XrHandTrackerEXT` otherwise the runtime must return `XR_ERROR_VALIDATION_FAILURE`.

The runtime must return `jointLocations` representing the range of motion of a human hand, without any obstructions. Input systems that obstruct the movement of the user’s hand (e.g.: a held controller preventing the user from making a fist) or that have only limited ability to track finger positions must
use the information available to them to emulate an unobstructed range of motion.

The runtime must update the jointLocations array ordered so that the application can index elements using the corresponding hand joint enum (e.g. XrHandJointEXT) as described by XrHandJointSetEXT when creating the XrHandTrackerEXT. For example, when the XrHandTrackerEXT is created with XR_HAND_JOINT_SET_DEFAULT_EXT, the application must set the jointCount to XR_HAND_JOINT_COUNT_EXT, and the runtime must fill the jointLocations array ordered so that it may be indexed by the XrHandJointEXT enum.

If the returned isActive is true, the runtime must return all joint locations with both XR_SPACE_LOCATION_POSITION_VALID_BIT and XR_SPACE_LOCATION_ORIENTATION_VALID_BIT set. Although, in this case, some joint space locations may be untracked (i.e. XR_SPACE_LOCATION_POSITION_TRACKED_BIT or XR_SPACE_LOCATION_ORIENTATION_TRACKED_BIT is unset).

If the returned isActive is false, it indicates the hand tracker did not detect the hand input or the application lost input focus. In this case, the runtime must return all jointLocations with neither XR_SPACE_LOCATION_POSITION_VALID_BIT nor XR_SPACE_LOCATION_ORIENTATION_VALID_BIT set.

Valid Usage (Implicit)

- The XR_EXT_hand_tracking extension must be enabled prior to using XrHandJointLocationsEXT
- type must be XR_TYPE_HAND_JOINT_LOCATIONS_EXT
- next must be NULL or a valid pointer to the next structure in a structure chain. See also: XrHandJointVelocitiesEXT, XrHandTrackingAimStateFB, XrHandTrackingCapsulesStateFB, XrHandTrackingScaleFB
- jointLocations must be a pointer to an array of jointCount XrHandJointLocationEXT structures
- The jointCount parameter must be greater than 0

XrHandJointLocationEXT structure describes the position, orientation, and radius of a hand joint.

typedef struct XrHandJointLocationEXT {
    XrSpaceLocationFlags locationFlags;
    XrPosef pose;
    float radius;
} XrHandJointLocationEXT;
Member Descriptions

- `locationFlags` is a bitfield, with bit masks defined in `XrSpaceLocationFlagBits`, to indicate which members contain valid data. If none of the bits are set, no other fields in this structure should be considered to be valid or meaningful.

- `pose` is an `XrPosef` defining the position and orientation of the origin of a hand joint within the reference frame of the corresponding `XrHandJointsLocateInfoEXT::baseSpace`.

- `radius` is a `float` value radius of the corresponding joint in units of meters.

If the returned `locationFlags` has `XR_SPACE_LOCATION_POSITION_VALID_BIT` set, the returned radius must be a positive value.

If the returned `locationFlags` has `XR_SPACE_LOCATION_POSITION_VALID_BIT` unset, the returned radius value is undefined and should be avoided.

Valid Usage (Implicit)

- The `XR_EXT_hand_tracking` extension must be enabled prior to using `XrHandJointLocationEXT`.

- `locationFlags` must be 0 or a valid combination of `XrSpaceLocationFlagBits` values.

The application can chain an `XrHandJointVelocitiesEXT` structure to the `next` pointer of `XrHandJointLocationsEXT` when calling `xrLocateHandJointsEXT` to retrieve the hand joint velocities.

typedef struct XrHandJointVelocitiesEXT {
    XrStructureType type;
    void* next;
    uint32_t jointCount;
    XrHandJointVelocityEXT* jointVelocities;
} XrHandJointVelocitiesEXT;
**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **jointCount** is a uint32_t describing the number of elements in jointVelocities array.
- **jointVelocities** is an array of XrHandJointVelocityEXT receiving the returned hand joint velocities.

The application **must** allocate the memory for the output array jointVelocities that can contain at least jointCount of XrHandJointVelocityEXT.

The application **must** input jointCount as described by the XrHandJointSetEXT when creating the XrHandTrackerEXT. Otherwise, the runtime **must** return XR_ERROR_VALIDATION_FAILURE.

The runtime **must** update the jointVelocities array in the order so that the application can index elements using the corresponding hand joint enum (e.g. XrHandJointEXT) as described by the XrHandJointSetEXT when creating the XrHandTrackerEXT. For example, when the XrHandTrackerEXT is created with XR_HAND_JOINT_SET_DEFAULT_EXT, the application **must** set the jointCount to XR_HAND_JOINT_COUNT_EXT, and the returned jointVelocities array **must** be ordered to be indexed by enum XrHandJointEXT enum.

If the returned XrHandJointLocationsEXT::isActive is false, it indicates the hand tracker did not detect a hand input or the application lost input focus. In this case, the runtime **must** return all jointVelocities with neither XR_SPACE_VELOCITY_LINEAR_VALID_BIT nor XR_SPACE_VELOCITY_ANGULAR_VALID_BIT set.

If an XrHandJointVelocitiesEXT structure is chained to XrHandJointLocationsEXT::next, the returned XrHandJointLocationsEXT::isActive is true, and the velocity is observed or can be calculated by the runtime, the runtime **must** fill in the linear velocity of each hand joint within the reference frame of baseSpace and set the XR_SPACE_VELOCITY_LINEAR_VALID_BIT. Similarly, if an XrHandJointVelocitiesEXT structure is chained to XrHandJointLocationsEXT::next, the returned XrHandJointLocationsEXT::isActive is true, and the angular velocity is observed or can be calculated by the runtime, the runtime **must** fill in the angular velocity of each joint within the reference frame of baseSpace and set the XR_SPACE_VELOCITY_ANGULAR_VALID_BIT.
Valid Usage (Implicit)

- The `XR_EXT_hand_tracking` extension must be enabled prior to using `XrHandJointVelocitiesEXT` type must be `XR_TYPE_HAND_JOINT_VELOCITIES_EXT`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `jointVelocities` must be a pointer to an array of `jointCount` `XrHandJointVelocityEXT` structures
- The `jointCount` parameter must be greater than 0

`XrHandJointVelocityEXT` structure describes the linear and angular velocity of a hand joint.

```c
typedef struct XrHandJointVelocityEXT {
    XrSpaceVelocityFlags velocityFlags;
    XrVector3f linearVelocity;
    XrVector3f angularVelocity;
} XrHandJointVelocityEXT;
```

Member Descriptions

- `velocityFlags` is a bitfield, with bit masks defined in `XrSpaceVelocityFlagBits`, to indicate which members contain valid data. If none of the bits are set, no other fields in this structure should be considered to be valid or meaningful.
- `linearVelocity` is the relative linear velocity of the hand joint with respect to and expressed in the reference frame of the corresponding `XrHandJointsLocateInfoEXT::baseSpace`, in units of meters per second.
- `angularVelocity` is the relative angular velocity of the hand joint with respect to the corresponding `XrHandJointsLocateInfoEXT::baseSpace`. The vector's direction is expressed in the reference frame of the corresponding `XrHandJointsLocateInfoEXT::baseSpace` and is parallel to the rotational axis of the hand joint. The vector's magnitude is the relative angular speed of the hand joint in radians per second. The vector follows the right-hand rule for torque/rotation.
Valid Usage (Implicit)

- The `XR_EXT_hand_tracking` extension **must** be enabled prior to using `XrHandJointVelocityEXT`.
- `velocityFlags` **must** be a valid combination of `XrSpaceVelocityFlagBits` values.
- `velocityFlags` **must** not be 0.

12.29.5. Example code for locating hand joints

The following example code demonstrates how to locate all hand joints relative to a world space.

```c
XrInstance instance; // previously initialized
XrSystemId systemId; // previously initialized
XrSession session;   // previously initialized
XrSpace worldSpace;  // previously initialized, e.g. from
                      // XR_REFERENCE_SPACE_TYPE_LOCAL

// Inspect hand tracking system properties
XrSystemHandTrackingPropertiesEXT handTrackingSystemProperties{
    XR_TYPE_SYSTEM_HAND_TRACKING_PROPERTIES_EXT};
XrSystemProperties systemProperties{XR_TYPE_SYSTEM_PROPERTIES,
    &handTrackingSystemProperties};
CHK_XR(xrGetSystemProperties(instance, systemId, &systemProperties));
if (!handTrackingSystemProperties.supportsHandTracking) {
    // The system does not support hand tracking
    return;
}

// Get function pointer for xrCreateHandTrackerEXT
PFN_xrCreateHandTrackerEXT pfnCreateHandTrackerEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrCreateHandTrackerEXT",
    reinterpret_cast<PFN_xrVoidFunction*>(
    &pfnCreateHandTrackerEXT)));

// Create a hand tracker for left hand that tracks default set of hand joints.
XrHandTrackerEXT leftHandTracker{};
{
    XrHandTrackerCreateInfoEXT createInfo{XR_TYPE_HAND_TRACKER_CREATE_INFO_EXT};
    createInfo.hand = XR_HAND_LEFT_EXT;
    createInfo.handJointSet = XR_HAND_JOINT_SET_DEFAULT_EXT;
    CHK_XR(pfnCreateHandTrackerEXT(session, &createInfo, &leftHandTracker));
}

// Allocate buffers to receive joint location and velocity data before frame
// loop starts
```
XrHandJointLocationEXT jointLocations[XR_HAND_JOINT_COUNT_EXT];
XrHandJointVelocityEXT jointVelocities[XR_HAND_JOINT_COUNT_EXT];

XrHandJointVelocitiesEXT velocities[XR_TYPE_HAND_JOINT VELOCITIES_EXT];
velocities.jointCount = XR_HAND_JOINT_COUNT_EXT;
velocities.jointVelocities = jointVelocities;

XrHandJointLocationsEXT locations[XR_TYPE_HAND_JOINT_LOCATIONS_EXT];
locations.next = &velocities;
locations.jointCount = XR_HAND_JOINT_COUNT_EXT;
locations.jointLocations = jointLocations;

// Get function pointer for xrLocateHandJointsEXT
PFN_xrLocateHandJointsEXT pfnLocateHandJointsEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrLocateHandJointsEXT",
reinterpret_cast<PFN_xrVoidFunction*>(
&pfnLocateHandJointsEXT)));

while (1) {
    // ...
    // For every frame in frame loop
    // ...
    XrFrameState frameState; // previously returned from xrWaitFrame
    const XrTime time = frameState.predictedDisplayTime;

    XrHandJointsLocateInfoEXT locateInfo[XR_TYPE_HAND JOINTS LOCATE INFO_EXT];
    locateInfo.baseSpace = worldSpace;
    locateInfo.time = time;

    CHK_XR(pfnLocateHandJointsEXT(leftHandTracker, &locateInfo, &locations));

    if (locations.isActive) {
        // The returned joint location array can be directly indexed with
        // XrHandJointEXT enum.
        const XrPosef &indexTipInWorld =
            jointLocations[XR_HAND_JOINT_INDEX_TIP_EXT].pose;
        const XrPosef &thumbTipInWorld =
            jointLocations[XR_HAND_JOINT_THUMB_TIP_EXT].pose;

        // using the returned radius and velocity of index finger tip.
        const float indexTipRadius =
            jointLocations[XR_HAND_JOINT_INDEX_TIP_EXT].radius;
        const XrHandJointVelocityEXT &indexTipVelocity =
            jointVelocities[XR_HAND_JOINT_INDEX_TIP_EXT];
    }
}
12.29.6. Conventions of hand joints

This extension defines 26 joints for hand tracking: 4 joints for the thumb finger, 5 joints for the other four fingers, and the wrist and palm of the hands.
typedef enum XrHandJointEXT {
    XR_HAND_JOINT_PALM_EXT = 0,
    XR_HAND_JOINT_WRIST_EXT = 1,
    XR_HAND_JOINT_THUMB_METACARPAL_EXT = 2,
    XR_HAND_JOINT_THUMB_PROXIMAL_EXT = 3,
    XR_HAND_JOINT_THUMB_DISTAL_EXT = 4,
    XR_HAND_JOINT_THUMB_TIP_EXT = 5,
    XR_HAND_JOINT_INDEX_METACARPAL_EXT = 6,
    XR_HAND_JOINT_INDEX_PROXIMAL_EXT = 7,
    XR_HAND_JOINT_INDEX_INTERMEDIATE_EXT = 8,
    XR_HAND_JOINT_INDEX_DISTAL_EXT = 9,
    XR_HAND_JOINT_INDEX_TIP_EXT = 10,
    XR_HAND_JOINT_MIDDLE_METACARPAL_EXT = 11,
    XR_HAND_JOINT_MIDDLE_PROXIMAL_EXT = 12,
    XR_HAND_JOINT_MIDDLE_INTERMEDIATE_EXT = 13,
    XR_HAND_JOINT_MIDDLE_DISTAL_EXT = 14,
    XR_HAND_JOINT_MIDDLE_TIP_EXT = 15,
    XR_HAND_JOINT_RING_METACARPAL_EXT = 16,
    XR_HAND_JOINT_RING_PROXIMAL_EXT = 17,
    XR_HAND_JOINT_RING_INTERMEDIATE_EXT = 18,
    XR_HAND_JOINT_RING_DISTAL_EXT = 19,
    XR_HAND_JOINT_RING_TIP_EXT = 20,
    XR_HAND_JOINT_LITTLE_METACARPAL_EXT = 21,
    XR_HAND_JOINT_LITTLE_PROXIMAL_EXT = 22,
    XR_HAND_JOINT_LITTLE_INTERMEDIATE_EXT = 23,
    XR_HAND_JOINT_LITTLE_DISTAL_EXT = 24,
    XR_HAND_JOINT_LITTLE_TIP_EXT = 25,
    XR_HAND_JOINT_MAX_ENUM_EXT = 0x7FFFFFFF
} XrHandJointEXT;

The finger joints, except the tips, are named after the corresponding bone at the further end of the bone from the finger tips. The joint's orientation is defined at a fully opened hand pose facing down as in the above picture.

**Note**

Many applications and game engines use names to identify joints rather than using indices. If possible, applications should use the joint name part of the `XrHandJointEXT` enum plus a hand identifier to help prevent joint name clashes (e.g. `Index_Metacarpal_L, Thumb_Tip_R`). Using consistent names increases the portability of assets between applications and engines. Including the hand in the identifier prevents ambiguity when both hands are used in the same skeleton, such as when they are combined with additional joints to form a full body skeleton.

The backward (+Z) direction is parallel to the corresponding bone and points away from the finger tip. The up (+Y) direction is pointing out of the back of and perpendicular to the corresponding finger nail.
at the fully opened hand pose. The X direction is perpendicular to Y and Z and follows the right hand rule.

The wrist joint is located at the pivot point of the wrist which is location invariant when twisting hand without moving the forearm. The backward (+Z) direction is parallel to the line from wrist joint to middle finger metacarpal joint, and points away from the finger tips. The up (+Y) direction points out towards back of hand and perpendicular to the skin at wrist. The X direction is perpendicular to the Y and Z directions and follows the right hand rule.

The palm joint is located at the center of the middle finger’s metacarpal bone. The backward (+Z) direction is parallel to the middle finger’s metacarpal bone, and points away from the finger tips. The up (+Y) direction is perpendicular to palm surface and pointing towards the back of the hand. The X direction is perpendicular to the Y and Z directions and follows the right hand rule.

The radius of each joint is the distance from the joint to the skin in meters. The application can use a sphere at the joint location with joint radius for collision detection for interactions, such as pushing a virtual button using the index finger tip.

For example, suppose the radius of the palm joint is \( r \) then the app can offset \( \{0, -r, 0\} \) to palm joint location to get the surface of hand palm center, or offset \( \{0, r, 0\} \) to get the back surface of the hand.

Note that the palm joint for the hand tracking is not the same as \(.../input/grip/pose\) when hand tracking is provided by controller tracking. A "grip" pose is located at the center of the controller handle when user is holding a controller, outside of the user’s hand. A "palm" pose is located at the center of middle finger metacarpal bone which is inside the user’s hand.

```c
#define XR_HAND_JOINT_COUNT_EXT 26
```

\(\text{XR_HAND_JOINT_COUNT_EXT}\) defines the number of hand joint enumerants defined in \texttt{XrHandJointEXT}

**New Object Types**

- \texttt{XrHandTrackerEXT}

**New Flag Types**

**New Enum Constants**

- \texttt{XR_HAND_JOINT_COUNT_EXT}

\texttt{XrObjectType} enumeration is extended with:

- \texttt{XR_OBJECT_TYPE_HAND_TRACKER_EXT}
The `XrStructureType` enumeration is extended with:

- `XR_TYPE_SYSTEM_HAND_TRACKING_PROPERTIES_EXT`
- `XR_TYPE_HAND_TRACKER_CREATE_INFO_EXT`
- `XR_TYPE_HAND_JOINTS_LOCATE_INFO_EXT`
- `XR_TYPE_HAND_JOINT_LOCATIONS_EXT`
- `XR_TYPE_HAND_JOINT VELOCITIES_EXT`

**New Enums**

- `XrHandEXT`
- `XrHandJointEXT`
- `XrHandJointSetEXT`

**New Structures**

- `XrSystemHandTrackingPropertiesEXT`
- `XrHandTrackerCreateInfoEXT`
- `XrHandJointsLocateInfoEXT`
- `XrHandJointLocationEXT`
- `XrHandJointVelocityEXT`
- `XrHandJointLocationsEXT`
- `XrHandJointVelocitiesEXT`

**New Functions**

- `xrCreateHandTrackerEXT`
- `xrDestroyHandTrackerEXT`
- `xrLocateHandJointsEXT`

**Issues**

**Version History**

- Revision 1, 2019-09-16 (Yin LI)
  - Initial extension description
- Revision 2, 2020-04-20 (Yin LI)
  - Replace hand joint spaces to locate hand joints function.
- Revision 3, 2021-04-13 (Ryan Pavlik, Rune Berg)
  - Fix example code to properly use `xrGetInstanceProcAddr`. 
Add recommended bone names

Revision 4, 2021-04-15 (Rune Berg)

Clarify that use of this extension produces an unobstructed hand range of motion.

12.30. XR_EXT_hp_mixed_reality_controller

Name String
XR_EXT_hp_mixed_reality_controller

Extension Type
Instance extension

Registered Extension Number
96

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2020-06-08

IP Status
No known IP claims.

Contributors
Alain Zanchetta, Microsoft
Lachlan Ford, Microsoft
Alex Turner, Microsoft
Yin Li, Microsoft
Nathan Nuber, HP Inc.

Overview
This extension added a new interaction profile path for the HP Reverb G2 Controllers:

• /interaction_profiles/hp/mixed_reality_controller

Valid for the user paths

• /user/hand/left
• /user/hand/right
Supported component paths:

- On `/user/hand/left only`
  - `…/input/x/click`
  - `…/input/y/click`

- On `/user/hand/right only`
  - `…/input/a/click`
  - `…/input/b/click`

- On both hands
  - `…/input/menu/click`
  - `…/input/squeeze/value`
  - `…/input/trigger/value`
  - `…/input/thumbstick/x`
  - `…/input/thumbstick/y`
  - `…/input/thumbstick/click`
  - `…/input/grip/pose`
  - `…/input/aim/pose`
  - `…/output/haptic`

Version History

- Revision 1, 2020-06-08 (Yin Li)
  - Initial extension proposal

12.31. XR_EXT_palm_pose

Name String

XR_EXT_palm_pose

Extension Type

Instance extension

Registered Extension Number

177

Revision

2
Overview

This extension defines a new "standard pose identifier" for interaction profiles, named "palm_ext". The new identifier is a pose that can be used to place application-specific visual content such as avatar visuals that may or may not match human hands. This extension also adds a new input component path using this "palm_ext" pose identifier to existing interaction profiles when active.

The application can use the .../input/palm_ext/pose component path to place visual content representing the user's physical hand location. Application visuals may depict, for example, realistic human hands that are very simply animated or creative depictions such as an animal, an alien, or robot limb extremity.

Note that this is not intended to be an alternative to extensions that perform hand tracking for more complex use cases: the use of "palm" in the name is to reflect that it is a user-focused pose rather than a held-object-focused pose.

Pose Identifier

When this extension is active, a runtime must behave as if the following were added to the list of Standard pose identifiers.

- palm_ext - a pose that allows applications to reliably anchor visual content relative to the user's physical hand, whether the user's hand is tracked directly or its position and orientation is inferred by a physical controller. The palm pose is defined as follows:
  - The palm position: The user's physical palm centroid, at the surface of the palm.
  - The palm orientation's +X axis: When a user is holding the controller and straightens their index finger, the ray that is normal to the user's palm (away from the palm in the left hand, into the palm in the right hand).
The palm orientation’s -Z axis: When a user is holding the controller and straightens their index finger, the ray that is parallel to their finger’s pointing direction.

The palm orientation’s +Y axis: orthogonal to +Z and +X using the right-hand rule.

Figure 7. Example palm pose for (from left to right) a generic motion controller, tracked hand, and a digital hand avatar). The X axis is depicted in red. The Y axis is depicted in green. The Z axis is depicted in blue.

This pose is explicitly static for rigid controller type devices.

**Interaction Profile Additions**

When this extension is active, a runtime **must** accept the `../input/palm_ext/pose` component path for all interaction profiles that are valid for at least one of the user paths listed below, including those interaction profiles enabled through extensions. Actions bound to such palm input component paths **must** behave as though those paths were listed in the original definition of an interaction profile.

Valid for the user paths

- `/user/hand/left`
- `/user/hand/right`

Supported component paths:

- On both user paths
  - `../input/palm_ext/pose`
Note

While this extension itself does not add the \textit{../input/palm\_ext/pose} input component path to interaction profiles defined in extensions, extension authors may update existing extensions to add this path, or submit new extensions defining new interaction profiles using this pose identifier and component path. For consistency, it is recommended that the \textit{../input/palm\_ext/pose} path in extension-defined interaction profiles be specified as only valid when this \texttt{XR\_EXT\_palm\_pose} extension is also enabled.

This extension does pose a challenge to API layer implementers attempting to provide interaction profile support through their layer. If a runtime implements \texttt{XR\_EXT\_palm\_pose}, and an application enables it, but such an API layer is unaware of it, the runtime may "accept" (not error) the additional suggested binding but the layer will not know to provide data or indicate an active binding. This behavior, while unexpected, does not violate the specification, and does not substantially increase the difficulty of providing additional input support using an API layer.

Version History

- Revision 1, 2020-07-26 (Jack Pritz)
  - Initial extension proposal
- Revision 2, 2022-05-18 (Lachlan Ford)
  - Modification and cleanup of extension proposal based on working group discussion

12.32. \texttt{XR\_EXT\_performance\_settings}

Name String

\texttt{XR\_EXT\_performance\_settings}

Extension Type

Instance extension

Registered Extension Number

16

Revision

3

Extension and Version Dependencies

- Requires OpenXR 1.0

Last Modified Date

2021-04-14
12.32.1. Overview

This extension defines an API for the application to give performance hints to the runtime and for the runtime to send performance related notifications back to the application. This allows both sides to dial in a suitable compromise between needed CPU and GPU performance, thermal sustainability and a consistent good user experience throughout the session.

The goal is to render frames consistently, in time, under varying system load without consuming more energy than necessary.

In summary, the APIs allow:

- setting performance level hints
- receiving performance related notifications

12.32.2. Setting Performance Levels Hints

Performance level hint definition

The XR performance level hints for a given hardware system are expressed as a level XrPerfSettingsLevelEXT for each of the XR-critical processing domains XrPerfSettingsDomainEXT (currently defined is a CPU and a GPU domain):

```c
typedef enum XrPerfSettingsDomainEXT {
    XR_PERF_SETTINGS_DOMAIN_CPU_EXT = 1,
    XR_PERF_SETTINGS_DOMAIN_GPU_EXT = 2,
    XR_PERF_SETTINGS_DOMAIN_MAX_ENUM_EXT = 0x7FFFFFFF
} XrPerfSettingsDomainEXT;
```
typedef enum XrPerfSettingsLevelEXT {
    XR_PERF_SETTINGS_LEVEL_POWER_SAVINGS_EXT = 0,
    XR_PERF_SETTINGS_LEVEL_SUSTAINED_LOW_EXT = 25,
    XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT = 50,
    XR_PERF_SETTINGS_LEVEL_BOOST_EXT = 75,
    XR_PERF_SETTINGS_LEVEL_MAX_ENUM_EXT = 0x7FFFFFFF
} XrPerfSettingsLevelEXT;

This extension defines platform-independent level hints:

- **XR_PERF_SETTINGS_LEVEL_POWER_SAVINGS_EXT** is used by the application to indicate that it enters a non-
  XR section (head-locked / static screen), during which power savings are to be prioritized. Consistent XR compositing, consistent frame rendering, and low latency are not needed.

- **XR_PERF_SETTINGS_LEVEL_SUSTAINED_LOW_EXT** is used by the application to indicate that it enters a low
  and stable complexity section, during which reducing power is more important than occasional
  late rendering frames. With such a hint, the XR Runtime still strives for consistent XR compositing
  (no tearing) within a thermally sustainable range(*), but is allowed to take measures to reduce
  power, such as increasing latencies or reducing headroom.

- **XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT** is used by the application to indicate that it enters a
  high or dynamic complexity section, during which the XR Runtime strives for consistent XR
  compositing and frame rendering within a thermally sustainable range(*).

- **XR_PERF_SETTINGS_LEVEL_BOOST_EXT** is used to indicate that the application enters a section with very
  high complexity, during which the XR Runtime is allowed to step up beyond the thermally
  sustainable range. As not thermally sustainable, this level is meant to be used for short-term
  durations (< 30 seconds).

(*) If the application chooses one of the two sustainable levels
(XR_PERF_SETTINGS_LEVEL_SUSTAINED_LOW_EXT or XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT), the device
may still run into thermal limits under non-nominal circumstances (high room temperature,
additional background loads, extended device operation) and therefore the application should also in
the sustainable modes be prepared to react to performance notifications (in particular
XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT and XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT in the
thermal sub-domain, see Notification level definition).

The XR Runtime shall select **XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT** as the default hint if the
application does not provide any. The function to call for setting performance level hints is
xrPerfSettingsSetPerformanceLevelEXT.

XrResult xrPerfSettingsSetPerformanceLevelEXT(
    XrSession session,
    XrPerfSettingsDomainEXT domain,
    XrPerfSettingsLevelEXT level);
**Example of using the short-term boost level hint**

For a limited amount of time, both the Mobile and PC systems can provide a higher level of performance than is thermally sustainable. It is desirable to make this extra computational power available for short complex scenes, then go back to a sustainable lower level. This section describes means for the application developer to apply settings directing the runtime to boost performance for a short-term duration.

The application developer must pay attention to keep these boost periods very short and carefully monitor the side effects, which may vary a lot between different hardware systems.

*Sample code for temporarily boosting the performance*

```c
extern XrInstance instance;  
extern XrSession session;

// Get function pointer for xrPerfSettingsSetPerformanceLevelEXT
PFN_xrPerfSettingsSetPerformanceLevelEXT pfnPerfSettingsSetPerformanceLevelEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrPerfSettingsSetPerformanceLevelEXT",
  (PFN_xrVoidFunction*)(
    &pfnPerfSettingsSetPerformanceLevelEXT)));

// before entering the high complexity section
pfnPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_CPU_EXT,
  XR_PERF_SETTINGS_LEVEL_BOOST_EXT);  
PfnPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_GPU_EXT,
  XR_PERF_SETTINGS_LEVEL_BOOST_EXT);

// entering the high complexity section
// ... running
// end of the high complexity section
pfnPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_CPU_EXT,
  XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT);  
PfnPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_GPU_EXT,
  XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT);
```

① we assume that `instance` and `session` are initialized and their handles are available

② setting performance level to `XR_PERF_SETTINGS_LEVEL_BOOST_EXT` on both CPU and GPU domains

③ going back to the sustainable `XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT`

**Example of using the sustained low level hint for the CPU domain**

---

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extern XrInstance instance; ①
extern XrSession session;

// Get function pointer for xrPerfSettingsSetPerformanceLevelEXT
PFN_xrPerfSettingsSetPerformanceLevelEXT pfnPerfSettingsSetPerformanceLevelEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrPerfSettingsSetPerformanceLevelEXT",
     (PFN_xrVoidFunction*)(
         &pfnPerfSettingsSetPerformanceLevelEXT)));

// before entering a low CPU complexity section
pfnPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_CPU_EXT,
    XR_PERF_SETTINGS_LEVEL_SUSTAINED_LOW_EXT);
pfnPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_GPU_EXT,
    XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT); ②

// entering the low complexity section
// ... running
// end of the low complexity section
pfnPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_CPU_EXT,
    XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT); ③

① we assume that instance and session are initialized and their handles are available
② the developer may choose to only reduce CPU domain and keep the GPU domain at
    XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT
③ going back to the sustainable XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT for CPU

12.32.3. Receiving Performance Related Notifications

The XR runtime shall provide performance related notifications to the application in the following situations:

• the compositing performance within the runtime has reached a new level, either improved or
degraded from the previous one (subDomain is set to XR_PERF_SETTINGS_SUB_DOMAIN_COMPOSITING_EXT)

• the application rendering performance has reached a new level, either improved or degraded from
the previous one (subDomain is set to XR_PERF_SETTINGS_SUB_DOMAIN_RENDERING_EXT)

• the temperature of the device has reached a new level, either improved or degraded from the
previous one (subDomain is set to XR_PERF_SETTINGS_SUB_DOMAIN_THERMAL_EXT).

When degradation is observed, the application should take measures reducing its workload, helping
the compositing or rendering subDomain to meet their deadlines, or the thermal subDomain to avoid or
stop throttling. When improvement is observed, the application can potentially rollback some of its
mitigations.
Compositing Sub-Domain

One of the major functions the runtime shall provide is the timely compositing of the submitted layers in the background. The runtime has to share the CPU and GPU system resources for this operation with the application. Since this is extremely time sensitive - the head room is only a few milliseconds - the runtime may have to ask the application via notifications to cooperate and relinquish some usage of the indicated resource (CPU or GPU domain). Performance issues in this area that the runtime notices are notified to the application with the `subDomain` set to `XR_PERF_SETTINGS_SUB_DOMAIN_COMPOSITING_EXT`.

Rendering Sub-Domain

The application submits rendered layers to the runtime for compositing. Performance issues in this area that the runtime notices (i.e. missing submission deadlines) are notified to the application with the `subDomain` set to `XR_PERF_SETTINGS_SUB_DOMAIN_RENDERING_EXT`.

Thermal Sub-Domain

XR applications run at a high-performance level during long periods of time, across a game or an entire movie session. As form factors shrink, especially on mobile solutions, the risk of reaching die thermal runaway or reaching the limits on skin and battery temperatures increases. When thermal limits are reached, the device mitigates the heat generation leading to severe performance reductions, which greatly affects user experience (dropped frames, high latency).

Better than dropping frames when it is too late, pro-active measures from the application should be encouraged.

The performance notification with the `subDomain` set to `XR_PERF_SETTINGS_SUB_DOMAIN_THERMAL_EXT` provides an early warning allowing the application to take mitigation actions.
Notification level definition

The levels are defined as follows:

```c
typedef enum XrPerfSettingsNotificationLevelEXT {
    XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT = 0,
    XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT = 25,
    XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT = 75,
    XR_PERF_SETTINGS_NOTIFICATION_LEVEL_MAX_ENUM_EXT = 0x7FFFFFFF
} XrPerfSettingsNotificationLevelEXT;
```

- **XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT** notifies that the sub-domain has reached a level where no further actions other than currently applied are necessary.
- **XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT** notifies that the sub-domain has reached an early warning level where the application should start proactive mitigation actions with the goal to return to the **XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT** level.
- **XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT** notifies that the sub-domain has reached a critical level with significant performance degradation. The application should take drastic mitigation action.

The above definitions summarize the broad interpretation of the notification levels, however sub-domain specific definitions of each level and their transitions are specified below:

- **XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT**
  - For the compositing sub-domain, **XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT** indicates that the composition headroom is consistently being met with sufficient margin.
  - Getting into **XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT** from **XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT** indicates that the composition headroom was consistently **met with sufficient margin during a sufficient time period**.
  - For the rendering sub-domain, **XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT** indicates that frames are being submitted in time to be used by the compositor.
  - Getting into **XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT** from **XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT** indicates that **during a sufficient time period, none** of the due layers was **too late** to be picked up by the compositor.
  - For the thermal sub-domain, **XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT** indicates that the current load should be sustainable in the near future.
  - Getting into **XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT** from **XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT** indicates that the runtime does not presuppose any further temperature mitigation action on the application side, other than the current ones.

- **XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT**
  - For the compositing sub-domain, **XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT** indicates that the compositing headroom of the current frame was met but the margin is considered insufficient by the runtime, and the application **should** reduce its workload in the notified domain to solve
this problem.

Getting into XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT from XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT indicates that the compositing deadline was not missed during a sufficient time period.

- For the rendering sub-domain, XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT indicates that at least one layer is regularly late to be picked up by the compositor, resulting in a degraded user experience, and that the application should take action to consistently provide frames in a more timely manner.
- Getting into XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT from XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT indicates that the runtime has stopped any of its own independent actions which are tied to the XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT level.
- For the thermal sub-domain, the XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT indicates that the runtime expects the device to overheat under the current load, and that the application should take mitigating action in order to prevent thermal throttling.
- Getting into XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT from XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT indicates that the underlying system thermal throttling has stopped.

- XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT
  - For the compositing sub-domain, XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT indicates that composition can no longer be maintained under the current workload. The runtime may take independent action that will interfere with the application (e.g. limiting the framerate, ignoring submitted layers, or shutting down the application) in order to correct this problem.
  - For the rendering sub-domain, XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT indicates that at least one layer is too often late to be picked up by the compositor, and consequently the runtime may take independent action that will interfere with the application (e.g. informing the user that the application is not responding, displaying a tracking environment in order to maintain user orientation).
  - For the thermal sub-domain, XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT indicates that the underlying system is taking measures, such as thermal throttling to reduce the temperature, impacting the XR experience.

Leaving XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT indicates that any mitigating actions by the runtime (e.g. down-clocking the device to stay within thermal limits) have ended.

Performance Settings API Reference

xrPerfSettingsSetPerformanceLevelEXT
XrResult xrPerfSettingsSetPerformanceLevelEXT(
    XrSession session,
    XrPerfSettingsDomainEXT domain,
    XrPerfSettingsLevelEXT level);

**Parameter Descriptions**

- **session** is a valid XrSession handle.
- **domain**: the processing domain for which the level hint is applied.
- **level**: the level hint to be applied.

**Valid Usage (Implicit)**

- The XR_EXT_performance_settings extension **must** be enabled prior to calling xrPerfSettingsSetPerformanceLevelEXT.
- **session** **must** be a valid XrSession handle.
- **domain** **must** be a valid XrPerfSettingsDomainEXT value.
- **level** **must** be a valid XrPerfSettingsLevelEXT value.

**Return Codes**

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST

Refer to Performance level hint definition for the definition of the level enumerations.
typedef struct XrEventDataPerfSettingsEXT {
    XrStructureType                       type;
    const void*                           next;
    XrPerfSettingsDomainEXT               domain;
    XrPerfSettingsSubDomainEXT            subDomain;
    XrPerfSettingsNotificationLevelEXT    fromLevel;
    XrPerfSettingsNotificationLevelEXT    toLevel;
} XrEventDataPerfSettingsEXT;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **domain**: processing domain in which a threshold has been crossed
- **subDomain**: system area in which a threshold has been crossed
- **fromLevel**: enumerated notification level which has been exited
- **toLevel**: enumerated notification level which has been entered

Valid Usage (Implicit)

- The XR_EXT_performance_settings extension must be enabled prior to using XrEventDataPerfSettingsEXT
- **type** must be XR_TYPE_EVENT_DATA_PERF_SETTINGS_EXT
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **domain** must be a valid XrPerfSettingsDomainEXT value
- **subDomain** must be a valid XrPerfSettingsSubDomainEXT value
- **fromLevel** must be a valid XrPerfSettingsNotificationLevelEXT value
- **toLevel** must be a valid XrPerfSettingsNotificationLevelEXT value
typedef enum XrPerfSettingsDomainEXT {
    XR_PERF_SETTINGS_DOMAIN_CPU_EXT = 1,
    XR_PERF_SETTINGS_DOMAIN_GPU_EXT = 2,
    XR_PERF_SETTINGS_DOMAIN_MAX_ENUM_EXT = 0x7FFFFFFF
} XrPerfSettingsDomainEXT;

typedef enum XrPerfSettingsSubDomainEXT {
    XR_PERF_SETTINGS_SUB_DOMAIN_COMPOSITING_EXT = 1,
    XR_PERF_SETTINGS_SUB_DOMAIN_RENDERING_EXT = 2,
    XR_PERF_SETTINGS_SUB_DOMAIN_THERMAL_EXT = 3,
    XR_PERF_SETTINGS_SUB_DOMAIN_MAX_ENUM_EXT = 0x7FFFFFFF
} XrPerfSettingsSubDomainEXT;

typedef enum XrPerfSettingsNotificationLevelEXT {
    XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT = 0,
    XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT = 25,
    XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT = 75,
    XR_PERF_SETTINGS_NOTIFICATION_LEVEL_MAX_ENUM_EXT = 0x7FFFFFFF
} XrPerfSettingsNotificationLevelEXT;

Version History

- Revision 1, 2017-11-30 (Armelle Laine)
- Revision 2, 2021-04-13 (Ryan Pavlik)
  - Correctly show function pointer retrieval in sample code
  - Fix sample code callouts
- Revision 3, 2021-04-14 (Ryan Pavlik)
  - Fix missing error code

12.33. XR_EXT_samsung_odyssey_controller

Name String

XR_EXT_samsung_odyssey_controller

Extension Type

Instance extension
Overview

This extension enables the application to differentiate the newer form factor of motion controller released with the Samsung Odyssey headset. It enables the application to customize the appearance and experience of the controller differently from the original mixed reality motion controller.

This extension added a new interaction profile /interaction_profiles/samsung/odyssey_controller to describe the Odyssey controller. The action bindings of this interaction profile work exactly the same as the /interaction_profiles/microsoft/motion_controller in terms of valid user paths and supported input and output component paths.

If the application doesn’t do its own custom rendering for specific motion controllers, it should avoid using this extension and instead just use ../microsoft/motion_controller, as runtimes should treat both controllers equally when applications declare action bindings only for that profile.

If the application wants to customize rendering for specific motion controllers, it should setup the suggested bindings for ../samsung/odyssey_controller the same as ../microsoft/motion_controller when calling xrSuggestInteractionProfileBindings, and expect the same action bindings. Then the application can listen to the XrEventDataInteractionProfileChanged event and inspect the returned interaction profile from xrGetCurrentInteractionProfile to differentiate which controller is being used by the user, and hence customize the appearance or experience of the motion controller specifically for the form factor of ../samsung/odyssey_controller.

Version History
**12.34. XR_EXT_thermal_query**

Name String  
XR_EXT_thermal_query

Extension Type  
Instance extension

Registered Extension Number  
17

Revision  
2

Extension and Version Dependencies  
- Requires OpenXR 1.0

Last Modified Date  
2021-04-14

IP Status  
No known IP claims.

Contributors  
Armelle Laine, Qualcomm Technologies Inc, on behalf of Qualcomm Innovation Center, Inc

**12.34.1. Overview**

This extension provides an API to query a domain’s current thermal warning level and current thermal trend.

**12.34.2. Querying the current thermal level and trend**

This query allows to determine the extent and urgency of the needed workload reduction and to verify that the mitigation measures efficiently reduce the temperature. This query allows the application to retrieve the current notificationLevel, allowing to quickly verify whether the underlying system’s thermal throttling is still in effect. It also provides the application with the remaining temperature headroom (tempHeadroom) until thermal throttling occurs, and the current rate of change (tempSlope). The most critical temperature of the domain is the one which is currently most likely to be relevant for thermal throttling.
To query the status of a given domain:

```c
XrResult xrThermalGetTemperatureTrendEXT(
  XrSession                                   session,
  XrPerfSettingsDomainEXT                     domain,
  XrPerfSettingsNotificationLevelEXT*         notificationLevel,
  float*                                      tempHeadroom,
  float*                                      tempSlope);
```

```c
typedef enum XrPerfSettingsDomainEXT {
  XR_PERF_SETTINGS_DOMAIN_CPU_EXT = 1,
  XR_PERF_SETTINGS_DOMAIN_GPU_EXT = 2,
  XR_PERF_SETTINGS_DOMAIN_MAX_ENUM_EXT = 0x7FFFFFFF
} XrPerfSettingsDomainEXT;
```

```c
typedef enum XrPerfSettingsNotificationLevelEXT {
  XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT = 0,
  XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT = 25,
  XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT = 75,
  XR_PERF_SETTINGS_NOTIFICATION_LEVEL_MAX_ENUM_EXT = 0x7FFFFFFF
} XrPerfSettingsNotificationLevelEXT;
```

For the definition of the notification levels, see [Notification level definition](#).

**Thermal Query API Reference**

**xrThermalGetTemperatureTrendEXT**

```c
XrResult xrThermalGetTemperatureTrendEXT(
  XrSession                                   session,
  XrPerfSettingsDomainEXT                     domain,
  XrPerfSettingsNotificationLevelEXT*         notificationLevel,
  float*                                      tempHeadroom,
  float*                                      tempSlope);
```

Allows to query the current temperature warning level of a domain, the remaining headroom and the trend.
Parameter Descriptions

- **session** is a valid XrSession handle.
- **domain**: the processing domain
- **notificationLevel**: the current warning level
- **tempHeadroom**: temperature headroom in degrees Celsius, expressing how far the most-critical temperature of the domain is from its thermal throttling threshold temperature.
- **tempSlope**: the current trend in degrees Celsius per second of the most critical temperature of the domain.

Valid Usage (Implicit)

- The XR_EXT_thermal_query extension **must** be enabled prior to calling xrThermalGetTemperatureTrendEXT
- **session** must be a valid XrSession handle
- **domain** must be a valid XrPerfSettingsDomainEXT value
- **notificationLevel** must be a pointer to an XrPerfSettingsNotificationLevelEXT value
- **tempHeadroom** must be a pointer to a float value
- **tempSlope** must be a pointer to a float value

Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
typedef enum XrPerfSettingsDomainEXT {
    XR_PERF_SETTINGS_DOMAIN_CPU_EXT = 1,
    XR_PERF_SETTINGS_DOMAIN_GPU_EXT = 2,
    XR_PERF_SETTINGS_DOMAIN_MAX_ENUM_EXT = 0x7FFFFFFF
} XrPerfSettingsDomainEXT;

typedef enum XrPerfSettingsNotificationLevelEXT {
    XR_PERF_SETTINGS_NOTIF_LEVEL_NORMAL_EXT = 0,
    XR_PERF_SETTINGS_NOTIF_LEVEL_WARNING_EXT = 25,
    XR_PERF_SETTINGS_NOTIF_LEVEL_IMPAIRED_EXT = 75,
    XR_PERF_SETTINGS_NOTIFICATION_LEVEL_MAX_ENUM_EXT = 0x7FFFFFFF
} XrPerfSettingsNotificationLevelEXT;

Version History

- Revision 1, 2017-11-30 (Armelle Laine)
- Revision 2, 2021-04-14 (Ryan Pavlik, Collabora)
  - Fix missing error code

12.35. XR_EXT_uuid

Name String
XR_EXT_uuid

Extension Type
Instance extension

Registered Extension Number
300

Revision
1

Extension and Version Dependencies
- Requires OpenXR 1.0

Last Modified Date
2021-10-27

IP Status
No known IP claims.
Contributors

Darryl Gough, Microsoft  
Yin Li, Microsoft  
Alex Turner, Microsoft  
David Fields, Microsoft

Overview

This extension defines a Universally Unique Identifier that follows RFC 4122.

The `XrUuidEXT` structure is a 128-bit Universally Unique Identifier and is defined as:

```c
typedef struct XrUuidEXT {
    uint8_t data[XR_UUID_SIZE_EXT];
} XrUuidEXT;
```

Member Descriptions

- `data` is a 128-bit Universally Unique Identifier.

The structure is composed of 16 octets, with the size and order of the fields defined in RFC 4122 section 4.1.2.

Valid Usage (Implicit)

- The `XR_FB_spatial_entity` extension must be enabled prior to using `XrUuidEXT`

New Object Types

New Flag Types

New Enum Constants

- `XR_UUID_SIZE_EXT`

New Enums

New Structures

- `XrUuidEXT`

New Functions
Issues

Version History

- Revision 1, 2021-10-27 (Darryl Gough)
  - Initial extension description

12.36. XR_EXT_view_configuration_depth_range

Name String

XR_EXT_view_configuration_depth_range

Extension Type

Instance extension

Registered Extension Number

47

Revision

1

Extension and Version Dependencies

- Requires OpenXR 1.0

Last Modified Date

2019-08-16

IP Status

No known IP claims.

Contributors

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Overview

For XR systems there may exist a per view recommended min/max depth range at which content should be rendered into the virtual world. The depth range may be driven by several factors, including user comfort, or fundamental capabilities of the system.
Displaying rendered content outside the recommended min/max depth range would violate the system requirements for a properly integrated application, and can result in a poor user experience due to observed visual artifacts, visual discomfort, or fatigue. The near/far depth values will fall in the range of \((0..+\text{infinity}]\) where \(\max(\text{recommendedNearZ}, \text{minNearZ}) < \min(\text{recommendedFarZ}, \text{maxFarZ})\). Infinity is defined matching the standard library definition such that std::isinf will return true for a returned infinite value.

In order to provide the application with the appropriate depth range at which to render content for each \texttt{XrViewConfigurationView}, this extension provides additional view configuration information, as defined by \texttt{XrViewConfigurationDepthRangeEXT}, to inform the application of the min/max recommended and absolute distances at which content should be rendered for that view.

**New Object Types**

**New Flag Types**

**New Enum Constants**

\texttt{XrStructureType} enumeration is extended with:

- \texttt{XR_TYPE_VIEW_CONFIGURATION_DEPTH_RANGE_EXT}

**New Enums**

**New Structures**

The \texttt{XrViewConfigurationDepthRangeEXT} structure is defined as:

```c
typedef struct XrViewConfigurationDepthRangeEXT {
    XrStructureType type;
    void* next;
    float recommendedNearZ;
    float minNearZ;
    float recommendedFarZ;
    float maxFarZ;
} XrViewConfigurationDepthRangeEXT;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **recommendedNearZ** is the recommended minimum positive distance in meters that content should be rendered for the view to achieve the best user experience.
- **minNearZ** is the absolute minimum positive distance in meters that content should be rendered for the view.
- **recommendedFarZ** is the recommended maximum positive distance in meters that content should be rendered for the view.
- **maxFarZ** is the absolute maximum positive distance in meters that content should be rendered for the view.

When enumerating the view configurations with `xrEnumerateViewConfigurationViews`, the application can provide a pointer to an `XrViewConfigurationDepthRangeEXT` in the next chain of `XrViewConfigurationView`.

Valid Usage (Implicit)

- The XR_EXT_view_configuration_depth_range extension **must** be enabled prior to using `XrViewConfigurationDepthRangeEXT`
- **type** **must** be XR_TYPE_VIEW_CONFIGURATION_DEPTH_RANGE_EXT
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain

New Functions

Issues

Version History

- Revision 1, 2019-10-01 (Blake Taylor)
  - Initial proposal.

12.37. **XR_EXT_win32_appcontainer_compatible**

Name String

```
XR_EXT_win32_appcontainer_compatible
```
Overview

To minimize opportunities for malicious manipulation, a common practice on the Windows OS is to isolate the application process in an AppContainer execution environment. In order for a runtime to work properly in such an application process, the runtime must properly set ACL to device resources and cross process resources.

An application running in an AppContainer process can request for a runtime to enable such AppContainer compatibility by adding XR_EXT_WIN32_APPCONTAINER_COMPATIBLE_EXTENSION_NAME to enabledExtensionNames of XrInstanceCreateInfo when calling xrCreateInstance. If the runtime is not capable of running properly within the AppContainer execution environment, it must return XR_ERROR_EXTENSION_NOT_PRESENT.

If the runtime supports this extension, it can further inspect the capability based on the connected device. If the XR system cannot support an AppContainer execution environment, the runtime must return XR_ERROR_FORM_FACTOR_UNAVAILABLE when the application calls xrGetSystem.

If the call to xrGetSystem successfully returned with a valid XrSystemId, the application can rely on the runtime working properly in the AppContainer execution environment.
12.38. XR_ALMALENCE_digital_lens_control

Name String
XR_ALMALENCE_digital_lens_control

Extension Type
Instance extension

Registered Extension Number
197

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2021-11-08

IP Status
No known IP claims.

Contributors
Ivan Chupakhin, Almalence Inc.
Dmitry Shmunk, Almalence Inc.

Overview
Digital Lens for VR (DLVR) is a computational lens aberration correction technology enabling high resolution, visual clarity and fidelity in VR head mounted displays. The Digital Lens allows to overcome
two fundamental factors limiting VR picture quality, size constraints and presence of a moving optical
element — the eye pupil.

Features:

- Complete removal of lateral chromatic aberrations, across the entire FoV, at all gaze directions.
- Correction of longitudinal chromatic aberrations, lens blur and higher order aberrations.
- Increase of visible resolution.
- Enhancement of edge contrast (otherwise degraded due to lens smear).
- Enables high quality at wide FoV.

For OpenXR runtimes DLVR is implemented as implicit API Layer distributed by Almalence Inc. as
installable package. DLVR utilize eye tracking data (eye pupil coordinates and gaze direction) to
produce corrections of render frames. As long as current core OpenXR API doesn't expose an eye
tracking data, DLVR API Layer relies on 3rd-party eye tracking runtimes.

List of supported eye tracking devices:

- Tobii_VR4_CARBON_P1 (HP Reverb G2 Omnience Edition)
- Tobii_VR4_U2_P2 (HTC Vive Pro Eye)

This extension enables the handling of the Digital Lens for VR API Layer by calling
xrSetDigitalLensControlALMALENCE.

New Object Types

New Flag Types

typedef XrFlags64 XrDigitalLensControlFlagsALMALENCE;

// Flag bits for XrDigitalLensControlFlagsALMALENCE
static const XrDigitalLensControlFlagsALMALENCE
XR_DIGITAL_LENS_CONTROL_PROCESSING_DISABLE_BIT_ALMALENCE = 0x00000001;

Flag Descriptions

- XR_DIGITAL_LENS_CONTROL_PROCESSING_DISABLE_BIT_ALMALENCE — disables Digital Lens processing
  of render textures
New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_DIGITAL_LENS_CONTROL_ALMALENCE

New Enums

New Structures

The XrDigitalLensControlALMALENCE structure is defined as:

```c
typedef struct XrDigitalLensControlALMALENCE {
    XrStructureType                       type;
    const void*                           next;
    XrDigitalLensControlFlagsALMALENCE    flags;
} XrDigitalLensControlALMALENCE;
```

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** must be NULL. No such structures are defined in core OpenXR or this extension.
- **flags** is a bitmask of XrDigitalLensControlFlagBitsALMALENCE indicating various characteristics desired for the Digital Lens.

Valid Usage (Implicit)

- The XR_ALMALENCE_digital_lens_control extension must be enabled prior to using XrDigitalLensControlALMALENCE
- **type** must be XR_TYPE_DIGITAL_LENS_CONTROL_ALMALENCE
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **flags** must be a valid combination of XrDigitalLensControlFlagBitsALMALENCE values
- **flags** must not be 0

New Functions

The xrSetDigitalLensControlALMALENCE function is defined as:
XrResult xrSetDigitalLensControlALMALENCE(
  XrSession session,
  const XrDigitalLensControlALMALENCE* digitalLensControl);

Parameter Descriptions

- **session** is a handle to a running XrSession.
- **digitalLensControl** is the XrDigitalLensControlALMALENCE that contains desired characteristics for the Digital Lens.

xrSetDigitalLensControlALMALENCE handles state of Digital Lens API Layer

Valid Usage (Implicit)

- The XR_ALMALENCE_digital_lens_control extension must be enabled prior to calling xrSetDigitalLensControlALMALENCE.
- **session** must be a valid XrSession handle.
- **digitalLensControl** must be a pointer to a valid XrDigitalLensControlALMALENCE structure.

Return Codes

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST

Issues

Version History

- Revision 1, 2021-11-08 (Ivan Chupakhin)
  - Initial draft
12.39. XR_EPIC_view_configuration_fov

Name String
    XR_EPIC_view_configuration_fov

Extension Type
    Instance extension

Registered Extension Number
    60

Revision
    2

Extension and Version Dependencies
    • Requires OpenXR 1.0

Last Modified Date
    2020-03-05

IP Status
    No known IP claims.

Contributors
    Jules Blok, Epic Games

Overview

This extension allows the application to retrieve the recommended and maximum field-of-view using xrEnumerateViewConfigurationViews. These field-of-view parameters can be used during initialization of the application before creating a session.

The field-of-view given here should not be used for rendering, see xrLocateViews to retrieve the field-of-view for rendering.

For views with fovMutable set to XR_TRUE the maximum field-of-view should specify the upper limit that runtime can support. If the view has fovMutable set to XR_FALSE the runtime must set maxMutableFov to be the same as recommendedFov.

New Object Types

New Flag Types

New Enum Constants

New Enums
New Structures

The `XrViewConfigurationViewFovEPIC` structure is an output struct which can be added to the next chain of `XrViewConfigurationView` to retrieve the field-of-view for that view.

typedef struct XrViewConfigurationViewFovEPIC {
    XrStructureType type;
    const void* next;
    XrFovf recommendedFov;
    XrFovf maxMutableFov;
} XrViewConfigurationViewFovEPIC;

Member Descriptions

• `type` is the `XrStructureType` of this structure.
• `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
• `recommendedFov` is the recommended field-of-view based on the current user IPD.
• `maxMutableFov` is the maximum field-of-view that the runtime can display.

Valid Usage (Implicit)

• The `XR_EPIC_view_configuration_fov` extension must be enabled prior to using `XrViewConfigurationViewFovEPIC`
• `type` must be `XR_TYPE_VIEW_CONFIGURATION_VIEW_FOV_EPIC`
• `next` must be `NULL` or a valid pointer to the next structure in a structure chain

New Functions

Issues

Version History

• Revision 2, 2020-06-04 (Jules Blok)
  ◦ Fixed incorrect member name.
• Revision 1, 2020-03-05 (Jules Blok)
  ◦ Initial version.
12.40. XR_FB_android_surface_swapchain_create

Name String
XR_FB_android_surface_swapchain_create

Extension Type
Instance extension

Registered Extension Number
71

Revision
1

Extension and Version Dependencies
- Requires OpenXR 1.0
- Requires XR_KHR_android_surface_swapchain

Contributors
Cass Everitt, Facebook
Gloria Kennickell, Facebook
Tomislav Novak, Facebook

Overview
This extension provides support for the specification of Android Surface specific swapchain create flags.

In order to enable the functionality of this extension, the application must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo::enabledExtensionNames parameter as indicated in the Extensions section.

These additional create flags are specified by attaching a XrAndroidSurfaceSwapchainCreateInfoFB structure to the next chain of an XrSwapchainCreateInfo structure.

New Object Types

New Flag Types

typedef XrFlags64 XrAndroidSurfaceSwapchainFlagsFB;
Flag Descriptions

- **XR_ANDROID_SURFACE_SWAPCHAIN_SYNCHRONOUS_BIT_FB** indicates the underlying BufferQueue should be created in synchronous mode, allowing multiple buffers to be queued instead of always replacing the last buffer. Buffers are retired in order, and the producer may block until a new buffer is available.

- **XR_ANDROID_SURFACE_SWAPCHAIN_USE_TIMESTAMPS_BIT_FB** indicates the compositor should acquire the most recent buffer whose presentation timestamp is not greater than the expected display time of the final composited frame.

New Enum Constants

- **XrStructureType** enumeration is extended with:
  - **XR_TYPE_ANDROID_SURFACE_SWAPCHAIN_CREATE_INFO_FB**

New Enums

- **XR_ANDROID_SURFACE_SWAPCHAIN_SYNCHRONOUS_BIT_FB**
- **XR_ANDROID_SURFACE_SWAPCHAIN_USE_TIMESTAMPS_BIT_FB**

New Structures

The **XrAndroidSurfaceSwapchainCreateInfoFB** structure is defined as:

```c
typedef struct XrAndroidSurfaceSwapchainCreateInfoFB {
    XrStructureType                     type;
    const void*                         next;
    XrAndroidSurfaceSwapchainFlagsFB    createFlags;
} XrAndroidSurfaceSwapchainCreateInfoFB;
```
Member Descriptions

• type is the XrStructureType of this structure.

• next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

• createFlags is 0 or one or more XrAndroidSurfaceSwapchainFlagBitsFB which indicate various characteristics desired for the Android Surface Swapchain.

XrAndroidSurfaceSwapchainCreateInfoFB contains additional Android Surface specific create flags when calling xrCreateSwapchainAndroidSurfaceKHR. The XrAndroidSurfaceSwapchainCreateInfoFB structure must be provided in the next chain of the XrSwapchainCreateInfo structure when calling xrCreateSwapchainAndroidSurfaceKHR.

Valid Usage (Implicit)

• The XR_FB_android_surface_swapchain_create extension must be enabled prior to using XrAndroidSurfaceSwapchainCreateInfoFB

• type must be XR_TYPE_ANDROID_SURFACE_SWAPCHAIN_CREATE_INFO_FB

• next must be NULL or a valid pointer to the next structure in a structure chain

• createFlags must be a valid combination of XrAndroidSurfaceSwapchainFlagBitsFB values

• createFlags must not be 0

New Functions

Issues

Version History

• Revision 1, 2020-12-10 (Gloria Kennickell)
  ◦ Initial draft

12.41. XR_FB_color_space

Name String

XR_FB_color_space

Extension Type

Instance extension
Registered Extension Number
109

Revision
2

Extension and Version Dependencies
• Requires OpenXR 1.0

Contributors
Volga Aksoy, Facebook
Cass Everitt, Facebook
Gloria Kennickell, Facebook

Overview
XR devices may use a color space that is different from many monitors used in development. Application developers may desire to specify the color space in which they have authored their application so appropriate colors are shown when the application is running on the XR device.

This extension allows:

• An application to get the native color space of the XR device.
• An application to enumerate the supported color spaces for the session.
• An application to set the color space for the session.

In order to enable the functionality of this extension, the application must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo::enabledExtensionNames` parameter as indicated in the Extensions section.

New Object Types

New Flag Types

New Enum Constants

`XrStructureType` enumeration is extended with:

• `XR_TYPE_SYSTEM_COLOR_SPACE_PROPERTIES_FB`

`XrResult` enumeration is extended with:

• `XR_ERROR_COLOR_SPACE_UNSUPPORTED_FB`

New Enums

The possible color spaces are specified by the `XrColorSpaceFB` enumeration.
typedef enum XrColorSpaceFB {
    XR_COLOR_SPACE_UNMANAGED_FB = 0,
    XR_COLOR_SPACE_REC2020_FB = 1,
    XR_COLOR_SPACE_REC709_FB = 2,
    XR_COLOR_SPACE_RIFT_CV1_FB = 3,
    XR_COLOR_SPACE_RIFT_S_FB = 4,
    XR_COLOR_SPACE_QUEST_FB = 5,
    XR_COLOR_SPACE_P3_FB = 6,
    XR_COLOR_SPACE_ADOBE_RGB_FB = 7,
    XR_COLOR_SPACE_MAX_ENUM_FB = 0x7FFFFFFF
} XrColorSpaceFB;
Enumerant Descriptions

- **XR_COLOR_SPACE_UNMANAGED_FB.** No color correction, not recommended for production use.
- **XR_COLOR_SPACE_REC2020_FB.** Standard Rec. 2020 chromacities with D65 white point.
- **XR_COLOR_SPACE_REC709_FB.** Standard Rec. 709 chromaticities, similar to sRGB.
- **XR_COLOR_SPACE_RIFT_CV1_FB.** Unique color space, between P3 and Adobe RGB using D75 white point. This is the preferred color space for standardized color across all Oculus HMDs.

Color Space Details with Chromacity Primaries in CIE 1931 xy:

- Red: (0.666, 0.334)
- Green: (0.238, 0.714)
- Blue: (0.139, 0.053)
- White: (0.298, 0.318)

- **XR_COLOR_SPACE_RIFT_S_FB.** Unique color space. Similar to Rec 709 using D75.

Color Space Details with Chromacity Primaries in CIE 1931 xy:

- Red: (0.640, 0.330)
- Green: (0.292, 0.586)
- Blue: (0.156, 0.058)
- White: (0.298, 0.318)

- **XR_COLOR_SPACE_QUEST_FB.** Unique color space. Similar to Rift CV1 using D75 white point.

Color Space Details with Chromacity Primaries in CIE 1931 xy:

- Red: (0.661, 0.338)
- Green: (0.228, 0.718)
- Blue: (0.142, 0.042)
- White: (0.298, 0.318)

- **XR_COLOR_SPACE_P3_FB.** Similar to DCI-P3, but uses D65 white point instead.

Color Space Details with Chromacity Primaries in CIE 1931 xy:

- Red: (0.680, 0.320)
- Green: (0.265, 0.690)
- Blue: (0.150, 0.060)
- White: (0.313, 0.329)

- **XR_COLOR_SPACE_ADOBE_RGB_FB.** Standard Adobe chromacities.
New Structures

An application may inspect the native color space of the system by chaining an `XrSystemColorSpacePropertiesFB` structure to the `XrSystemProperties` when calling `xrGetSystemProperties`.

The `XrSystemColorSpacePropertiesFB` structure is defined as:

```c
typedef struct XrSystemColorSpacePropertiesFB {
    XrStructureType   type;
    void*             next;
    XrColorSpaceFB    colorSpace;
} XrSystemColorSpacePropertiesFB;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **colorSpace** is the native color space of the XR device.

**Valid Usage (Implicit)**

- The `XR_FB_color_space` extension **must** be enabled prior to using `XrSystemColorSpacePropertiesFB`
- **type** **must** be `XR_TYPE_SYSTEM_COLOR_SPACE_PROPERTIES_FB`
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain
- **colorSpace** **must** be a valid `XrColorSpaceFB` value

New Functions

The `xrEnumerateColorSpacesFB` function is defined as:
XrResult xrEnumerateColorSpacesFB(
    XrSession                                   session,
    uint32_t                                    colorSpaceCapacityInput,
    uint32_t*                                   colorSpaceCountOutput,
    XrColorSpaceFB*                             colorSpaces);

Parameter Descriptions

- **session** is the session that enumerates the supported color spaces.
- **colorSpaceCapacityInput** is the capacity of the **colorSpaces** array, or 0 to retrieve the required capacity.
- **colorSpaceCountOutput** is a pointer to the count of **XrColorSpaceFB** colorSpaces written, or a pointer to the required capacity in the case that **colorSpaceCapacityInput** is insufficient.
- **colorSpaces** is a pointer to an array of **XrColorSpaceFB** color spaces, but can be **NULL** if **colorSpaceCapacityInput** is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required **colorSpaces** size.

xrEnumerateColorSpacesFB enumerates the color spaces supported by the current session. Runtimes **must** always return identical buffer contents from this enumeration for the lifetime of the session.

Valid Usage (Implicit)

- The XR_FB_color_space extension **must** be enabled prior to calling **xrEnumerateColorSpacesFB**
- **session** **must** be a valid **XrSession** handle
- **colorSpaceCountOutput** **must** be a pointer to a uint32_t value
- If **colorSpaceCapacityInput** is not 0, **colorSpaces** **must** be a pointer to an array of **colorSpaceCapacityInput** **XrColorSpaceFB** values
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_SIZE_INSUFFICIENT

The `xrSetColorSpaceFB` function is defined as:

```c
XrResult xrSetColorSpaceFB(XrSession session, const XrColorSpaceFB colorspace);
```

Parameter Descriptions

• `session` is a valid `XrSession` handle.
• `colorSpace` is a supported color space. Supported color spaces are indicated by `xrEnumerateColorSpacesFB`.

`xrSetColorSpaceFB` provides a mechanism for an application to specify the color space used in the final rendered frame. If this function is not called, the session will use the color space deemed appropriate by the runtime. Oculus HMDs for both PC and Mobile product lines default to `XR_COLOR_SPACE_RIFT_CV1_FB`. The runtime must return `XR_ERROR_COLOR_SPACE_UNSUPPORTED_FB` if `colorSpace` is not one of the values enumerated by `xrEnumerateColorSpacesFB`.

Formal definitions of color spaces contain a number of aspects such as gamma correction, max luminance and more. However, `xrSetColorSpaceFB` will only affect the color gamut of the output by transforming the color gamut from the source (defined by the `colorSpace` parameter) to the HMD display's color gamut (defined by the hardware internally). This call will not affect gamma correction,
leaving that to follow the GPU texture format standards. Luminance, tonemapping, and other aspects of the color space will also remain unaffected.

For more info on color management in Oculus HMDs, please refer to this guide: Color Management in Oculus Headsets

### Valid Usage (Implicit)

- The `XR_FB_color_space` extension **must** be enabled prior to calling `xrSetColorSpaceFB`
- `session` **must** be a valid `XrSession` handle
- `colorspace` **must** be a valid `XrColorSpaceFB` value

### Return Codes

#### Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

#### Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_FEATURE_UNSUPPORTED`
- `XR_ERROR_COLOR_SPACE_UNSUPPORTED_FB`

### Issues

### Version History

- Revision 1, 2020-11-09 (Gloria Kennickell)
  - Initial extension description
- Revision 2, 2021-09-28 (Ryan Pavlik, Collabora, Ltd.)
  - Fix XML markup to indicate that `XrSystemColorSpacePropertiesFB` is chained to `XrSystemProperties`.
12.42. XR_FB_composition_layer_alpha_blend

Name String
XR_FB_composition_layer_alpha_blend

Extension Type
Instance extension

Registered Extension Number
42

Revision
2

Extension and Version Dependencies
• Requires OpenXR 1.0

Contributors
Cass Everitt, Facebook
Gloria Kennickell, Facebook
Johannes Schmid, Facebook

Overview
This extension provides explicit control over source and destination blend factors, with separate controls for color and alpha. When specified, these blend controls supersede the behavior of XR_COMPOSITION_LAYER_BLEND_TEXTURE_SOURCE_ALPHA_BIT.

When XR_COMPOSITION_LAYER_UNPREMULTIPLIED_ALPHA_BIT is specified, the source color is unpremultiplied alpha.

Like color, destination alpha is initialized to 0 before composition begins.

In order to enable the functionality of this extension, the application must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo::enabledExtensionNames parameter as indicated in the Extensions section.

These blend factors are specified by attaching a XrCompositionLayerAlphaBlendFB structure to the next chain of a XrCompositionLayerBaseHeader-derived layer structure.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:
New Enums

The possible blend factors are specified by the `XrBlendFactorFB` enumeration.

typedef enum XrBlendFactorFB {
    XR_BLEND_FACTOR_ZERO_FB = 0,
    XR_BLEND_FACTOR_ONE_FB = 1,
    XR_BLEND_FACTOR_SRC_ALPHA_FB = 2,
    XR_BLEND_FACTOR_ONE_MINUS_SRC_ALPHA_FB = 3,
    XR_BLEND_FACTOR_DST_ALPHA_FB = 4,
    XR_BLEND_FACTOR_ONE_MINUS_DST_ALPHA_FB = 5,
    XR_BLEND_FACTOR_MAX_ENUM_FB = 0x7FFFFFFF
} XrBlendFactorFB;

New Structures

The `XrCompositionLayerAlphaBlendFB` structure is defined as:

typedef struct XrCompositionLayerAlphaBlendFB {
    XrStructureType type;
    void* next;
    XrBlendFactorFB srcFactorColor;
    XrBlendFactorFB dstFactorColor;
    XrBlendFactorFB srcFactorAlpha;
    XrBlendFactorFB dstFactorAlpha;
} XrCompositionLayerAlphaBlendFB;

Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain.
- `srcFactorColor` specifies the source color blend factor.
- `dstFactorColor` specifies the destination color blend factor.
- `srcFactorAlpha` specifies the source alpha blend factor.
- `dstFactorAlpha` specifies the destination alpha blend factor.
XrCompositionLayerAlphaBlendFB provides applications with explicit control over source and destination blend factors.

The XrCompositionLayerAlphaBlendFB structure must be provided in the next chain of the XrCompositionLayerBaseHeader structure.

### Valid Usage (Implicit)

- The XR_FB_composition_layer_alpha_blend extension must be enabled prior to using XrCompositionLayerAlphaBlendFB
- `type` must be XR_TYPE_COMPOSITION_LAYER_ALPHA_BLEND_FB
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `srcFactorColor` must be a valid XrBlendFactorFB value
- `dstFactorColor` must be a valid XrBlendFactorFB value
- `srcFactorAlpha` must be a valid XrBlendFactorFB value
- `dstFactorAlpha` must be a valid XrBlendFactorFB value

### New Functions

### Issues

- Should we add separate blend controls for color and alpha?
  - Yes. New use cases necessitated adding separate blend controls for color and alpha.

### Version History

- Revision 1, 2020-06-22 (Gloria Kennickell)
  - Initial draft
- Revision 2, 2020-06-22 (Gloria Kennickell)
  - Provide separate controls for color and alpha blend factors.

### 12.43. XR_FB_composition_layer_image_layout

### Name String

XR_FB_composition_layer_image_layout

### Extension Type

Instance extension

### Registered Extension Number

41
Revision
1

Extension and Version Dependencies
- Requires OpenXR 1.0

Contributors
- Cass Everitt, Facebook
- Gloria Kennickell, Facebook

Overview

This extension does not define a new composition layer type, but rather it defines parameters that change the interpretation of the image layout, where the default image layout is dictated by the Graphics API.

In order to enable the functionality of this extension, you must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo::enabledExtensionNames` parameter as indicated in the Extensions section.

New Object Types

New Flag Types

```c
typedef XrFlags64 XrCompositionLayerImageLayoutFlagsFB;
```

// Flag bits for XrCompositionLayerImageLayoutFlagsFB
static const XrCompositionLayerImageLayoutFlagsFB
XR_COMPOSITION_LAYER_IMAGE_LAYOUT_VERTICAL_FLIP_BIT_FB = 0x00000001;

Flag Descriptions

- `XR_COMPOSITION_LAYER_IMAGE_LAYOUT_VERTICAL_FLIP_BIT_FB` indicates the coordinate origin must be considered flipped vertically.

New Enum Constants

`XrStructureType` enumeration is extended with:

- `XR_TYPE_COMPOSITION_LAYER_IMAGE_LAYOUT_FB`
New Enums

- XR_COMPOSITION_LAYER_IMAGE_LAYOUT_VERTICAL_FLIP_BIT_FB

New Structures

The XrCompositionLayerImageLayoutFB structure is defined as:

```c
typedef struct XrCompositionLayerImageLayoutFB {
    XrStructureType type;
    void* next;
    XrCompositionLayerImageLayoutFlagsFB flags;
} XrCompositionLayerImageLayoutFB;
```

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **flags** is a bitmask of XrCompositionLayerImageLayoutFlagBitsFB.

XrCompositionLayerImageLayoutFB contains additional flags used to change the interpretation of the image layout for a composition layer.

To specify the additional flags, you **must** create a XrCompositionLayerImageLayoutFB structure and pass it via the XrCompositionLayerBaseHeader structure's next parameter.

Valid Usage (Implicit)

- The XR_FB_composition_layer_image_layout extension **must** be enabled prior to using XrCompositionLayerImageLayoutFB
- **type** **must** be XR_TYPE_COMPOSITION_LAYER_IMAGE_LAYOUT_FB
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain
- **flags** **must** be 0 or a valid combination of XrCompositionLayerImageLayoutFlagBitsFB values

New Functions

Issues

Version History
12.44. XR_FB_composition_layer_secure_content

Name String
XR_FB_composition_layer_secure_content

Extension Type
Instance extension

Registered Extension Number
73

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Contributors
Cass Everitt, Facebook
Gloria Kennickell, Facebook

Overview
This extension does not define a new composition layer type, but rather it provides support for the application to specify an existing composition layer type has secure content and whether it must be completely excluded from external outputs, like video or screen capture, or if proxy content must be rendered in its place.

In order to enable the functionality of this extension, you must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo::enabledExtensionNames parameter as indicated in the Extensions section.

New Object Types

New Flag Types

typedef XrFlags64 XrCompositionLayerSecureContentFlagsFB;
Flag Descriptions

- **XR_COMPOSITION_LAYER_SECURE_CONTENT_EXCLUDE_LAYER_BIT_FB** — Indicates the layer will only be visible inside the HMD, and not visible to external sources
- **XR_COMPOSITION_LAYER_SECURE_CONTENT_REPLACE_LAYER_BIT_FB** — Indicates the layer will be displayed inside the HMD, but replaced by proxy content when written to external sources

New Enum Constants

XrStructureType enumeration is extended with:

- **XR_TYPE_COMPOSITION_LAYER_SECURE_CONTENT_FB**

New Enums

- **XR_COMPOSITION_LAYER_SECURE_CONTENT_EXCLUDE_LAYER_BIT_FB**
- **XR_COMPOSITION_LAYER_SECURE_CONTENT_REPLACE_LAYER_BIT_FB**

New Structures

The XrCompositionLayerSecureContentFB structure is defined as:

```c
typedef struct XrCompositionLayerSecureContentFB {
    XrStructureType type;
    const void* next;
    XrCompositionLayerSecureContentFlagsFB flags;
} XrCompositionLayerSecureContentFB;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **flags** is a bitmask of XrCompositionLayerSecureContentFlagBitsFB.

XrCompositionLayerSecureContentFB contains additional flags to indicate a composition layer contains secure content and must not be written to external outputs.

If both XR_COMPOSITION_LAYER_SECURE_CONTENT_EXCLUDE_LAYER_BIT_FB and XR_COMPOSITION_LAYER_SECURE_CONTENT_REPLACE_LAYER_BIT_FB are set, XR_COMPOSITION_LAYER_SECURE_CONTENT_EXCLUDE_LAYER_BIT_FB will take precedence.

To specify the additional flags, you must create a XrCompositionLayerSecureContentFB structure and pass it via the XrCompositionLayerBaseHeader structure’s next parameter.

Valid Usage (Implicit)

- The XR_FB_composition_layer_secure_content extension must be enabled prior to using XrCompositionLayerSecureContentFB
- **type** must be XR_TYPE_COMPOSITION_LAYER_SECURE_CONTENT_FB
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **flags** must be a valid combination of XrCompositionLayerSecureContentFlagBitsFB values
- **flags** must not be 0

New Functions

Issues

Version History

- Revision 1, 2020-06-16 (Gloria Kennickell)
  - Initial draft

12.45. XR_FB_composition_layer_settings

Name String

XR_FB_composition_layer_settings
Extension Type

Instance extension

Registered Extension Number

205

Revision

1

Extension and Version Dependencies

• Requires OpenXR 1.0

Contributors

Grant Yang, Meta Platforms

Overview

This extension allows applications to request the use of processing options such as sharpening or super-sampling on a composition layer.

In order to enable the functionality of this extension, you must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo::enabledExtensionNames` parameter as indicated in the Extensions section.

New Object Types

New Flag Types

typedef XrFlags64 XrCompositionLayerSettingsFlagsFB;

// Flag bits for XrCompositionLayerSettingsFlagsFB
static const XrCompositionLayerSettingsFlagsFB
XR_COMPOSITION_LAYER_SETTINGS_NORMAL_SUPER_SAMPLING_BIT_FB = 0x00000001;
static const XrCompositionLayerSettingsFlagsFB
XR_COMPOSITION_LAYER_SETTINGS_QUALITY_SUPER_SAMPLING_BIT_FB = 0x00000002;
static const XrCompositionLayerSettingsFlagsFB
XR_COMPOSITION_LAYER_SETTINGS_NORMAL_SHARPENING_BIT_FB = 0x00000004;
static const XrCompositionLayerSettingsFlagsFB
XR_COMPOSITION_LAYER_SETTINGS_QUALITY_SHARPENING_BIT_FB = 0x00000008;
Flag Descriptions

- **XR_COMPOSITION_LAYER_SETTINGS_NORMAL_SUPER_SAMPLING_BIT_FB** — Indicates compositor may use layer texture supersampling.
- **XR_COMPOSITION_LAYER_SETTINGS_QUALITY_SUPER_SAMPLING_BIT_FB** — Indicates compositor may use high quality layer texture supersampling.
- **XR_COMPOSITION_LAYER_SETTINGS_NORMAL_SHARPENING_BIT_FB** — Indicates compositor may use layer texture sharpening.
- **XR_COMPOSITION_LAYER_SETTINGS_QUALITY_SHARPENING_BIT_FB** — Indicates compositor may use high quality layer texture sharpening.

New Enum Constants

*XrStructureType* enumeration is extended with:

- **XR_TYPE_COMPOSITION_LAYER_SETTINGS_FB**

New Enums

- **XR_COMPOSITION_LAYER_SETTINGS_NORMAL_SUPER_SAMPLING_BIT_FB**
- **XR_COMPOSITION_LAYER_SETTINGS_QUALITY_SUPER_SAMPLING_BIT_FB**
- **XR_COMPOSITION_LAYER_SETTINGS_NORMAL_SHARPENING_BIT_FB**
- **XR_COMPOSITION_LAYER_SETTINGS_QUALITY_SHARPENING_BIT_FB**

New Structures

The *XrCompositionLayerSettingsFB* structure is defined as:

```c
typedef struct XrCompositionLayerSettingsFB {
    XrStructureType                      type;
    const void*                          next;
    XrCompositionLayerSettingsFlagsFB    layerFlags;
} XrCompositionLayerSettingsFB;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **flags** is a bitmask of XrCompositionLayerSettingsFlagBitsFB.

**XrCompositionLayerSettingsFB** contains additional flags to indicate which processing steps to perform on a composition layer.

If both XR_COMPOSITION_LAYER_SETTINGS_NORMAL_SUPER_SAMPLING_BIT_FB and XR_COMPOSITION_LAYER_SETTINGS_QUALITY_SUPER_SAMPLING_BIT_FB are set, XR_COMPOSITION_LAYER_SETTINGS_NORMAL_SUPER_SAMPLING_BIT_FB will take precedence.

If both XR_COMPOSITION_LAYER_SETTINGS_NORMAL_SHARPENING_BIT_FB and XR_COMPOSITION_LAYER_SETTINGS_QUALITY_SHARPENING_BIT_FB are set, XR_COMPOSITION_LAYER_SETTINGS_NORMAL_SHARPENING_BIT_FB will take precedence.

To specify the additional flags, create an XrCompositionLayerSettingsFB structure and pass it via the XrCompositionLayerBaseHeader structure’s next parameter.

Valid Usage (Implicit)

- The XR_FB_composition_layer_settings extension must be enabled prior to using XrCompositionLayerSettingsFB
- type must be XR_TYPE_COMPOSITION_LAYER_SETTINGS_FB
- next must be NULL or a valid pointer to the next structure in a structure chain
- layerFlags must be a valid combination of XrCompositionLayerSettingsFlagBitsFB values
- layerFlags must not be 0

New Functions

Issues

Version History

- Revision 1, 2022-03-08 (Grant Yang)
  - Initial draft
12.46. XR_FB_display_refresh_rate

Name String
XR_FB_display_refresh_rate

Extension Type
Instance extension

Registered Extension Number
102

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Contributors
Cass Everitt, Facebook
Gloria Kennickell, Facebook

Overview
On platforms which support dynamically adjusting the display refresh rate, application developers may request a specific display refresh rate in order to improve the overall user experience, examples include:

• A video application may choose a display refresh rate which better matches the video content playback rate in order to achieve smoother video frames.

• An application which can support a higher frame rate may choose to render at the higher rate to improve the overall perceptual quality, for example, lower latency and less flicker.

This extension allows:

• An application to identify what display refresh rates the session supports and the current display refresh rate.

• An application to request a display refresh rate to indicate its preference to the runtime.

• An application to receive notification of changes to the display refresh rate which are delivered via events.

In order to enable the functionality of this extension, the application must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo::enabledExtensionNames parameter as indicated in the Extensions section.

New Object Types
New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_EVENT_DATA_DISPLAY_REFRESH_RATE_CHANGED_FB

XrResult enumeration is extended with:

- XR_ERROR_DISPLAY_REFRESH_RATE_UNSUPPORTED_FB

New Enums

New Structures

Receiving the XrEventDataDisplayRefreshRateChangedFB event structure indicates that the display refresh rate has changed.

The XrEventDataDisplayRefreshRateChangedFB structure is defined as:

```c
typedef struct XrEventDataDisplayRefreshRateChangedFB {
    XrStructureType type;
    const void* next;
    float fromDisplayRefreshRate;
    float toDisplayRefreshRate;
} XrEventDataDisplayRefreshRateChangedFB;
```

Member Descriptions

- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- fromDisplayRefreshRate is the previous display refresh rate.
- toDisplayRefreshRate is the new display refresh rate.
Valid Usage (Implicit)

- The `XR_FB_display_refresh_rate` extension **must** be enabled prior to using `XrEventDataDisplayRefreshRateChangedFB`
- **type** **must** be `XR_TYPE_EVENT_DATA_DISPLAY_REFRESH_RATE_CHANGED_FB`
- **next** **must** be `NULL` or a valid pointer to the **next** structure in a structure chain

New Functions

The `xrEnumerateDisplayRefreshRatesFB` function is defined as:

```c
XrResult xrEnumerateDisplayRefreshRatesFB(
    XrSession session,
    uint32_t displayRefreshRateCapacityInput,
    uint32_t* displayRefreshRateCountOutput,
    float* displayRefreshRates);
```

Parameter Descriptions

- **session** is the session that enumerates the supported display refresh rates.
- **displayRefreshRateCapacityInput** is the capacity of the `displayRefreshRates`, or 0 to retrieve the required capacity.
- **displayRefreshRateCountOutput** is a pointer to the count of `float displayRefreshRates` written, or a pointer to the required capacity in the case that `displayRefreshRateCapacityInput` is insufficient.
- **displayRefreshRates** is a pointer to an array of `float` display refresh rates, but **can** be `NULL` if `displayRefreshRateCapacityInput` is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required `displayRefreshRates` size.

`xrEnumerateDisplayRefreshRatesFB` enumerates the display refresh rates supported by the current session. Display refresh rates **must** be in order from lowest to highest supported display refresh rates. Runtimes **must** always return identical buffer contents from this enumeration for the lifetime of the session.
Valid Usage (Implicit)

• The **XR_FB_display_refresh_rate** extension **must** be enabled prior to calling `xrEnumerateDisplayRefreshRatesFB`.

• **session** **must** be a valid **XrSession** handle.

• **displayRefreshRateCountOutput** **must** be a pointer to a **uint32_t** value.

• If **displayRefreshRateCapacityInput** is not 0, **displayRefreshRates** **must** be a pointer to an array of **displayRefreshRateCapacityInput float** values.

Return Codes

Success

• XR_SUCCESS

• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED

• XR_ERROR_VALIDATION_FAILURE

• XR_ERROR_RUNTIME_FAILURE

• XR_ERROR_HANDLE_INVALID

• XR_ERROR_INSTANCE_LOST

• XR_ERROR_SESSION_LOST

• XR_ERROR_SIZE_INSUFFICIENT

The **xrGetDisplayRefreshRateFB** function is defined as:

```c
XrResult xrGetDisplayRefreshRateFB(
    XrSession session,
    float* displayRefreshRate);
```
Parameter Descriptions

• **session** is the **XrSession** to query.

• **displayRefreshRate** is a pointer to a float into which the current display refresh rate will be placed.

**xrGetDisplayRefreshRateFB** retrieves the current display refresh rate.

Valid Usage (Implicit)

• The **XR_FB_display_refresh_rate** extension **must** be enabled prior to calling **xrGetDisplayRefreshRateFB**

• **session** **must** be a valid **XrSession** handle

• **displayRefreshRate** **must** be a pointer to a **float** value

Return Codes

**Success**

• **XR_SUCCESS**

• **XR_SESSION_LOSS_PENDING**

**Failure**

• **XR_ERROR_FUNCTION_UNSUPPORTED**

• **XR_ERROR_VALIDATION_FAILURE**

• **XR_ERROR_RUNTIME_FAILURE**

• **XR_ERROR_HANDLE_INVALID**

• **XR_ERROR_INSTANCE_LOST**

• **XR_ERROR_SESSION_LOST**

The **xrRequestDisplayRefreshRateFB** function is defined as:

```c
XrResult xrRequestDisplayRefreshRateFB(
    XrSession session,
    float displayRefreshRate);
```
Parameter Descriptions

- `session` is a valid `XrSession` handle.
- `displayRefreshRate` is 0.0f or a supported display refresh rate. Supported display refresh rates are indicated by `xrEnumerateDisplayRefreshRatesFB`.

xrRequestDisplayRefreshRateFB provides a mechanism for an application to request the system to dynamically change the display refresh rate to the application preferred value. The runtime **must** return `XR_ERROR_DISPLAY_REFRESH_RATE_UNSUPPORTED_FB` if `displayRefreshRate` is not either 0.0f or one of the values enumerated by `xrEnumerateDisplayRefreshRatesFB`. A display refresh rate of 0.0f indicates the application has no preference.

Note that this is only a request and does not guarantee the system will switch to the requested display refresh rate.

Valid Usage (Implicit)

- The `XR_FB_display_refresh_rate` extension **must** be enabled prior to calling `xrRequestDisplayRefreshRateFB`
- `session` **must** be a valid `XrSession` handle

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_FEATURE_UNSUPPORTED`
- `XR_ERROR_DISPLAY_REFRESH_RATE_UNSUPPORTED_FB`

Issues
Changing the display refresh rate from its system default does not come without trade-offs. Increasing the display refresh rate puts more load on the entire system and can lead to thermal degradation. Conversely, lowering the display refresh rate can provide better thermal sustainability but at the cost of more perceptual issues, like higher latency and flickering.

**Version History**

- Revision 1, 2020-10-05 (Gloria Kennickell)
  - Initial extension description

**12.47. XR_FB_foveation**

**Name String**

XR_FB_foveation

**Extension Type**

Instance extension

**Registered Extension Number**

115

**Revision**

1

**Extension and Version Dependencies**

- Requires OpenXR 1.0
- Requires XR_FB_swapchain_update_state

**Contributors**

Kevin Xiao, Facebook  
Ross Ning, Facebook  
Remi Palandri, Facebook  
Cass Everitt, Facebook  
Gloria Kennickell, Facebook

**Overview**

Foveation in the context of XR is a rendering technique that allows the area of an image near the focal point or fovea of the eye to be displayed at higher resolution than areas in the periphery. This trades some visual fidelity in the periphery, where it is less noticeable for the user, for improved rendering performance, most notably regarding the fragment shader, as fewer pixels or subpixels in the periphery need to be shaded and processed. On platforms which support foveation patterns and features tailored towards the optical properties, performance profiles, and hardware support of specific HMDs, application developers may request and use available foveation profiles from the
runtime. Foveation profiles refer to a set of properties describing how, when, and where foveation will be applied.

This extension allows:

- An application to create swapchains that can support foveation for its graphics API.
- An application to request foveation profiles supported by the runtime and apply them to foveation-supported swapchains.

In order to enable the functionality of this extension, you must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo enabledExtensionNames` parameter as indicated in the Extensions section.

**New Object Types**

```c
XR_DEFINE_HANDLE(XrFoveationProfileFB)
```

`XrFoveationProfileFB` represents a set of properties and resources that define a foveation pattern for the runtime, which can be applied to individual swapchains.

**New Flag Types**

```c
typedef XrFlags64 XrSwapchainCreateFoveationFlagsFB;
```

```c
// Flag bits for XrSwapchainCreateFoveationFlagsFB
static const XrSwapchainCreateFoveationFlagsFB
XR_SWAPCHAIN_CREATE_FOVEATION_SCALED_BIN_BIT_FB = 0x00000001;
static const XrSwapchainCreateFoveationFlagsFB
XR_SWAPCHAIN_CREATE_FOVEATION_FRAGMENT_DENSITY_MAP_BIT_FB = 0x00000002;
```
Flag Descriptions

- **XR_SWAPCHAIN_CREATE_FOVEATION_SCALED_BIN_BIT_FB** — Explicitly create the swapchain with scaled bin foveation support. The application must ensure that the swapchain is using the OpenGL graphics API and that the QCOM_texture_foveated extension is supported and enabled.

- **XR_SWAPCHAIN_CREATE_FOVEATION_FRAGMENT_DENSITY_MAP_BIT_FB** — Explicitly create the swapchain with fragment density map foveation support. The application must ensure that the swapchain is using the Vulkan graphics API and that the VK_EXT_fragment_density_map extension is supported and enabled.

```cpp
typedef XrFlags64 XrSwapchainStateFoveationFlagsFB;
```

// Flag bits for XrSwapchainStateFoveationFlagsFB

There are currently no foveation swapchain state flags. This is reserved for future use.

**New Enum Constants**

**XrObjectType** enumeration is extended with:

- **XR_OBJECT_TYPE_FOVEATION_PROFILE_FB**

**XrStructureType** enumeration is extended with:

- **XR_TYPE_FOVEATION_PROFILE_CREATE_INFO_FB**
- **XR_TYPE_SWAPCHAIN_CREATE_INFO_FOVEATION_FB**
- **XR_TYPE_SWAPCHAIN_STATE_FOVEATION_FB**

**New Enums**

**New Structures**

**XrFoveationProfileCreateInfoFB** **must** be provided when calling **xrCreateFoveationProfileFB**. The runtime **must** interpret **XrFoveationProfileCreateInfoFB** without any additional structs in its **next** chain as a request to create a foveation profile that will apply no foveation to any area of the swapchain.

The **XrFoveationProfileCreateInfoFB** structure is defined as:
typedef struct XrFoveationProfileCreateInfoFB {
    XrStructureType    type;
    void*              next;
} XrFoveationProfileCreateInfoFB;

### Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

### Valid Usage (Implicit)

- The `XR_FB_foveation` extension **must** be enabled prior to using `XrFoveationProfileCreateInfoFB`
- **type** **must** be `XR_TYPE_FOVEATION_PROFILE_CREATE_INFO_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrFoveationLevelProfileCreateInfoFB`

`XrSwapchainCreateInfoFoveationFB` can be provided in the next chain of `XrSwapchainCreateInfo` when calling `xrCreateSwapchain` to indicate to the runtime that the swapchain **must** be created with foveation support in the corresponding graphics API. `XrSwapchainCreateInfoFoveationFB` contains additional foveation-specific flags for swapchain creation.

The `XrSwapchainCreateInfoFoveationFB` structure is defined as:

typedef struct XrSwapchainCreateInfoFoveationFB {
    XrStructureType                      type;
    void*                                next;
    XrSwapchainCreateFoveationFlagsFB    flags;
} XrSwapchainCreateInfoFoveationFB;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **flags** is a bitmask of XrSwapchainCreateFoveationFlagBitsFB which indicate various characteristics for how foveation is enabled on the swapchain.

Valid Usage (Implicit)

- The XR_FB_foveation extension must be enabled prior to using XrSwapchainCreateInfoFoveationFB
- **type** must be XR_TYPE_SWAPCHAIN_CREATE_INFO_FOVEATION_FB
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **flags** must be 0 or a valid combination of XrSwapchainCreateFoveationFlagBitsFB values

XrSwapchainStateFoveationFB can be provided in place of XrSwapchainStateBaseHeaderFB when calling xrUpdateSwapchainFB to update the foveation properties of the swapchain. XrSwapchainCreateInfoFoveationFB contains the desired foveation profile and additional foveation specific flags for updating the swapchain.

The XrSwapchainStateFoveationFB structure is defined as:

```c
typedef struct XrSwapchainStateFoveationFB {
  XrStructureType                     type;
  void*                               next;
  XrSwapchainStateFoveationFlagsFB    flags;
  XrFoveationProfileFB                profile;
} XrSwapchainStateFoveationFB;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **flags** is a bitmask of `XrSwapchainStateFoveationFlagBitsFB` which indicate various characteristics of how and when the foveation properties of the swapchain **must** be updated.
- **profile** is an `XrFoveationProfileFB` defining the desired foveation properties to be applied to the swapchain.

Valid Usage (Implicit)

- The `XR_FB_foveation` extension **must** be enabled prior to using `XrSwapchainStateFoveationFB`
- **type** **must** be `XR_TYPE_SWAPCHAIN_STATE_FOVEATION_FB`
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain
- **flags** **must** be 0
- **profile** **must** be a valid `XrFoveationProfileFB` handle

New Functions

The `xrCreateFoveationProfileFB` function is defined as:

```c
XrResult xrCreateFoveationProfileFB(
    XrSession                                   session,
    const XrFoveationProfileCreateInfoFB*       createInfo,
    XrFoveationProfileFB*                       profile);
```

Parameter Descriptions

- **session** is the `XrSession` that created the swapchains to which this foveation profile will be applied.
- **createInfo** is a pointer to an `XrFoveationProfileCreateInfoFB` structure containing parameters to be used to create the foveation profile.
- **profile** is a pointer to a handle in which the created `XrFoveationProfileFB` is returned.

Creates an `XrFoveationProfileFB` handle. The returned foveation profile handle **may** be subsequently
Valid Usage (Implicit)

- The `XR_FB_foveation` extension **must** be enabled prior to calling `xrCreateFoveationProfileFB`.
- `session` **must** be a valid `XrSession` handle.
- `createInfo` **must** be a pointer to a valid `XrFoveationProfileCreateInfoFB` structure.
- `profile` **must** be a pointer to an `XrFoveationProfileFB` handle.

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_LIMIT_REACHED`

The `xrDestroyFoveationProfileFB` function is defined as:

```c
XrResult xrDestroyFoveationProfileFB(
    XrFoveationProfileFB profile);
```

Parameter Descriptions

- `profile` is the `XrFoveationProfileFB` to destroy.
XrFoveationProfileFB may be safely destroyed after being applied to a swapchain state using xrUpdateSwapchainFB without affecting the foveation parameters of the swapchain. The application is responsible for ensuring that it has no calls using profile in progress when the foveation profile is destroyed.

### Valid Usage (Implicit)

- The XR_FB_foveation extension must be enabled prior to calling xrDestroyFoveationProfileFB
- profile must be a valid XrFoveationProfileFB handle

### Thread Safety

- Access to profile, and any child handles, must be externally synchronized

### Return Codes

#### Success

- XR_SUCCESS

#### Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID

### Issues

### Version History

- Revision 1, 2021-05-13 (Kevin Xiao)
  - Initial extension description

### 12.48. XR_FB_foveation_configuration

#### Name String

XR_FB_foveation_configuration

#### Extension Type

Instance extension
Overview

On Facebook HMDs, developers may create foveation profiles generated by the runtime for the optical properties and performance profile of the specific HMD.

This extension allows:

- An application to request foveation profiles generated by the runtime for the current HMD.

In order to enable the functionality of this extension, you must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo enabledExtensionNames parameter as indicated in the Extensions section.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_FOVEATION_LEVEL_PROFILE_CREATE_INFO_FB

New Enums

The possible foveation levels are specified by the XrFoveationLevelFB enumeration:
typedef enum XrFoveationLevelFB {
    XR_FOVEATION_LEVEL_NONE_FB = 0,
    XR_FOVEATION_LEVEL_LOW_FB = 1,
    XR_FOVEATION_LEVEL_MEDIUM_FB = 2,
    XR_FOVEATION_LEVEL_HIGH_FB = 3,
    XR_FOVEATION_LEVEL_MAX_ENUM_FB = 0x7FFFFFFF
} XrFoveationLevelFB;

**Enumerant Descriptions**

- **XR_FOVEATION_LEVEL_NONE_FB** — No foveation
- **XR_FOVEATION_LEVEL_LOW_FB** — Less foveation (higher periphery visual fidelity, lower performance)
- **XR_FOVEATION_LEVEL_MEDIUM_FB** — Medium foveation (medium periphery visual fidelity, medium performance)
- **XR_FOVEATION_LEVEL_HIGH_FB** — High foveation (lower periphery visual fidelity, higher performance)

The possible foveation levels are specified by the `XrFoveationDynamicFB` enumeration:

typedef enum XrFoveationDynamicFB {
    XR_FOVEATION_DYNAMIC_DISABLED_FB = 0,
    XR_FOVEATION_DYNAMIC_LEVEL_ENABLED_FB = 1,
    XR_FOVEATION_DYNAMIC_MAX_ENUM_FB = 0x7FFFFFFF
} XrFoveationDynamicFB;

**Enumerant Descriptions**

- **XR_FOVEATION_DYNAMIC_DISABLED_FB** — Static foveation at the maximum desired level
- **XR_FOVEATION_DYNAMIC_LEVEL_ENABLED_FB** — Dynamic changing foveation based on performance headroom available up to the maximum desired level

**New Structures**

`XrFoveationLevelProfileCreateInfoFB` can be provided in the next chain of `XrFoveationProfileCreateInfoFB` when calling `xrCreateFoveationProfileFB`. The runtime must interpret `XrSwapchainCreateInfoFoveationFB` with `XrFoveationLevelProfileCreateInfoFB` in its next chain as a request to create a foveation profile that will apply a fixed foveation pattern according to the
parameters defined in the \texttt{XrFoveationLevelProfileCreateInfoFB}.

The \texttt{XrFoveationLevelProfileCreateInfoFB} structure is defined as:

```c
typedef struct XrFoveationLevelProfileCreateInfoFB {
    XrStructureType         type;
    void*                   next;
    XrFoveationLevelFB      level;
    float                   verticalOffset;
    XrFoveationDynamicFB    dynamic;
} XrFoveationLevelProfileCreateInfoFB;
```

### Member Descriptions

- **\texttt{type}** is the \texttt{XrStructureType} of this structure.
- **\texttt{next}** is \texttt{NULL} or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **\texttt{level}** is the maximum desired foveation level.
- **\texttt{verticalOffset}** is the desired vertical offset in degrees for the center of the foveation pattern.
- **\texttt{dynamic}** is the desired dynamic foveation setting.

### Valid Usage (Implicit)

- The \texttt{XR_FB_foveation_configuration} extension \textbf{must} be enabled prior to using \texttt{XrFoveationLevelProfileCreateInfoFB}
- **\texttt{type}** \textbf{must} be \texttt{XR_TYPE_FOVEATION_LEVEL_PROFILE_CREATE_INFO_FB}
- **\texttt{next}** \textbf{must} be \texttt{NULL} or a valid pointer to the next structure in a structure chain
- **\texttt{level}** \textbf{must} be a valid \texttt{XrFoveationLevelFB} value
- **\texttt{dynamic}** \textbf{must} be a valid \texttt{XrFoveationDynamicFB} value

### New Functions

### Issues

### Version History

- Revision 1, 2021-05-13 (Kevin Xiao)
  - Initial extension description
12.49. XR_FB_foveation_vulkan

Name String
  XR_FB_foveation_vulkan

Extension Type
  Instance extension

Registered Extension Number
  161

Revision
  1

Extension and Version Dependencies
  • Requires OpenXR 1.0
  • Requires XR_FB_foveation

Contributors
  Kevin Xiao, Facebook
  Ross Ning, Facebook
  Remi Palandri, Facebook
  Cass Everitt, Facebook
  Gloria Kennickell, Facebook

Overview

The Vulkan graphics API requires an image to be applied to the swapchain to apply a foveation pattern.

This extension allows:

  • An application to obtain foveation textures or constructs needed for foveated rendering in Vulkan.

In order to enable the functionality of this extension, you must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo` `enabledExtensionNames` parameter as indicated in the Extensions section.

New Object Types

New Flag Types

New Enum Constants

`XrStructureType` enumeration is extended with:
New Enums

New Structures

XrSwapchainImageFoveationVulkanFB can be provided in the next chain of XrSwapchainImageVulkanKHR when calling xrEnumerateSwapchainImages on a swapchain created with xrCreateSwapchain, if XrSwapchainCreateInfoFoveationFB was in the next chain of XrSwapchainCreateInfo and XrSwapchainCreateInfoFoveationFB had the XR_SWAPCHAIN_CREATE_FOVEATION_FRAGMENT_DENSITY_MAP_BIT_FB flag set. The image, width, and height will be populated by xrEnumerateSwapchainImages to be compatible with the corresponding XrSwapchainImageVulkanKHR.

The XrSwapchainImageFoveationVulkanFB structure is defined as:

```c
typedef struct XrSwapchainImageFoveationVulkanFB {
    XrStructureType    type;
    void*              next;
    VkImage            image;
    uint32_t           width;
    uint32_t           height;
} XrSwapchainImageFoveationVulkanFB;
```

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **image** is a valid Vulkan VkImage to use.
- **width** is the horizontal width in pixels of the image.
- **height** is the vertical height in pixels of the image.
Valid Usage (Implicit)

- The `XR_FB_foveation_vulkan` extension must be enabled prior to using `XrSwapchainImageFoveationVulkanFB`
- `type` must be `XR_TYPE_SWAPCHAIN_IMAGE_FOVEATION_VULKAN_FB`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain

New Functions

Issues

Version History

- Revision 1, 2021-05-26 (Kevin Xiao)
  - Initial extension description

12.50. `XR_FB_hand_tracking_aim`

Name String

`XR_FB_hand_tracking_aim`

Extension Type

Instance extension

Registered Extension Number

112

Revision

2

Extension and Version Dependencies

- Requires OpenXR 1.0
- Requires `XR_EXT_hand_tracking`

Contributors

Federico Schliemann, Facebook
James Hillery, Facebook
Gloria Kennickell, Facebook

Overview

The `XR_EXT_hand_tracking` extension provides a list of hand joint poses which represent the current configuration of the tracked hands. This extension adds a layer of gesture recognition that is used by
the system.

This extension allows:

- An application to get a set of basic gesture states for the hand when using the XR_EXT_hand_tracking extension.

**New Object Types**

**New Flag Types**

```c
typedef XrFlags64 XrHandTrackingAimFlagsFB;
```

```c
// Flag bits for XrHandTrackingAimFlagsFB
static const XrHandTrackingAimFlagsFB XR_HAND_TRACKING_AIM_COMPUTED_BIT_FB = 0x00000001;
static const XrHandTrackingAimFlagsFB XR_HAND_TRACKING_AIM_VALID_BIT_FB = 0x00000002;
static const XrHandTrackingAimFlagsFB XR_HAND_TRACKING_AIM_INDEX_PINCHING_BIT_FB = 0x00000004;
static const XrHandTrackingAimFlagsFB XR_HAND_TRACKING_AIM_MIDDLE_PINCHING_BIT_FB =
  0x00000008;
static const XrHandTrackingAimFlagsFB XR_HAND_TRACKING_AIM_RING_PINCHING_BIT_FB =
  0x00000010;
static const XrHandTrackingAimFlagsFB XR_HAND_TRACKING_AIM_LITTLE_PINCHING_BIT_FB =
  0x00000020;
static const XrHandTrackingAimFlagsFB XR_HAND_TRACKING_AIM_SYSTEM_GESTURE_BIT_FB =
  0x00000040;
static const XrHandTrackingAimFlagsFB XR_HAND_TRACKING_AIM_DOMINANT_HAND_BIT_FB =
  0x00000080;
static const XrHandTrackingAimFlagsFB XR_HAND_TRACKING_AIM_MENU_PRESSED_BIT_FB =
  0x00000100;
```
Flag Descriptions

- **XR_HAND_TRACKING_AIM_COMPUTED_BIT_FB** — Aiming data is computed from additional sources beyond the hand data in the base structure
- **XR_HAND_TRACKING_AIM_VALID_BIT_FB** — Aiming data is valid
- **XR_HAND_TRACKING_AIM_INDEX_PINCHING_BIT_FB** — Index finger pinch discrete signal
- **XR_HAND_TRACKING_AIM_MIDDLE_PINCHING_BIT_FB** — Middle finger pinch discrete signal
- **XR_HAND_TRACKING_AIM_RING_PINCHING_BIT_FB** — Ring finger pinch discrete signal
- **XR_HAND_TRACKING_AIM_LITTLE_PINCHING_BIT_FB** — Little finger pinch discrete signal
- **XR_HAND_TRACKING_AIM_SYSTEM_GESTURE_BIT_FB** — System gesture is active
- **XR_HAND_TRACKING_AIM_DOMINANT_HAND_BIT_FB** — Hand is currently marked as dominant for the system
- **XR_HAND_TRACKING_AIM_MENU_PRESSED_BIT_FB** — System menu gesture is active

New Enum Constants

`XrStructureType` enumeration is extended with:

- **XR_TYPE_HAND_TRACKING_AIM_STATE_FB**

New Enums

New Structures

`XrHandTrackingAimStateFB` can be provided in the next chain of `XrHandJointLocationsEXT` when calling `xrLocateHandJointsEXT` to request aiming gesture information associated with this hand.

The `XrHandTrackingAimStateFB` structure is defined as:

```c
typedef struct XrHandTrackingAimStateFB {
    XrStructureType             type;
    void*                       next;
    XrHandTrackingAimFlagsFB    status;
    XrPosef                     aimPose;
    float                       pinchStrengthIndex;
    float                       pinchStrengthMiddle;
    float                       pinchStrengthRing;
    float                       pinchStrengthLittle;
} XrHandTrackingAimStateFB;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is **NULL** or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **status** is a bitmask of XrHandTrackingAimFlagBitsFB describing the availability and state of other signals.
- **aimPose** is a system-determined "aim" pose, similar in intent and convention to the aim poses used with the action system, based on hand data.
- **pinchStrengthIndex** is the current pinching strength for the index finger of this hand. Range is 0.0 to 1.0, with 1.0 meaning index and thumb are fully touching.
- **pinchStrengthMiddle** is the current pinching strength for the middle finger of this hand. Range is 0.0 to 1.0, with 1.0 meaning middle and thumb are fully touching.
- **pinchStrengthRing** is the current pinching strength for the ring finger of this hand. Range is 0.0 to 1.0, with 1.0 meaning ring and thumb are fully touching.
- **pinchStrengthLittle** is the current pinching strength for the little finger of this hand. Range is 0.0 to 1.0, with 1.0 meaning little and thumb are fully touching.

Valid Usage (Implicit)

- The XR_FB_hand_tracking_aim extension **must** be enabled prior to using XrHandTrackingAimStateFB
- **type** **must** be XR_TYPE_HAND_TRACKING_AIM_STATE_FB
- **next** **must** be **NULL** or a valid pointer to the next structure in a structure chain

New Functions

Issues

Version History

- Revision 1, 2021-07-07 (Federico Schliemann)
  - Initial extension description
- Revision 2, 2022-04-20 (John Kearney)
  - Correct next chain parent for XrHandTrackingAimStateFB to XrHandJointLocationsEXT
12.51. XR_FB_hand_tracking_capsules

Name String
XR_FB_hand_tracking_capsules

Extension Type
Instance extension

Registered Extension Number
113

Revision
3

Extension and Version Dependencies
• Requires OpenXR 1.0
• Requires XR_EXT_hand_tracking

Contributors
Federico Schliemann, Facebook
James Hillery, Facebook
Gloria Kennickell, Facebook

Overview
The XR_EXT_hand_tracking extension provides a list of hand joint poses which include a collision
sphere for each joint. However some physics systems prefer to use capsules as a collision stand in for
the hands.

This extension allows:

• An application to get a list of capsules that represent the volume of the hand when using the
XR_EXT_hand_tracking extension.

New Object Types

New Flag Types

New Enum Constants

• XR_HAND_TRACKING_CAPSULE_POINT_COUNT_FB
  • XR_FB_HAND_TRACKING_CAPSULE_POINT_COUNT was the original name, and is still provided as an alias
    for backward compatibility.

• XR_HAND_TRACKING_CAPSULE_COUNT_FB
  • XR_FB_HAND_TRACKING_CAPSULE_COUNT was the original name, and is still provided as an alias for
backward compatibility.

*XrStructureType* enumeration is extended with:

- `XR_TYPE_HAND_TRACKING_capsules_STATE_FB`

**New Enums**

**New Structures**

The *XrHandCapsuleFB* structure is defined as:

```c
typedef struct XrHandCapsuleFB {
    XrVector3f      points[XR_HAND_TRACKING_capsule_POINT_COUNT_FB];
    float           radius;
    XrHandJointEXT  joint;
} XrHandCapsuleFB;
```

It describes a collision capsule associated with a hand joint.

**Member Descriptions**

- **points** are the two points defining the capsule length.
- **radius** is the radius of the capsule.
- **joint** is the hand joint that drives this capsule’s transform. Multiple capsules can be attached to the same joint.

**Valid Usage (Implicit)**

- The *XR_FB_hand_tracking_capsules* extension must be enabled prior to using *XrHandCapsuleFB*

*XrHandTrackingCapsulesStateFB* can be provided in the next chain of *XrHandJointLocationsEXT* when calling *xrLocateHandJointsEXT* to request collision capsule information associated with this hand.

The *XrHandTrackingCapsulesStateFB* structure is defined as:
typedef struct XrHandTrackingCapsulesStateFB {
    XrStructureType    type;
    void*              next;
    XrHandCapsuleFB    capsules[XR_HAND_TRACKING_CAPSULE_COUNT_FB];
} XrHandTrackingCapsulesStateFB;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **capsules** is an array of capsules.

**Valid Usage (Implicit)**

- The XR_FB_hand_tracking_capsules extension **must** be enabled prior to using XrHandTrackingCapsulesStateFB
- **type** **must** be XR_TYPE_HAND_TRACKING_CAPSULES_STATE_FB
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain

**New Functions**

**Issues**

**Version History**

- Revision 1, 2021-07-07 (Federico Schliemann)
  - Initial extension description
- Revision 2, 2021-11-18 (Ryan Pavlik, Collabora, Ltd)
  - Fix typos/naming convention errors: rename XR_FB_HAND_TRACKING_CAPSULE_POINT_COUNT to XR_HAND_TRACKING_CAPSULE_POINT_COUNT_FB and XR_FB_HAND_TRACKING_CAPSULE_COUNT to XR_HAND_TRACKING_CAPSULE_COUNT_FB, providing the old names as compatibility aliases.
- Revision 3, 2022-04-20 (John Kearney)
  - Correct next chain parent for XrHandTrackingCapsulesStateFB to XrHandJointLocationsEXT

**12.52. XR_FB_hand_tracking_mesh**
Name String

XR_FB_hand_tracking_mesh

Extension Type
Instance extension

Registered Extension Number
111

Revision
2

Extension and Version Dependencies
• Requires OpenXR 1.0
• Requires XR_EXT_hand_tracking

Contributors
Federico Schliemann, Facebook
James Hillery, Facebook
Gloria Kennickell, Facebook

Overview
The XR_EXT_hand_tracking extension provides a list of hand joint poses but no mechanism to render a skinned hand mesh.

This extension allows:

• An application to get a skinned hand mesh and a bind pose skeleton that can be used to render a hand object driven by the joints from the XR_EXT_hand_tracking extension.
• Control the scale of the hand joints returned by XR_EXT_hand_tracking.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

• XR_TYPE_HAND_TRACKING_MESH_FB
• XR_TYPE_HAND_TRACKING_SCALE_FB

New Enums

New Structures
The `XrVector4sFB` structure is defined as:

```c
typedef struct XrVector4sFB {
    int16_t    x;
    int16_t    y;
    int16_t    z;
    int16_t    w;
} XrVector4sFB;
```

This is a short integer, four component vector type, used for per-vertex joint indexing for mesh skinning.

### Member Descriptions

- `x` is the `x` component of the vector.
- `y` is the `y` component of the vector.
- `z` is the `z` component of the vector.
- `w` is the `w` component of the vector.

### Valid Usage (Implicit)

- The `XR_FB_hand_tracking_mesh` extension must be enabled prior to using `XrVector4sFB`.

The `XrHandTrackingMeshFB` structure contains three sets of parallel, application-allocated arrays: one with per-joint data, one with vertex data, and one with index data.

The `XrHandTrackingMeshFB` structure is defined as:
typedef struct XrHandTrackingMeshFB {
    XrStructureType    type;
    void*              next;
    uint32_t           jointCapacityInput;
    uint32_t           jointCountOutput;
    XrPosef*           jointBindPoses;
    float*             jointRadii;
    XrHandJointEXT*    jointParents;
    uint32_t           vertexCapacityInput;
    uint32_t           vertexCountOutput;
    XrVector3f*        vertexPositions;
    XrVector3f*        vertexNormals;
    XrVector2f*        vertexUVs;
    XrVector4sFB*      vertexBlendIndices;
    XrVector4f*        vertexBlendWeights;
    uint32_t           indexCapacityInput;
    uint32_t           indexCountOutput;
    int16_t*           indices;
} XrHandTrackingMeshFB;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **jointCapacityInput** is the capacity of the joint data arrays in this structure, or 0 to indicate a request to retrieve the required capacity.
- **jointCountOutput** is filled in by the runtime with the count of joint data elements written, or the required capacity in the case that any of jointCapacityInput, vertexCapacityInput, or indexCapacityInput is insufficient.
- **jointBindPoses** is an array of poses that matches what is returned by xrLocateHandJointsEXT which describes the hand skeleton's bind pose.
- **jointRadii** is an array of joint radii at bind pose.
- **jointParents** is an array of joint parents to define a bone hierarchy for the hand skeleton.
- **vertexCapacityInput** is the capacity of the vertex data arrays in this structure, or 0 to indicate a request to retrieve the required capacity.
- **vertexCountOutput** is filled in by the runtime with the count of vertex data elements written, or the required capacity in the case that any of jointCapacityInput, vertexCapacityInput, or indexCapacityInput is insufficient.
- **vertexPositions** is an array of 3D vertex positions.
- **vertexNormals** is an array of 3D vertex normals.
- **vertexUVs** is an array of texture coordinates for this vertex.
- **vertexBlendIndices** is an array of bone blend indices.
- **vertexBlendWeights** is an array of bone blend weights.
- **indexCapacityInput** is the capacity of the index data arrays in this structure, or 0 to indicate a request to retrieve the required capacity.
- **indexCountOutput** is filled in by the runtime with the count of index data elements written, or the required capacity in the case that any of jointCapacityInput, vertexCapacityInput, or indexCapacityInput is insufficient.
- **indices** is an array of triangle indices.
- See the <<buffer-size-parameters> section for a detailed description of retrieving the required array sizes in the "struct form" as used here.

All arrays are application-allocated, and all may be NULL if any of jointCapacityInput, vertexCapacityInput, or indexCapacityInput is 0.

The data in a fully-populated XrHandTrackingMeshFB is immutable during the lifetime of the
corresponding XrInstance, and is intended to be retrieved once then used in combination with data changing per-frame retrieved from xrLocateHandJointsEXT.

### Valid Usage (Implicit)

- The XR_FB_hand_tracking_mesh extension **must** be enabled prior to using XrHandTrackingMeshFB
- **type** must be XR_TYPE_HAND_TRACKING_MESH_FB
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **jointBindPoses** must be a pointer to an array of jointCapacityInput XrPosef structures
- **jointRadii** must be a pointer to an array of jointCapacityInput float values
- **jointParents** must be a pointer to an array of jointCapacityInput XrHandJointEXT values
- **vertexPositions** must be a pointer to an array of vertexCapacityInput XrVector3f structures
- **vertexNormals** must be a pointer to an array of vertexCapacityInput XrVector3f structures
- **vertexUVs** must be a pointer to an array of vertexCapacityInput XrVector2f structures
- **vertexBlendIndices** must be a pointer to an array of vertexCapacityInput XrVector4sFB structures
- **vertexBlendWeights** must be a pointer to an array of vertexCapacityInput XrVector4f structures
- **indices** must be a pointer to an array of indexCapacityInput int16_t values
- The jointCapacityInput parameter **must** be greater than 0
- The vertexCapacityInput parameter **must** be greater than 0
- The indexCapacityInput parameter **must** be greater than 0

XrHandTrackingScaleFB can be provided in the next chain of XrHandJointLocationsEXT when calling xrLocateHandJointsEXT to indicate to the runtime that the requested joints need to be scaled to a different size and to query the existing scale value. This is useful in breaking up the overall scale out of the skinning transforms.

The XrHandTrackingScaleFB structure is defined as:
```c
typedef struct XrHandTrackingScaleFB {
    XrStructureType    type;
    void*              next;
    float              sensorOutput;
    float              currentOutput;
    XrBool32           overrideHandScale;
    float              overrideValueInput;
} XrHandTrackingScaleFB;
```

### Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **sensorOutput** is an output value: the currently measured scale as would be applied without passing this structure.
- **currentOutput** is an output value: the effective output that the bind skeleton is getting on the current call, which may be subject to filtering, scaling, or validation.
- **overrideHandScale** indicates whether the runtime should scale the output of this `xrLocateHandJointsEXT` call according to `overrideValueInput`.
- **overrideValueInput** is an optional input value, enabled only when the `overrideHandScale` parameter is set. Setting this to 1.0 and setting `overrideHandScale` to `true` will give the joints in mesh binding scale.

### Valid Usage (Implicit)

- The `XR_FB_hand_tracking_mesh` extension **must** be enabled prior to using `XrHandTrackingScaleFB`.
- `type` **must** be `XR_TYPE_HAND_TRACKING_SCALE_FB`.
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain.

### New Functions

The `xrGetHandMeshFB` function is defined as:
XrResult xrGetHandMeshFB(
    XrHandTrackerEXT                  handTracker,
    XrHandTrackingMeshFB*            mesh);

Parameter Descriptions

- **handTracker** is the XrHandTrackerEXT that is associated with a particular hand.
- **mesh** is the XrHandTrackingMeshFB output structure.

The **xrGetHandMeshFB** function populates an XrHandTrackingMeshFB structure with enough information to render a skinned mesh driven by the hand joints. As discussed in the specification for that structure, the data enumerated by this call is constant during the lifetime of an XrInstance.

Valid Usage (Implicit)

- The **XR_FB_hand_tracking_mesh** extension **must** be enabled prior to calling **xrGetHandMeshFB**
- **handTracker** **must** be a valid XrHandTrackerEXT handle
- **mesh** **must** be a pointer to an XrHandTrackingMeshFB structure

Return Codes

**Success**
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_FEATURE_UNSUPPORTED

Issues
Version History

- Revision 1, 2021-07-07 (Federico Schliemann)
  - Initial extension description
- Revision 2, 2022-04-20 (John Kearney)
  - Correct next chain parent for XrHandTrackingScaleFB to XrHandJointLocationsEXT

12.53. XR_FB_keyboard_tracking

Name String
XR_FB_keyboard_tracking

Extension Type
Instance extension

Registered Extension Number
117

Revision
1

Extension and Version Dependencies
- Requires OpenXR 1.0

Contributors
- Federico Schliemann, Facebook
- Robert Memmot, Facebook
- Cass Everitt, Facebook

Overview

This extension allows the application to query the system for a supported trackable keyboard type and obtain an XrSpace handle to track it. It also provides relevant metadata about the keyboard itself, including bounds and a human readable identifier.

New Object Types

New Flag Types

typedef XrFlags64 XrKeyboardTrackingFlagsFB;
// Flag bits for XrKeyboardTrackingFlagsFB
static const XrKeyboardTrackingFlagsFB XR_KEYBOARD_TRACKING_EXISTS_BIT_FB = 0x00000001;
static const XrKeyboardTrackingFlagsFB XR_KEYBOARD_TRACKING_LOCAL_BIT_FB = 0x00000002;
static const XrKeyboardTrackingFlagsFB XR_KEYBOARD_TRACKING_REMOTE_BIT_FB = 0x00000004;
static const XrKeyboardTrackingFlagsFB XR_KEYBOARD_TRACKING_CONNECTED_BIT_FB = 0x00000008;

Flag Descriptions

- **XR_KEYBOARD_TRACKING_EXISTS_BIT_FB** — indicates that the system has a physically tracked keyboard to report. If not set then no other bits should be considered to be valid or meaningful. If set either `XR_KEYBOARD_TRACKING_LOCAL_BIT_FB` or `XR_KEYBOARD_TRACKING_REMOTE_BIT_FB` must also be set.

- **XR_KEYBOARD_TRACKING_LOCAL_BIT_FB** — indicates that the physically tracked keyboard is intended to be used in a local pairing with the system. Mutually exclusive with `XR_KEYBOARD_TRACKING_REMOTE_BIT_FB`.

- **XR_KEYBOARD_TRACKING_REMOTE_BIT_FB** — indicates that the physically tracked keyboard is intended to be used while paired to a separate remote computing device. Mutually exclusive with `XR_KEYBOARD_TRACKING_LOCAL_BIT_FB`.

- **XR_KEYBOARD_TRACKING_CONNECTED_BIT_FB** — indicates that the physically tracked keyboard is actively connected to the headset and capable of sending key data

typedef XrFlags64 XrKeyboardTrackingQueryFlagsFB;

// Flag bits for XrKeyboardTrackingQueryFlagsFB
static const XrKeyboardTrackingQueryFlagsFB XR_KEYBOARD_TRACKING_QUERY_LOCAL_BIT_FB = 0x00000002;
static const XrKeyboardTrackingQueryFlagsFB XR_KEYBOARD_TRACKING_QUERY_REMOTE_BIT_FB = 0x00000004;
Flag Descriptions

- **XR_KEYBOARD_TRACKING_QUERY_LOCAL_BIT_FB** — indicates the query is for the physically tracked keyboard that is intended to be used in a local pairing with the System. Mutually exclusive with XR_KEYBOARD_TRACKING_QUERY_REMOTE_BIT_FB.

- **XR_KEYBOARD_TRACKING_QUERY_REMOTE_BIT_FB** — indicates the query is for the physically tracked keyboard that may be connected to a separate remote computing device. Mutually exclusive with XR_KEYBOARD_TRACKING_QUERY_LOCAL_BIT_FB.

New Enum Constants

- **XR_MAX_KEYBOARD_TRACKING_NAME_SIZE_FB**

**XrStructureType** enumeration is extended with:

- **XR_TYPE_KEYBOARD_SPACE_CREATE_INFO_FB**
- **XR_TYPE_KEYBOARD_TRACKING_QUERY_FB**
- **XR_TYPE_SYSTEM_KEYBOARD_TRACKING_PROPERTIES_FB**

New Enums

New Structures

The **XrSystemKeyboardTrackingPropertiesFB** structure is defined as:

```c
typedef struct XrSystemKeyboardTrackingPropertiesFB {
    XrStructureType    type;
    void*              next;
    XrBool32           supportsKeyboardTracking;
} XrSystemKeyboardTrackingPropertiesFB;
```

Member Descriptions

- **type** is the **XrStructureType** of this structure.
- **next** is **NULL** or a pointer to the next structure in a structure chain.
- **supportsKeyboardTracking** defines whether the system supports the tracked keyboard feature.

**XrSystemKeyboardTrackingPropertiesFB** is populated with information from the system about tracked keyboard support.
Valid Usage (Implicit)

- The XR_FB_keyboard_tracking extension must be enabled prior to using XrSystemKeyboardTrackingPropertiesFB
- type must be XR_TYPE_SYSTEM_KEYBOARD_TRACKING_PROPERTIES_FB
- next must be NULL or a valid pointer to the next structure in a structure chain

The XrKeyboardTrackingQueryFB structure is defined as:

```c
typedef struct XrKeyboardTrackingQueryFB {
    XrStructureType                   type;
    void*                             next;
    XrKeyboardTrackingQueryFlagsFB    flags;
} XrKeyboardTrackingQueryFB;
```

Member Descriptions

- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain.
- flags is a bitmask of XrKeyboardTrackingQueryFlagsFB.

XrKeyboardTrackingQueryFB specifies input data needed to determine which type of tracked keyboard to query for.

Valid Usage (Implicit)

- The XR_FB_keyboard_tracking extension must be enabled prior to using XrKeyboardTrackingQueryFB
- type must be XR_TYPE_KEYBOARD_TRACKING_QUERY_FB
- next must be NULL or a valid pointer to the next structure in a structure chain
- flags must be a valid combination of XrKeyboardTrackingQueryFlagBitsFB values
- flags must not be 0

The XrKeyboardTrackingDescriptionFB structure is defined as:
typedef struct XrKeyboardTrackingDescriptionFB {
    uint64_t trackedKeyboardId;
    XrVector3f size;
    XrKeyboardTrackingFlagsFB flags;
    char name[XR_MAX_KEYBOARD_TRACKING_NAME_SIZE_FB];
} XrKeyboardTrackingDescriptionFB;

Member Descriptions

- **trackedKeyboardId** abstract identifier describing the type of keyboard.
- **size** bounding box.
- **flags** additional information on the type of keyboard available. If XR_KEYBOARD_TRACKING_EXISTS_BIT_FB is not set there is no keyboard.
- **name** human readable keyboard identifier.

XrKeyboardTrackingDescriptionFB describes a trackable keyboard and its associated metadata.

Valid Usage (Implicit)

- The XR_FB_keyboard_tracking extension must be enabled prior to using XrKeyboardTrackingDescriptionFB

The XrKeyboardSpaceCreateInfoFB structure is defined as:

typedef struct XrKeyboardSpaceCreateInfoFB {
    XrStructureType type;
    void* next;
    uint64_t trackedKeyboardId;
} XrKeyboardSpaceCreateInfoFB;

Member Descriptions

- **trackedKeyboardId** abstract identifier describing the type of keyboard to track.

XrKeyboardSpaceCreateInfoFB describes a request for the system needed to create a trackable XrSpace associated with the keyboard.
Valid Usage (Implicit)

- The `XR_FB_keyboard_tracking` extension must be enabled prior to using `XrKeyboardSpaceCreateInfoFB`
- **type** must be `XR_TYPE_KEYBOARD_SPACE_CREATE_INFO_FB`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

New Functions

The `xrQuerySystemTrackedKeyboardFB` function is defined as:

```c
XrResult xrQuerySystemTrackedKeyboardFB(
    XrSession session,
    const XrKeyboardTrackingQueryFB* queryInfo,
    XrKeyboardTrackingDescriptionFB* keyboard);
```

Parameter Descriptions

- **session** is the session that will be associated with a keyboard space.
- **queryInfo** is the `XrKeyboardTrackingQueryFB` that describes the type of keyboard to return. `queryInfo` must have either `XR_KEYBOARD_TRACKING_QUERY_LOCAL_BIT_FB` or `XR_KEYBOARD_TRACKING_QUERY_REMOTE_BIT_FB` set.
- **keyboard** is the `XrKeyboardTrackingDescriptionFB` output structure.

The `xrQuerySystemTrackedKeyboardFB` function populates an `XrKeyboardTrackingDescriptionFB` structure with enough information to describe a keyboard that the system can locate.

Valid Usage (Implicit)

- The `XR_FB_keyboard_tracking` extension must be enabled prior to calling `xrQuerySystemTrackedKeyboardFB`
- **session** must be a valid `XrSession` handle
- **queryInfo** must be a pointer to a valid `XrKeyboardTrackingQueryFB` structure
- **keyboard** must be a pointer to an `XrKeyboardTrackingDescriptionFB` structure
## Return Codes

### Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

### Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_FEATURE_UNSUPPORTED

The `xrCreateKeyboardSpaceFB` function is defined as:

```c
XrResult xrCreateKeyboardSpaceFB(
    XrSession                                       session,
    const XrKeyboardSpaceCreateInfoFB*             createInfo,
    XrSpace*                                       keyboardSpace);
```

### Parameter Descriptions
- **session** is the session that will be associated with the returned keyboard space.
- **createInfo** is the `XrKeyboardSpaceCreateInfoFB` that describes the type of keyboard to track.
- **keyboardSpace** is the `XrSpace` output structure.

The `xrCreateKeyboardSpaceFB` function returns an `XrSpace` that can be used to locate a physical keyboard in space. The origin of the created `XrSpace` is located in the center of the bounding box in the x and z axes, and at the top of the y axis (meaning the keyboard is located entirely in negative y).
Valid Usage (Implicit)

- The `XR_FB_keyboard_tracking` extension must be enabled prior to calling `xrCreateKeyboardSpaceFB`
- `session` must be a valid `XrSession` handle
- `createInfo` must be a pointer to a valid `XrKeyboardSpaceCreateInfoFB` structure
- `keyboardSpace` must be a pointer to an `XrSpace` handle

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_LIMIT_REACHED`
- `XR_ERROR_FEATURE_UNSUPPORTED`

Issues

Version History

- Revision 1, 2021-08-27 (Federico Schliemann)
  - Initial extension description

12.54. XR_FB_passthrough

Name String

`XR_FB_passthrough`
Extension Type
Instance extension

Registered Extension Number
119

Revision
2

Extension and Version Dependencies
• Requires OpenXR 1.0

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Overview
Passthrough is a way to show a user their physical environment in a light-blocking VR headset. Applications may use passthrough in a multitude of ways, including:

• Creating AR-like experiences, where virtual objects augment the user’s environment.
• Bringing real objects into a VR experience.
• Mapping the playspace such that a VR experience is customized to it.

This extension allows:

• An application to request passthrough to be composited with the application content.
• An application to specify the compositing and blending rules between passthrough and VR content.
• An application to apply styles, such as color mapping and edge rendering, to passthrough.
• An application to provide a geometry to be used in place of the user's physical environment. Camera images will be projected onto the surface provided by the application. In some cases where a part of the environment, such as a desk, can be approximated well, this provides better visual experience.

New Object Types

XR_DEFINE_HANDLE(XrPassthroughFB)
**XrPassthroughFB** represents a passthrough feature.

```c
XR_DEFINE_HANDLE(XrPassthroughLayerFB)
```

**XrPassthroughLayerFB** represents a layer of passthrough content.

```c
XR_DEFINE_HANDLE(XrGeometryInstanceFB)
```

**XrGeometryInstanceFB** represents a geometry instance used in a passthrough layer.

### New Flag Types

```c
typedef XrFlags64 XrPassthroughFlagsFB;
```

Specify additional creation behavior.

```c
// Flag bits for XrPassthroughFlagsFB
static const XrPassthroughFlagsFB XR_PASSTHROUGH_IS_RUNNING_AT_CREATION_BIT_FB = 0x00000001;
```

#### Flag Descriptions

- **XR_PASSTHROUGH_IS_RUNNING_AT_CREATION_BIT_FB** — The object (passthrough, layer) is running at creation.

```c
typedef XrFlags64 XrPassthroughStateChangedFlagsFB;
```

Specify additional state change behavior.
// Flag bits for XrPassthroughStateChangedFlagsFB
static const XrPassthroughStateChangedFlagsFB
XR_PASSTHROUGH_STATE_CHANGED_REINIT_REQUIRED_BIT_FB = 0x00000001;
static const XrPassthroughStateChangedFlagsFB
XR_PASSTHROUGH_STATE_CHANGED_NON_RECOVERABLE_ERROR_BIT_FB = 0x00000002;
static const XrPassthroughStateChangedFlagsFB
XR_PASSTHROUGH_STATE_CHANGED_RECOVERABLE_ERROR_BIT_FB = 0x00000004;
static const XrPassthroughStateChangedFlagsFB
XR_PASSTHROUGH_STATE_CHANGED_RESTORED_ERROR_BIT_FB = 0x00000008;

Flag Descriptions

- **XR_PASSTHROUGH_STATE_CHANGED_REINIT_REQUIRED_BIT_FB** — Passthrough system requires reinitialization.
- **XR_PASSTHROUGH_STATE_CHANGED_NON_RECOVERABLE_ERROR_BIT_FB** — Non-recoverable error has occurred. A device reboot or a firmware update may be required.
- **XR_PASSTHROUGH_STATE_CHANGED_RECOVERABLE_ERROR_BIT_FB** — A recoverable error has occurred. The runtime will attempt to recover, but some functionality may be temporarily unavailable.
- **XR_PASSTHROUGH_STATE_CHANGED_RESTORED_ERROR_BIT_FB** — The runtime has recovered from a previous error and is functioning normally.

New Enum Constants

- **XR_PASSTHROUGH_COLOR_MAP_MONO_SIZE_FB**

*XrStructureType* enumeration is extended with:

- **XR_TYPE_SYSTEM_PASSTHROUGH_PROPERTIES_FB**
- **XR_TYPE_PASSTHROUGH_CREATE_INFO_FB**
- **XR_TYPE_PASSTHROUGH_LAYER_CREATE_INFO_FB**
- **XR_TYPE_COMPOSITION_LAYER_PASSTHROUGH_FB**
- **XR_TYPE_GEOMETRY_INSTANCE_CREATE_INFO_FB**
- **XR_TYPE_GEOMETRY_INSTANCE_TRANSFORM_FB**
- **XR_TYPE_PASSTHROUGH_STYLE_FB**
- **XR_TYPE_PASSTHROUGH_COLOR_MAP_MONO_TO_RGBA_FB**
- **XR_TYPE_PASSTHROUGH_COLOR_MAP_MONO_TO_MONO_FB**
- **XR_TYPE_PASSTHROUGH_BRIGHTNESS_CONTRAST_SATURATION_FB**
- **XR_TYPE_EVENT_DATA_PASSTHROUGH_STATE_CHANGED_FB**
**XrResult** enumeration is extended with:

- **XR_ERROR_UNEXPECTED_STATE_PASSTHROUGH_FB** The state of an object for which a function is called is not one of the expected states for that function.
- **XR_ERROR_FEATURE_ALREADY_CREATED_PASSTHROUGH_FB** An application attempted to create a feature when one has already been created and only one can exist.
- **XR_ERROR_FEATURE_REQUIRED_PASSTHROUGH_FB** A feature is required before the function can be called.
- **XR_ERROR_NOT_PERMITTED_PASSTHROUGH_FB** Operation is not permitted.
- **XR_ERROR_INSUFFICIENT_RESOURCES_PASSTHROUGH_FB** The runtime does not have sufficient resources to perform the operation. Either the object being created is too large, or too many objects of a specific kind have been created.

**New Enums**

Specify the kind of passthrough behavior the layer provides.

```c
typedef enum XrPassthroughLayerPurposeFB {
    XR_PASSTHROUGH_LAYER_PURPOSE_RECONSTRUCTION_FB = 0,
    XR_PASSTHROUGH_LAYER_PURPOSE_PROJECTED_FB = 1,
    XR_PASSTHROUGH_LAYER_PURPOSE_TRACKED_KEYBOARD_HANDS_FB = 1000203001,
    XR_PASSTHROUGH_LAYER_PURPOSE_TRACKED_KEYBOARD_MASKED_HANDS_FB = 1000203002,
    XR_PASSTHROUGH_LAYER_PURPOSE_MAX_ENUM_FB = 0x7FFFFFFF
} XrPassthroughLayerPurposeFB;
```

**Enumerant Descriptions**

- **XR_PASSTHROUGH_LAYER_PURPOSE_RECONSTRUCTION_FB** — Reconstruction passthrough (full screen environment)
- **XR_PASSTHROUGH_LAYER_PURPOSE_PROJECTED_FB** — Projected passthrough (using a custom surface)
- **XR_PASSTHROUGH_LAYER_PURPOSE_TRACKED_KEYBOARD_HANDS_FB** — Passthrough layer purpose for keyboard hands presence.
- **XR_PASSTHROUGH_LAYER_PURPOSE_TRACKED_KEYBOARD_MASKED_HANDS_FB** — Passthrough layer purpose for keyboard hands presence with keyboard masked hand transitions (i.e. passthrough hands rendered only when they are over the keyboard).

**New Structures**

The **XrSystemPassthroughPropertiesFB** structure is defined as:
typedef struct XrSystemPassthroughPropertiesFB {
    XrStructureType    type;
    const void*        next;
    XrBool32           supportsPassthrough;
} XrSystemPassthroughPropertiesFB;

It describes a passthrough system property.

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **supportsPassthrough** defines whether the system supports the passthrough feature.

**Valid Usage (Implicit)**

- The XR_FB_passthrough extension must be enabled prior to using XrSystemPassthroughPropertiesFB
- **type** must be XR_TYPE_SYSTEM_PASSTHROUGH_PROPERTIES_FB
- **next** must be NULL or a valid pointer to the next structure in a structure chain

The XrPassthroughCreateInfoFB structure is defined as:

typedef struct XrPassthroughCreateInfoFB {
    XrStructureType         type;
    const void*             next;
    XrPassthroughFlagsFB    flags;
} XrPassthroughCreateInfoFB;

It contains parameters used to specify a new passthrough feature.
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **flags** is a bitmask of `XrPassthroughFlagBitsFB` that specify additional behavior.

Valid Usage (Implicit)

- The `XR_FB_passthrough` extension **must** be enabled prior to using `XrPassthroughCreateInfoFB`
- **type** **must** be `XR_TYPE_PASSTHROUGH_CREATE_INFO_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **flags** **must** be a valid combination of `XrPassthroughFlagBitsFB` values
- **flags** **must** not be `0`

The `XrPassthroughLayerCreateInfoFB` structure is defined as:

```c
typedef struct XrPassthroughLayerCreateInfoFB {
    XrStructureType                type;
    const void*                    next;
    XrPassthroughFB                passthrough;
    XrPassthroughFlagsFB           flags;
    XrPassthroughLayerPurposeFB    purpose;
} XrPassthroughLayerCreateInfoFB;
```

It contains parameters used to specify a new passthrough layer.

Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **flags** `XrPassthroughFlagsFB` that specify additional behavior.
- **purpose** `XrPassthroughLayerPurposeFB` that specifies the layer's purpose.
Valid Usage (Implicit)

- The XR_FB_passthrough extension **must** be enabled prior to using XrPassthroughLayerCreateInfoFB
- **type** **must** be XR_TYPE_PASSTHROUGH_LAYER_CREATE_INFO_FB
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain
- **passthrough** **must** be a valid XrPassthroughFB handle
- **flags** **must** be a valid combination of XrPassthroughFlagBitsFB values
- **flags** **must** not be 0
- **purpose** **must** be a valid XrPassthroughLayerPurposeFB value

The XrCompositionLayerPassthroughFB structure is defined as:

```c
typedef struct XrCompositionLayerPassthroughFB {
    XrStructureType            type;
    const void*                next;
    XrCompositionLayerFlags    flags;
    XrSpace                    space;
    XrPassthroughLayerFB       layerHandle;
} XrCompositionLayerPassthroughFB;
```

It is a composition layer type that may be submitted in xrEndFrame where an XrCompositionLayerBaseHeader is specified, as a stand-in for the actual passthrough contents.

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **flags** is a bitmask of XrCompositionLayerFlagBits that specify additional behavior.
- **space** is the XrSpace that specifies the layer’s space - **must** be XR_NULL_HANDLE.
- **layer** is the XrPassthroughLayerFB that defines this layer’s behavior.
Valid Usage (Implicit)

- The XR_FB_passthrough extension must be enabled prior to using XrCompositionLayerPassthroughFB
- type must be XR_TYPE_COMPOSITION_LAYER_PASSTHROUGH_FB
- next must be NULL or a valid pointer to the next structure in a structure chain
- flags must be a valid combination of XrCompositionLayerFlagBits values
- flags must not be 0
- space must be a valid XrSpace handle
- layerHandle must be a valid XrPassthroughLayerFB handle
- Both of layerHandle and space must have been created, allocated, or retrieved from the same XrSession

The XrGeometryInstanceCreateInfoFB structure is defined as:

```c
typedef struct XrGeometryInstanceCreateInfoFB {
  XrStructureType         type;
  const void*             next;
  XrPassthroughLayerFB    layer;
  XrTriangleMeshFB        mesh;
  XrSpace                 baseSpace;
  XrPosef                 pose;
  XrVector3f              scale;
} XrGeometryInstanceCreateInfoFB;
```

It contains parameters to specify a new geometry instance.
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **layer** is the `XrPassthroughLayerFB`.
- **mesh** is the `XrTriangleMeshFB`.
- **baseSpace** is the `XrSpace` that defines the geometry instance’s base space for transformations.
- **pose** is the `XrPosef` that defines the geometry instance’s pose.
- **scale** is the `XrVector3f` that defines the geometry instance’s scale.

Valid Usage (Implicit)

- The XR_FB_passthrough extension **must** be enabled prior to using `XrGeometryInstanceCreateInfoFB`
- **type** **must** be `XR_TYPE_GEOMETRY_INSTANCE_CREATE_INFO_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **layer** **must** be a valid `XrPassthroughLayerFB` handle
- **mesh** **must** be a valid `XrTriangleMeshFB` handle
- **baseSpace** **must** be a valid `XrSpace` handle
- Each of **baseSpace**, **layer**, and **mesh** **must** have been created, allocated, or retrieved from the same `XrSession`

The `XrGeometryInstanceTransformFB` structure is defined as:

```c
typedef struct XrGeometryInstanceTransformFB {
    XrStructureType    type;
    const void*        next;
    XrSpace            baseSpace;
    XrTime             time;
    XrPosef            pose;
    XrVector3f         scale;
} XrGeometryInstanceTransformFB;
```

It describes a transformation for a geometry instance.
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **baseSpace** is the `XrSpace` that defines the geometry instance’s base space for transformations.
- **time** is the `XrTime` that define the time at which the transform is applied.
- **pose** is the `XrPosef` that defines the geometry instance’s pose.
- **scale** is the `XrVector3f` that defines the geometry instance’s scale.

Valid Usage (Implicit)

- The `XR_FB_passthrough` extension **must** be enabled prior to using `XrGeometryInstanceTransformFB`
- **type** **must** be `XR_TYPE_GEOMETRY_INSTANCE_TRANSFORM_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **baseSpace** **must** be a valid `XrSpace` handle

The `XrPassthroughStyleFB` structure is defined as:

```c
typedef struct XrPassthroughStyleFB {
    XrStructureType    type;
    const void*        next;
    float              textureOpacityFactor;
    XrColor4f          edgeColor;
} XrPassthroughStyleFB;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain.
- **textureOpacityFactor** is the opacity of the passthrough imagery in the range [0, 1].
- **edgeColor** is the `XrColor4f` that defines the edge rendering color. Edges are detected in the original passthrough imagery and rendered on top of it. Edge rendering is disabled when the alpha value of `edgeColor` is zero.

`XrPassthroughStyleFB` lets applications customize the appearance of passthrough layers. In addition to the parameters specified here, applications **may** add one of the following structures to the structure chain: `XrPassthroughColorMapMonoToRgbaFB`, `XrPassthroughColorMapMonoToMonoFB`, `XrPassthroughBrightnessContrastSaturationFB`. These structures are mutually exclusive. The runtime **must** return `XR_ERROR_VALIDATION_FAILURE` if more than one of them are present in the structure chain.

Valid Usage (Implicit)

- The `XR_FB_passthrough` extension **must** be enabled prior to using `XrPassthroughStyleFB`
- **type** **must** be `XR_TYPE_PASSTHROUGH_STYLE_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrPassthroughBrightnessContrastSaturationFB`, `XrPassthroughColorMapMonoToMonoFB`, `XrPassthroughColorMapMonoToRgbaFB`

The `XrPassthroughColorMapMonoToRgbaFB` structure is defined as:

```c
typedef struct XrPassthroughColorMapMonoToRgbaFB {
    XrStructureType type;
    const void* next;
    XrColor4f textureColorMap[XR_PASSTHROUGH_COLOR_MAP_MONO_SIZE_FB];
} XrPassthroughColorMapMonoToRgbaFB;
```
XrPassthroughColorMapMonoToRgbaFB lets applications define a map which replaces each input luminance value in the passthrough imagery with an RGBA color value. The map is applied before any additional effects (such as edges) are rendered on top.

XrPassthroughColorMapMonoToRgbaFB is provided in the next chain of XrPassthroughStyleFB.

XrPassthroughColorMapMonoToMonoFB lets applications define a map which replaces each input luminance value in the passthrough imagery with a grayscale color value defined in textureColorMap.
The map is applied before any additional effects (such as edges) are rendered on top.

**XrPassthroughColorMapMonoToMonoFB** is provided in the next chain of **XrPassthroughStyleFB**.

### Valid Usage (Implicit)

- The **XR_FB_passthrough** extension must be enabled prior to using **XrPassthroughColorMapMonoToMonoFB**
- **type** must be **XR_TYPE_PASSTHROUGH_COLOR_MAP_MONO_TO_MONO_FB**
- **next** must be **NULL** or a valid pointer to the next structure in a structure chain.

The **XrPassthroughBrightnessContrastSaturationFB** structure is defined as:

```c
typedef struct XrPassthroughBrightnessContrastSaturationFB {
  XrStructureType type;
  const void* next;
  float brightness;
  float contrast;
  float saturation;
} XrPassthroughBrightnessContrastSaturationFB;
```

### Member Descriptions

- **type** is the **XrStructureType** of this structure.

- **next** is **NULL** or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

- **brightness** is the brightness adjustment value in the range [-100, 100]. The neutral element is 0.

- **contrast** is the contrast adjustment value in the range [0, Infinity]. The neutral element is 1.

- **saturation** is the saturation adjustment value in the range [0, Infinity]. The neutral element is 1.

**XrPassthroughBrightnessContrastSaturationFB** lets applications adjust the brightness, contrast, and saturation of passthrough layers. The adjustments only are applied before any additional effects (such as edges) are rendered on top.

The adjustments are applied in CIELAB color space (white point D65) using the following formulas:

- \( L'' = \text{clamp}(L' - 50 \times \text{contrast} + 50, 0, 100) \)
\[
\begin{align*}
\text{L''} &= \text{clamp} (\text{L'} + \text{brightness}, 0, 100) \\
(a'^*, b'^*) &= (a*, b*) \times \text{saturation} \\
\text{Resulting color: } (\text{L''}, a'^*, b'^*)
\end{align*}
\]

\text{XrPassthroughBrightnessContrastSaturationFB} is provided in the next chain of \text{XrPassthroughStyleFB}.

**Valid Usage (Implicit)**

- The \text{XR_FB_passthrough} extension \textbf{must} be enabled prior to using \text{XrPassthroughBrightnessContrastSaturationFB}
- \text{type} \textbf{must} be \text{XR_TYPE_PASSTHROUGH_BRIGHTNESS_CONTRAST_SATURATION_FB}
- \text{next} \textbf{must} be \text{NULL} or a valid pointer to the next structure in a structure chain

The \text{XrEventDataPassthroughStateChangedFB} structure is defined as:

```c
typedef struct XrEventDataPassthroughStateChangedFB {
    XrStructureType                     type;
    const void*                         next;
    XrPassthroughStateChangedFlagsFB    flags;
} XrEventDataPassthroughStateChangedFB;
```

It describes an event data for state changes return by \text{xrPollEvent}.

**Member Descriptions**

- \text{type} is the \text{XrStructureType} of this structure.
- \text{next} is \text{NULL} or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- \text{flags} \text{XrPassthroughStateChangedFlagsFB} that specify additional behavior.
Valid Usage (Implicit)

- The XR_FB_passthrough extension must be enabled prior to using XrEventDataPassthroughStateChangedFB
- type must be XR_TYPE_EVENT_DATA_PASSTHROUGH_STATE_CHANGED_FB
- next must be NULL or a valid pointer to the next structure in a structure chain
- flags must be a valid combination of XrPassthroughStateChangedFlagBitsFB values
- flags must not be 0

New Functions

The xrCreatePassthroughFB function is defined as:

```c
XrResult xrCreatePassthroughFB(
    XrSession session,
    const XrPassthroughCreateInfoFB* createInfo,
    XrPassthroughFB* outPassthrough);
```

Parameter Descriptions

- session is the XrSession.
- createInfo is the XrPassthroughCreateInfoFB.
- outPassthrough is the XrPassthroughFB.

Creates an XrPassthroughFB handle. The returned passthrough handle may be subsequently used in API calls.

Valid Usage (Implicit)

- The XR_FB_passthrough extension must be enabled prior to calling xrCreatePassthroughFB
- session must be a valid XrSession handle
- createInfo must be a pointer to a valid XrPassthroughCreateInfoFB structure
- outPassthrough must be a pointer to an XrPassthroughFB handle
Return Codes

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_UNKNOWN_PASSTHROUGH_FB
- XR_ERROR_NOT_PERMITTED_PASSTHROUGH_FB
- XR_ERROR_FEATURE_UNSUPPORTED
- XR_ERROR_FEATURE_ALREADY_CREATED_PASSTHROUGH_FB

The `xrDestroyPassthroughFB` function is defined as:

```c
XrResult xrDestroyPassthroughFB(
    XrPassthroughFB                passthrough);
```

**Parameter Descriptions**

- `passthrough` is the `XrPassthroughFB` to be destroyed.

Destroys an `XrPassthroughFB` handle.
Valid Usage (Implicit)

- The `XR_FB_passthrough` extension **must** be enabled prior to calling `xrDestroyPassthroughFB`
- `passthrough` **must** be a valid `XrPassthroughFB` handle

Thread Safety

- Access to `passthrough`, and any child handles, **must** be externally synchronized

Return Codes

**Success**

- `XR_SUCCESS`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_FEATURE_UNSUPPORTED`

The `xrPassthroughStartFB` function is defined as:

```c
XrResult xrPassthroughStartFB(
  XrPassthroughFB passthrough);
```

Parameter Descriptions

- `passthrough` is the `XrPassthroughFB` to be started.

Starts an `XrPassthroughFB` feature. If the feature is not started, either explicitly with a call to `xrPassthroughStartFB`, or implicitly at creation using the behavior flags, it is considered paused. When the feature is paused, runtime will stop rendering and compositing all passthrough layers produced on behalf of the application, and may free up some or all the resources used to produce passthrough until `xrPassthroughStartFB` is called.
Valid Usage (Implicit)

- The **XR_FB_passthrough** extension **must** be enabled prior to calling **xrPassthroughStartFB**
- **passthrough** **must** be a valid **XrPassthroughFB** handle

Return Codes

**Success**
- **XR_SUCCESS**
- **XR_SESSION_LOSS_PENDING**

**Failure**
- **XR_ERROR_FUNCTION_UNSUPPORTED**
- **XR_ERROR_VALIDATION_FAILURE**
- **XR_ERROR_RUNTIME_FAILURE**
- **XR_ERROR_HANDLE_INVALID**
- **XR_ERROR_INSTANCE_LOST**
- **XR_ERROR_SESSION_LOST**
- **XR_ERROR_UNEXPECTED_STATE_PASSTHROUGH_FB**
- **XR_ERROR_FEATURE_UNSUPPORTED**

The **xrPassthroughPauseFB** function is defined as:

```c
XrResult xrPassthroughPauseFB(
    XrPassthroughFB passthrough);
```

Parameter Descriptions

- **passthrough** is the **XrPassthroughFB** to be paused.

Pauses an **XrPassthroughFB** feature. When the feature is paused, runtime will stop rendering and compositing all passthrough layers produced on behalf of the application, and may free up some or all the resources used to produce passthrough until **xrPassthroughStartFB** is called.
Valid Usage (Implicit)

- The XR_FB_passthrough extension must be enabled prior to calling xrPassthroughPauseFB
- passthrough must be a valid XrPassthroughFB handle

Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_UNEXPECTED_STATE_PASSTHROUGH_FB
- XR_ERROR_FEATURE_UNSUPPORTED

The xrCreatePassthroughLayerFB function is defined as:

```c
XrResult xrCreatePassthroughLayerFB(
    XrSession                                   session,
    const XrPassthroughLayerCreateInfoFB*       createInfo,
    XrPassthroughLayerFB*                       outLayer);
```

Parameter Descriptions

- session is the XrSession.
- createInfo is the XrPassthroughLayerCreateInfoFB.
- outLayer is the XrPassthroughLayerFB.
Creates an XrPassthroughLayerFB handle. The returned layer handle may be subsequently used in API calls. Layer objects may be used to specify rendering properties of the layer, such as styles, and compositing rules.

Valid Usage (Implicit)

- The XR_FB_passthrough extension must be enabled prior to calling xrCreatePassthroughLayerFB
- `session` must be a valid XrSession handle
- `createInfo` must be a pointer to a valid XrPassthroughLayerCreateInfoFB structure
- `outLayer` must be a pointer to an XrPassthroughLayerFB handle

Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_UNKNOWN_PASSTHROUGH_FB
- XR_ERROR_INSUFFICIENT_RESOURCES_PASSTHROUGH_FB
- XR_ERROR_FEATURE_UNSUPPORTED
- XR_ERROR_FEATURE_REQUIRED_PASSTHROUGH_FB

The xrDestroyPassthroughLayerFB function is defined as:
XrResult xrDestroyPassthroughLayerFB(XrPassthroughLayerFB layer);

Parameter Descriptions

- `layer` is the XrPassthroughLayerFB to be destroyed.

Destroys an XrPassthroughLayerFB handle.

Valid Usage (Implicit)

- The XR_FB_passthrough extension must be enabled prior to calling xrDestroyPassthroughLayerFB
- `layer` must be a valid XrPassthroughLayerFB handle

Thread Safety

- Access to `layer`, and any child handles, must be externally synchronized

Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_FEATURE_UNSUPPORTED

The xrPassthroughLayerPauseFB function is defined as:

XrResult xrPassthroughLayerPauseFB(XrPassthroughLayerFB layer);
Parameter Descriptions

- **layer** is the XrPassthroughLayerFB to be paused.

Pauses an XrPassthroughLayerFB layer. Runtime will not render or composite paused layers.

Valid Usage (Implicit)

- The XR_FB_passthrough extension must be enabled prior to calling xrPassthroughLayerPauseFB
- **layer** must be a valid XrPassthroughLayerFB handle

Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_UNEXPECTED_STATE_PASSTHROUGH_FB
- XR_ERROR_FEATURE_UNSUPPORTED

The xrPassthroughLayerResumeFB function is defined as:

```c
XrResult xrPassthroughLayerResumeFB(
    XrPassthroughLayerFB layer);
```
Parameter Descriptions

- **layer** is the *XrPassthroughLayerFB* to be resumed.

Resumes an *XrPassthroughLayerFB* layer.

Valid Usage (Implicit)

- The *XR_FB_passthrough* extension **must** be enabled prior to calling *xrPassthroughLayerResumeFB*
- **layer** **must** be a valid *XrPassthroughLayerFB* handle

Return Codes

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_UNEXPECTED_STATE_PASSTHROUGH_FB
- XR_ERROR_FEATURE_UNSUPPORTED

The *xrPassthroughLayerSetStyleFB* function is defined as:

```c
XrResult xrPassthroughLayerSetStyleFB(
    XrPassthroughLayerFB                        layer,
    const XrPassthroughStyleFB*                 style);
```
Parameter Descriptions

- **layer** is the `XrPassthroughLayerFB` to get the style.
- **style** is the `XrPassthroughStyleFB` to be set.

Sets an `XrPassthroughStyleFB` style on an `XrPassthroughLayerFB` layer.

Valid Usage (Implicit)

- The `XR_FB_passthrough` extension **must** be enabled prior to calling `xrPassthroughLayerSetStyleFB`
- **layer** **must** be a valid `XrPassthroughLayerFB` handle
- **style** **must** be a pointer to a valid `XrPassthroughStyleFB` structure

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_FEATURE_UNSUPPORTED`

The `xrCreateGeometryInstanceFB` function is defined as:

```c
XrResult xrCreateGeometryInstanceFB(
    XrSession                                   session,
    const XrGeometryInstanceCreateInfoFB*       createInfo,
    XrGeometryInstanceFB*                       outGeometryInstance);
```
Parameter Descriptions

- **session** is the XrSession.
- **createInfo** is the XrGeometryInstanceCreateInfoFB.
- **outGeometryInstance** is the XrGeometryInstanceFB.

Creates an XrGeometryInstanceFB handle. Geometry instance functionality requires XR_FB_triangle_mesh extension to be enabled. An XrGeometryInstanceFB connects a layer, a mesh, and a transformation, with the semantics that a specific mesh will be instantiated in a specific layer with a specific transformation. A mesh can be instantiated multiple times, in the same or in different layers.

Valid Usage (Implicit)

- The XR_FB_passthrough extension must be enabled prior to calling xrCreateGeometryInstanceFB
- **session** must be a valid XrSession handle
- **createInfo** must be a pointer to a valid XrGeometryInstanceCreateInfoFB structure
- **outGeometryInstance** must be a pointer to an XrGeometryInstanceFB handle
Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_POSE_INVALID
- XR_ERROR_INSUFFICIENT_RESOURCES_PASSTHROUGH_FB
- XR_ERROR_FEATURE_UNSUPPORTED

The `xrDestroyGeometryInstanceFB` function is defined as:

```c
XrResult xrDestroyGeometryInstanceFB(
    XrGeometryInstanceFB instance);
```

Parameter Descriptions

- `geometryInstance` is the `XrGeometryInstanceFB` to be destroyed.

Destroys an `XrGeometryInstanceFB` handle. Destroying an `XrGeometryInstanceFB` does not destroy a mesh and does not free mesh resources. Destroying a layer invalidates all geometry instances attached to it. Destroying a mesh invalidates all its instances.
Valid Usage (Implicit)

- The XR_FB_passthrough extension must be enabled prior to calling `xrDestroyGeometryInstanceFB`
- `instance` must be a valid `XrGeometryInstanceFB` handle

Thread Safety

- Access to `instance`, and any child handles, must be externally synchronized

Return Codes

Success
- `XR_SUCCESS`

Failure
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_FEATURE_UNSUPPORTED`

The `xrGeometryInstanceSetTransformFB` function is defined as:

```c
XrResult xrGeometryInstanceSetTransformFB(
    XrGeometryInstanceFB                        instance,
    const XrGeometryInstanceTransformFB*        transformation);
```

Parameter Descriptions

- `geometryInstance` is the `XrGeometryInstanceFB` to get the transform.
- `transform` is the `XrGeometryInstanceTransformFB` to be set.

Sets an `XrGeometryInstanceTransformFB` transform on an `XrGeometryInstanceFB` geometry instance.
Valid Usage (Implicit)

- The `XR_FB_passthrough` extension must be enabled prior to calling `xrGeometryInstanceSetTransformFB`
- `instance` must be a valid `XrGeometryInstanceFB` handle
- `transformation` must be a pointer to a valid `XrGeometryInstanceTransformFB` structure

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_TIME_INVALID`
- `XR_ERROR_POSE_INVALID`
- `XR_ERROR_FEATURE_UNSUPPORTED`

Issues

Version History

- Revision 1, 2021-09-01 (Anton Vaneev)
  - Initial extension description
- Revision 2, 2022-03-16 (Johannes Schmid)
  - Introduce `XrPassthroughBrightnessContrastSaturationFB`.
  - Revise the documentation of `XrPassthroughStyleFB` and its descendants.
12.55. XR_FB_passthrough_keyboard_hands

Name String
XR_FB_passthrough_keyboard_hands

Extension Type
Instance extension

Registered Extension Number
204

Revision
2

Extension and Version Dependencies
- Requires OpenXR 1.0
- Requires XR_FB_passthrough

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Overview
This extension enables applications to show passthrough hands when hands are placed over the tracked keyboard. It enables users to see their hands over the keyboard in a mixed reality application. This extension is dependent on XR_FB_passthrough extension which can be used to create a passthrough layer for hand presence use-case.

The extension supports a single pair of hands (one left and one right hand), multiple pair of hands are not supported.

This extension allows:
- Creation of keyboard hands passthrough layer using xrCreatePassthroughLayerFB
- Setting the level of intensity for the hand mask in a passthrough layer with purpose XrPassthroughLayerPurposeFB as XR_PASSTHROUGH_LAYER_PURPOSE_TRACKED_KEYBOARD_HANDS_FB or XR_PASSTHROUGH_LAYER_PURPOSE_TRACKED_KEYBOARD_MASKED_HANDS_FB

New Enum Constants
XrPassthroughLayerPurposeFB enumeration is extended with a new constant:
- **XR_PASSTHROUGH_LAYER_PURPOSE_TRACKED_KEYBOARD_HANDS_FB** - It defines a keyboard hands presence purpose of passthrough layer (i.e. basic mode, without hand transitions).

- **XR_PASSTHROUGH_LAYER_PURPOSE_TRACKED_KEYBOARD_MASKED_HANDS_FB** - It defines a keyboard hands presence purpose of passthrough layer with keyboard masked hand transitions. A hand mask will be visible only when hands are inside the region of VR keyboard (i.e. hands over the keyboard).

*XrStructureType* enumeration is extended with:

- **XR_TYPE_PASSTHROUGH_KEYBOARD_HANDS_INTENSITY_FB**

**New Structures**

The *XrPassthroughKeyboardHandsIntensityFB* structure is defined as:

```c
typedef struct XrPassthroughKeyboardHandsIntensityFB {
    XrStructureType type;
    const void* next;
    float leftHandIntensity;
    float rightHandIntensity;
} XrPassthroughKeyboardHandsIntensityFB;
```

**Member Descriptions**

- **type** is the *XrStructureType* of this structure.
- **next** is **NULL** or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **leftHandIntensity** defines an intensity for the left tracked hand.
- **rightHandIntensity** defines an intensity for the right tracked hand.

*XrPassthroughKeyboardHandsIntensityFB* describes intensities of passthrough hands, and is used as a parameter to *xrPassthroughLayerSetKeyboardHandsIntensityFB*.

Each of the intensity values **leftHandIntensity** and **rightHandIntensity** must be in the range [0.0, 1.0]. The hand intensity value represents the level of visibility of rendered hand, the minimal value of the intensity 0.0 represents the fully transparent hand (not visible), the maximal value of 1.0 represented fully opaque hands (maximal visibility).

If either **leftHandIntensity** or **rightHandIntensity** is outside the range [0.0, 1.0], the runtime must return **XR_ERROR_VALIDATION_FAILURE**.
Valid Usage (Implicit)

- The `XR_FB_passsthrough_keyboard_hands` extension **must** be enabled prior to using `XrPassthroughKeyboardHandsIntensityFB`
- `type` **must** be `XR_TYPE_PASSTHROUGH_KEYBOARD_HANDS_INTENSITY_FB`
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain

New Functions

The `xrPassthroughLayerSetKeyboardHandsIntensityFB` function is defined as:

```c
XrResult xrPassthroughLayerSetKeyboardHandsIntensityFB(
    XrPassthroughLayerFB layer,
    const XrPassthroughKeyboardHandsIntensityFB* intensity);
```

Parameter Descriptions

- `layer` is the `XrPassthroughLayerFB` to apply the intensity.
- `intensity` is the `XrPassthroughKeyboardHandsIntensityFB` to be set.

Sets an `XrPassthroughKeyboardHandsIntensityFB` intensity on an `XrPassthroughLayerFB` layer.

Valid Usage (Implicit)

- The `XR_FB_passsthrough_keyboard_hands` extension **must** be enabled prior to calling `xrPassthroughLayerSetKeyboardHandsIntensityFB`
- `layer` **must** be a valid `XrPassthroughLayerFB` handle
- `intensity` **must** be a pointer to a valid `XrPassthroughKeyboardHandsIntensityFB` structure
Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_FEATURE_UNSUPPORTED

Issues

Version History

- Revision 1, 2021-11-23 (Ante Trbojevic)
  ◦ Initial extension description
- Revision 2, 2022-03-16 (Ante Trbojevic)
  ◦ Introduce XR_PASSTHROUGH_LAYER_PURPOSE_TRACKED_KEYBOARD_MASKED_HANDS_FB

12.56. XR_FB_render_model

Name String

XR_FB_render_model

Extension Type

Instance extension

Registered Extension Number

120

Revision

2

Extension and Version Dependencies

- Requires OpenXR 1.0
Overview

This extension allows applications to request GLTF models for certain connected devices supported by the runtime. Paths that correspond to these devices will be provided through the extension and can be used to get information about the models as well as loading them.

New Flag Types

```c
typedef XrFlags64 XrRenderModelFlagsFB;
```

```c
// Flag bits for XrRenderModelFlagsFB
static const XrRenderModelFlagsFB XR_RENDER_MODEL_SUPPORTS_GLTF_2_0_SUBSET_1_BIT_FB = 0x00000001;
static const XrRenderModelFlagsFB XR_RENDER_MODEL_SUPPORTS_GLTF_2_0_SUBSET_2_BIT_FB = 0x00000002;
```

**Flag Descriptions**

- **XR_RENDER_MODEL_SUPPORTS_GLTF_2_0_SUBSET_1_BIT_FB** — Minimal level of support. Can only contain a single mesh. Can only contain a single texture. Can not contain transparency. Assumes unlit rendering. Requires Extension KHR_texturebasisu.

- **XR_RENDER_MODEL_SUPPORTS_GLTF_2_0_SUBSET_2_BIT_FB** — All of XR_RENDER_MODEL_SUPPORTS_GLTF_2_0_SUBSET_1_BIT_FB support plus: Multiple meshes. Multiple Textures. Texture Transparency.

Render Model Support Levels: An application **should** request a model of a certain complexity via the `XrRenderModelCapabilitiesRequestFB` on the structure chain of `XrRenderModelPropertiesFB` passed into `xrGetRenderModelPropertiesFB`. The flags on the `XrRenderModelCapabilitiesRequestFB` are an acknowledgement of the application’s ability to render such a model. Multiple values of `XrRenderModelFlagBitsFB` can be set on this variable to indicate acceptance of different support levels. The flags parameter on the `XrRenderModelPropertiesFB` will indicate what capabilities the model in the runtime actually requires. It will be set to a single value of `XrRenderModelFlagBitsFB`.

New Enum Constants
XrStructureType enumeration is extended with:

- XR_TYPE_SYSTEM_RENDER_MODEL_PROPERTIES_FB
- XR_TYPE_RENDER_MODEL_PATH_INFO_FB
- XR_TYPE_RENDER_MODEL_PROPERTIES_FB
- XR_TYPE_RENDER_MODEL_BUFFER_FB
- XR_TYPE_RENDER_MODEL_LOAD_INFO_FB
- XR_MAX_RENDER_MODEL_NAME_SIZE_FB

New Defines

```c
#define XR_NULL_RENDER_MODEL_KEY_FB 0
```

XR_NULL_RENDER_MODEL_KEY_FB defines an invalid model key atom.

New Base Types

```c
XR_DEFINE_ATOM(XrRenderModelKeyFB)
```

The unique model key used to retrieve the data for the render model that is valid across multiple
instances and installs. The application can use this key along with the model version to update its
cached or saved version of the model.

New Structures

The XrSystemRenderModelPropertiesFB structure is defined as:

```c
typedef struct XrSystemRenderModelPropertiesFB {
    XrStructureType    type;
    void*              next;
    XrBool32           supportsRenderModelLoading;
} XrSystemRenderModelPropertiesFB;
```

It describes a render model system property.
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **supportsRenderModelLoading** defines whether the system supports loading render models.

Valid Usage (Implicit)

- The `XR_FB_render_model` extension **must** be enabled prior to using `XrSystemRenderModelPropertiesFB`.
- **type** **must** be `XR_TYPE_SYSTEM_RENDER_MODEL_PROPERTIES_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain.

The `XrRenderModelPathInfoFB` structure is defined as:

```c
typedef struct XrRenderModelPathInfoFB {
    XrStructureType    type;
    void*              next;
    XrPath             path;
} XrRenderModelPathInfoFB;
```

Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **path** is a valid `XrPath` used for retrieving model properties from `xrGetRenderModelPropertiesFB`.

`XrRenderModelPathInfoFB` contains a model path supported by the device when returned from `xrEnumerateRenderModelPathsFB`. This path can be used to request information about the render model for the connected device that the path represents using `xrGetRenderModelPropertiesFB`.
Possible Render Model Paths

- Controller models with origin at the grip pose.
  - /model_fb/controller/left
  - /model_fb/controller/right
- Keyboard models with origin at the center of its bounding box.
  - /model_fb/keyboard/local
  - /model_fb/keyboard/remote

Valid Usage (Implicit)

- The XR_FB_render_model extension must be enabled prior to using XrRenderModelPathInfoFB
- type must be XR_TYPE_RENDER_MODEL_PATH_INFO_FB
- next must be NULL or a valid pointer to the next structure in a structure chain

The XrRenderModelPropertiesFB structure is defined as:

typedef struct XrRenderModelPropertiesFB {
  XrStructureType type;
  void* next;
  uint32_t vendorId;
  char modelName[XR_MAX_RENDER_MODEL_NAME_SIZE_FB];
  XrRenderModelKeyFB modelKey;
  uint32_t modelVersion;
  XrRenderModelFlagsFB flags;
} XrRenderModelPropertiesFB;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. `XrRenderModelCapabilitiesRequestFB` is a structure in this structure chain and **should** be linked when this structure is passed to `xrGetRenderModelPropertiesFB`.
- **vendorId** is the vendor id of the model.
- **modelName** is the name of the model.
- **modelKey** is the unique model key used to load the model in `xrLoadRenderModelFB`.
- **modelVersion** is the version number of the model.
- **flags** is a bitmask of `XrRenderModelFlagsFB`. After a successful call to `xrGetRenderModelPropertiesFB`, flags must contain the support level of the model and no other support levels.

`XrRenderModelPropertiesFB` contains information about the render model for a device. `XrRenderModelPropertiesFB` **must** be provided when calling `xrGetRenderModelPropertiesFB`. The `XrRenderModelKeyFB` included in the properties is a unique key for each render model that is valid across multiple instances and installs.

If the application decides to cache or save the render model in any way, **modelVersion** can be used to determine if the render model has changed. The application **should** then update its cached or saved version.

Valid Usage (Implicit)

- The `XR_FB_render_model` extension **must** be enabled prior to using `XrRenderModelPropertiesFB`
- **type** **must** be `XR_TYPE_RENDER_MODEL_PROPERTIES_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **modelName** **must** be a null-terminated UTF-8 string whose length is less than or equal to `XR_MAX_RENDER_MODEL_NAME_SIZE_FB`
- **flags** **must** be a valid combination of `XrRenderModelFlagBitsFB` values
- **flags** **must** not be `0`

The `XrRenderModelCapabilitiesRequestFB` structure is defined as:
typedef struct XrRenderModelCapabilitiesRequestFB {
    XrStructureType         type;
    void*                   next;
    XrRenderModelFlagsFB    flags;
} XrRenderModelCapabilitiesRequestFB;

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **flags** is a bit mask of the model complexities that the application is able to support.

`XrRenderModelCapabilitiesRequestFB` contains information about the render capabilities requested for a model. `XrRenderModelCapabilitiesRequestFB` **must** be set in the structure chain of the `next` pointer on the `XrRenderModelPropertiesFB` passed into the `xrGetRenderModelPropertiesFB` call. The `flags` on `XrRenderModelCapabilitiesRequestFB` represent an acknowledgement of being able to handle the individual model capability levels. If no `XrRenderModelCapabilitiesRequestFB` is on the structure chain then the runtime **should** treat it as if a value of `XR_RENDER_MODEL_SUPPORTS_GLTF_2_0_SUBSET_1_BIT_FB` was set. If the runtime does not have a model available that matches any of the supports flags set, then it **must** return a `XR_RENDER_MODEL_UNAVAILABLE_FB` result.

**Valid Usage (Implicit)**

- The `XR_FB_render_model` extension **must** be enabled prior to using `XrRenderModelCapabilitiesRequestFB`
- `type` **must** be `XR_TYPE_RENDER_MODEL_CAPABILITIES_REQUEST_FB`
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain
- `flags` **must** be a valid combination of `XrRenderModelFlagBitsFB` values
- `flags` **must** not be 0

The `XrRenderModelLoadInfoFB` structure is defined as:
typedef struct XrRenderModelLoadInfoFB {
    XrStructureType type;
    void* next;
    XrRenderModelKeyFB modelKey;
} XrRenderModelLoadInfoFB;

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **modelKey** is the unique model key for a connected device.

XrRenderModelLoadInfoFB is used to provide information about which render model to load. XrRenderModelLoadInfoFB must be provided when calling `xrLoadRenderModelFB`.

**Valid Usage (Implicit)**

- The `XR_FB_render_model` extension must be enabled prior to using XrRenderModelLoadInfoFB
- **type** must be `XR_TYPE_RENDER_MODEL_LOAD_INFO_FB`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

The XrRenderModelBufferFB structure is defined as:

typedef struct XrRenderModelBufferFB {
    XrStructureType type;
    void* next;
    uint32_t bufferCapacityInput;
    uint32_t bufferCountOutput;
    uint8_t* buffer;
} XrRenderModelBufferFB;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is **NULL** or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **bufferCapacityInput** is the capacity of the `buffer`, or 0 to retrieve the required capacity.
- **bufferCountOutput** is the count of `uint8_t` `buffer` written, or the required capacity in the case that `bufferCapacityInput` is insufficient.
- **buffer** is a pointer to an application-allocated array that will be filled with the render model binary data.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required `buffer` size.

`XrRenderModelBufferFB` is used when loading the binary data for a render model. `XrRenderModelBufferFB` **must** be provided when calling `xrLoadRenderModelFB`.

Valid Usage (Implicit)

- The `XR_FB_render_model` extension **must** be enabled prior to using `XrRenderModelBufferFB`
- **type** **must** be `XR_TYPE_RENDER_MODEL_BUFFER_FB`
- **next** **must** be **NULL** or a valid pointer to the next structure in a structure chain
- If `bufferCapacityInput` is not 0, **buffer** **must** be a pointer to an array of `bufferCapacityInput` `uint8_t` values

New Functions

The `xrEnumerateRenderModelPathsFB` function is defined as:

```c
XrResult xrEnumerateRenderModelPathsFB(
    XrSession session,
    uint32_t pathCapacityInput,
    uint32_t* pathCountOutput,
    XrRenderModelPathInfoFB* paths);
```
Parameter Descriptions

- **session** is the specified `XrSession`.
- **pathCapacityInput** is the capacity of the **paths**, or 0 to retrieve the required capacity.
- **pathCountOutput** is a pointer to the count of **float paths** written, or a pointer to the required capacity in the case that **pathCapacityInput** is insufficient.
- **paths** is a pointer to an application-allocated array that will be filled with `XrRenderModelPathInfoFb` values that are supported by the runtime, but can be **NULL** if **pathCapacityInput** is 0.
- See **Buffer Size Parameters** chapter for a detailed description of retrieving the required **paths** size.

The application **must** call `xrEnumerateRenderModelPathsFB` to enumerate the valid render model paths that are supported by the runtime before calling `xrGetRenderModelPropertiesFB`. The paths returned **may** be used later in `xrGetRenderModelPropertiesFB`.

Valid Usage (Implicit)

- The **XR_FB_render_model** extension **must** be enabled prior to calling `xrEnumerateRenderModelPathsFB`.
- **session** **must** be a valid **XrSession** handle.
- **pathCountOutput** **must** be a pointer to a **uint32_t** value.
- If **pathCapacityInput** is not 0, **paths** **must** be a pointer to an array of `pathCapacityInput XrRenderModelPathInfoFb` structures.
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY

The `xrGetRenderModelPropertiesFB` function is defined as:

```c
XrResult xrGetRenderModelPropertiesFB(
    XrSession session,
    XrPath path,
    XrRenderModelPropertiesFB* properties);
```

Parameter Descriptions

- `session` is the specified `XrSession`.
- `path` is the path of the render model to get the properties for.
- `properties` is a pointer to the `XrRenderModelPropertiesFB` to write the render model information to.

`xrGetRenderModelPropertiesFB` is used for getting information for a render model using a path retrieved from `xrEnumerateRenderModelPathsFB`. The information returned will be for the connected device that corresponds to the path given. For example, using `/model_fb/controller/left` will return information for the left controller that is currently connected and will change if a different device that also represents a left controller is connected.

The runtime **must** return `XR_ERROR_CALL_ORDER_INVALID` if `xrGetRenderModelPropertiesFB` is called with render model paths before calling `xrEnumerateRenderModelPathsFB`. The runtime **must** return `XR_ERROR_PATH_INVALID` if a path not given by `xrEnumerateRenderModelPathsFB` is used.
If `xrGetRenderModelPropertiesFB` returns a success code of `XR_RENDER_MODEL_UNAVAILABLE_FB` and has a `modelKey` of `XR_NULL_RENDER_MODEL_KEY_FB`, this indicates that the model for the device is unavailable. The application may keep calling `xrGetRenderModelPropertiesFB` because the model may become available later when a device is connected.

### Valid Usage (Implicit)

- The `XR_FB_render_model` extension must be enabled prior to calling `xrGetRenderModelPropertiesFB`
- `session` must be a valid `XrSession` handle
- `properties` must be a pointer to an `XrRenderModelPropertiesFB` structure

### Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`
- `XR_RENDER_MODEL_UNAVAILABLE_FB`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_CALL_ORDER_INVALID`

The `xrLoadRenderModelFB` function is defined as:
XrResult xrLoadRenderModelFB(
    XrSession session,
    const XrRenderModelLoadInfoFB* info,
    XrRenderModelBufferFB* buffer);

Parameter Descriptions

- session is the specified XrSession.
- info is a pointer to the XrRenderModelLoadInfoFB structure.
- buffer is a pointer to the XrRenderModelBufferFB structure to write the binary data into.

xrLoadRenderModelFB is used to load the GLTF model data using a valid modelKey. xrLoadRenderModelFB loads the model as a byte buffer containing the GLTF in the binary format (GLB). The GLB data must conform to the glTF 2.0 format defined at https://github.com/KhronosGroup/gltf/tree/master/specification/2.0. The GLB may contain texture data in a format that requires the use of the KHR_texture_basisu GLTF extension defined at https://github.com/KhronosGroup/gltf/tree/master/extensions/2.0/Khronos/KHR_texture_basisu. Therefore, the application should ensure it can handle this extension.

If the device for the requested model is disconnected or does not match the modelKey provided, xrLoadRenderModelFB must return XR_RENDER_MODEL_UNAVAILABLE_FB as well as a bufferCountOutput value of 0 indicating that the model was not available.

The xrLoadRenderModelFB function may be slow, therefore applications should call it from a non-time sensitive thread.

Valid Usage (Implicit)

- The XR_FB_render_model extension must be enabled prior to calling xrLoadRenderModelFB
- session must be a valid XrSession handle
- info must be a pointer to a valid XrRenderModelLoadInfoFB structure
- buffer must be a pointer to an XrRenderModelBufferFB structure
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING
- XR_RENDER_MODEL_UNAVAILABLE_FB

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_RENDER_MODEL_KEY_INVALID_FB

Issues

Version History
- Revision 1, 2021-08-17 (Leonard Tsai)
  - Initial extension description
- Revision 2, 2022-05-03 (Robert Memmott)
  - Render Model Support Subsets

12.57. XR_FB_scene

Name String
XR_FB_scene

Extension Type
Instance extension

Registered Extension Number
176

Revision
1
Extension and Version Dependencies

- Requires OpenXR 1.0
- Requires XR_FB.spatial_entity

Contributors

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Overview

This extension expands on the concept of spatial entities to include a way for a spatial entity to represent rooms, objects, or other boundaries in a scene.

In order to enable the functionality of this extension, you must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo::enabledExtensionNames` parameter as indicated in the Extensions section.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

- `XR_TYPE_SEMANTIC_LABELS_FB`
- `XR_TYPE_ROOM_LAYOUT_FB`
- `XR_TYPE_BOUNDARY_2D_FB`

New Enums

New Structures

The `XrExtent3DfFB` structure is defined as:

```c
typedef struct XrExtent3DfFB {
    float width;
    float height;
    float depth;
} XrExtent3DfFB;
```
Member Descriptions

- **width** is the floating-point width of the extent.
- **height** is the floating-point height of the extent.
- **depth** is the floating-point depth of the extent.

This structure is used for component values that may be fractional (floating-point). If used to represent physical distances, values must be in meters. The width, height, and depth values must be non-negative.

Valid Usage (Implicit)

- The XR_FB_scene extension **must** be enabled prior to using XrExtent3DfFB

The XrOffset3DfFB structure is defined as:

```c
typedef struct XrOffset3DfFB {
    float    x;
    float    y;
    float    z;
} XrOffset3DfFB;
```

Member Descriptions

- **x** is the floating-point offset in the x direction.
- **y** is the floating-point offset in the y direction.
- **z** is the floating-point offset in the z direction.

This structure is used for component values that may be fractional (floating-point). If used to represent physical distances, values must be in meters.

Valid Usage (Implicit)

- The XR_FB_scene extension **must** be enabled prior to using XrOffset3DfFB

The XrRect3DfFB structure is defined as:
typedef struct XrRect3DfFB {
  XrOffset3DfFB    offset;
  XrExtent3DfFB    extent;
} XrRect3DfFB;

### Member Descriptions

- **offset** is the XrOffset3DfFB specifying the rectangle offset.
- **extent** is the XrExtent3DfFB specifying the rectangle extent.

This structure is used for component values that may be fractional (floating-point).

### Valid Usage (Implicit)

- The XR_FB_scene extension must be enabled prior to using XrRect3DfFB

The XrSemanticLabelsFB structure is defined as:

typedef struct XrSemanticLabelsFB {
  XrStructureType    type;
  const void*        next;
  uint32_t           bufferCapacityInput;
  uint32_t           bufferCountOutput;
  char*              buffer;
} XrSemanticLabelsFB;
**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **bufferCapacityInput** is the capacity of the `buffer` array, in bytes, or 0 to indicate a request to retrieve the required capacity.
- **bufferCountOutput** is a pointer to the count of bytes written, or a pointer to the required capacity in the case that `bufferCapacityInput` is insufficient.
- **buffer** is a pointer to an array of bytes, but can be `NULL` if `bufferCapacityInput` is 0. Multiple labels represented by raw string, separated by comma (,).
- See **Buffer Size Parameters** chapter for a detailed description of retrieving the required `buffer` size.

This structure is used by the `xrGetSpaceSemanticLabelsFB` function to provide the application with the intended usage of the spatial entity.

**Valid Usage (Implicit)**

- The `XR_FB_scene` extension **must** be enabled prior to using `XrSemanticLabelsFB`
- **type** **must** be `XR_TYPE_SEMANTIC_LABELS_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **If** `bufferCapacityInput` **is not** 0, **buffer** **must** be a pointer to an array of `bufferCapacityInput` char values

The `XrRoomLayoutFB` structure is defined as:

```c
typedef struct XrRoomLayoutFB {
    XrStructureType    type;
    const void*        next;
    XrUuidEXT          floorUuid;
    XrUuidEXT          ceilingUuid;
    uint32_t           wallUuidCapacityInput;
    uint32_t           wallUuidCountOutput;
    XrUuidEXT*         wallUuids;
} XrRoomLayoutFB;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **floorUuid** is the UUID of the spatial entity representing the room floor
- **ceilingUuid** is the UUID of the spatial entity representing the room ceiling
- **wallUuidCapacityInput** is the capacity of the `wallUuids` array, in bytes, or 0 to indicate a request to retrieve the required capacity.
- **wallUuidCountOutput** is a pointer to the count of `XrUuidEXT` handles written, or a pointer to the required capacity in the case that `wallUuidCapacityInput` is insufficient.
- **wallUuids** is a pointer to an array of `XrUuidEXT` handles, but can be `NULL` if `wallUuidCapacityInput` is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required `wallUuids` array size.

This structure is used by the `xrGetSpaceRoomLayoutFB` function to provide the application with the `XrUuidEXT` handles representing the various surfaces of a room.

Valid Usage (Implicit)

- The `XR_FB_scene` extension **must** be enabled prior to using `XrRoomLayoutFB`
- **type** **must** be `XR_TYPE_ROOM_LAYOUT_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- If `wallUuidCapacityInput` is not 0, `wallUuids` **must** be a pointer to an array of `wallUuidCapacityInput` `XrUuidEXT` structures

The `XrBoundary2DFB` structure is defined as:

```c
typedef struct XrBoundary2DFB {
    XrStructureType    type;
    const void*        next;
    uint32_t           vertexCapacityInput;
    uint32_t           vertexCountOutput;
    XrVector2f*        vertices;
} XrBoundary2DFB;
```
**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **vertexCapacityInput** is the capacity of the vertices array, in bytes, or 0 to indicate a request to retrieve the required capacity.
- **vertexCountOutput** is a pointer to the count of XrVector2f written, or a pointer to the required capacity in the case that vertexCapacityInput is insufficient.
- **vertices** is a pointer to an array of XrVector2f, but can be NULL if vertexCapacityInput is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required vertices array size.

This structure is used by the xrGetSpaceBoundary2DFB function to provide the application with the XrVector2f vertices representing a spatial entity with a boundary.

**Valid Usage (Implicit)**

- The XR_FB_scene extension must be enabled prior to using XrBoundary2DFB
- **type** must be XR_TYPE_BOUNDARY_2D_FB
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- If vertexCapacityInput is not 0, **vertices** must be a pointer to an array of vertexCapacityInput XrVector2f structures

**New Functions**

The xrGetSpaceBoundingBox2DFB function is defined as:

```c
XrResult xrGetSpaceBoundingBox2DFB(
    XrSession session,
    XrSpace space,
    XrRect2Df* boundingBox2DOutput);
```
Parameter Descriptions

- `session` is a handle to an `XrSession`.
- `space` is the `XrSpace` handle to the spatial entity.
- `boundingBox2DOutput` is an output parameter pointing to the structure containing the 2D bounding box for `space`.

Gets the 2D bounding box for a spatial entity with the `XR_SPACE_COMPONENT_TYPE_BOUNDED_2D_FB` component type enabled.

Valid Usage (Implicit)

- The `XR_FB_scene` extension must be enabled prior to calling `xrGetSpaceBoundingBox2DFB`
- `session` must be a valid `XrSession` handle
- `space` must be a valid `XrSpace` handle
- `boundingBox2DOutput` must be a pointer to an `XrRect2Df` structure
- `space` must have been created, allocated, or retrieved from `session`

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB`
- `XR_ERROR_FEATURE_UNSUPPORTED`

The `xrGetSpaceBoundingBox3DFB` function is defined as:
XRResult xrGetSpaceBoundingBox3DFB(
    XrSession session,
    XrSpace space,
    XrRect3DfFB* boundingBox3DOutput);

**Parameter Descriptions**

- **session** is a handle to an XrSession.
- **space** is the XrSpace handle to the spatial entity.
- **boundingBox3DOutput** is an output parameter pointing to the structure containing the 3D bounding box for **space**.

Gets the 3D bounding box for a spatial entity with the XR_SPACE_COMPONENT_TYPE_BOUNDED_3D_FB component type enabled.

**Valid Usage (Implicit)**

- The XR_FB_scene extension must be enabled prior to calling xrGetSpaceBoundingBox3DFB
- **session** must be a valid XrSession handle
- **space** must be a valid XrSpace handle
- **boundingBox3DOutput** must be a pointer to an XrRect3DfFB structure
- **space** must have been created, allocated, or retrieved from **session**
Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB
• XR_ERROR_FEATURE_UNSUPPORTED

The xrGetSpaceSemanticLabelsFB function is defined as:

```c
XrResult xrGetSpaceSemanticLabelsFB(
    XrSession                                   session,
    XrSpace                                     space,
    XrSemanticLabelsFB*                         semanticLabelsOutput);
```

Parameter Descriptions

• session is a handle to an XrSession.
• space is the XrSpace handle to the spatial entity.
• semanticLabelsOutput is an output parameter pointing to the structure containing the XrSemanticLabelsFB for space.

Gets the semantic labels for a spatial entity with the XR_SPACE_COMPONENT_TYPE_SEMANTIC_LABELS_FB component type enabled.
Valid Usage (Implicit)

- The XR_FB_scene extension must be enabled prior to calling xrGetSpaceSemanticLabelsFB.
- session must be a valid XrSession handle.
- space must be a valid XrSpace handle.
- semanticLabelsOutput must be a pointer to an XrSemanticLabelsFB structure.
- space must have been created, allocated, or retrieved from session.

Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB
- XR_ERROR_FEATURE_UNSUPPORTED

The xrGetSpaceBoundary2DFB function is defined as:

```c
XrResult xrGetSpaceBoundary2DFB(
    XrSession session,
    XrSpace space,
    XrBoundary2DFB* boundary2DOutput);
```
Parameter Descriptions

- **session** is a handle to an **XrSession**.
- **space** is the **XrSpace** handle to the spatial entity.
- **boundary2DOutput** is an output parameter pointing to the structure containing the **XrBoundary2DFB** for **space**.

Gets the 2D boundary, specified by vertices, for a spatial entity with the **XR_SPACE_COMPONENT_TYPE_BOUNDED_2D_FB** component type enabled.

Valid Usage (Implicit)

- The **XR_FB_scene** extension **must** be enabled prior to calling **xrGetSpaceBoundary2DFB**
- **session** **must** be a valid **XrSession** handle
- **space** **must** be a valid **XrSpace** handle
- **boundary2DOutput** **must** be a pointer to an **XrBoundary2DFB** structure
- **space** **must** have been created, allocated, or retrieved from **session**

Return Codes

**Success**

- **XR_SUCCESS**
- **XR_SESSION_LOSS_PENDING**

**Failure**

- **XR_ERROR_FUNCTION_UNSUPPORTED**
- **XR_ERROR_VALIDATION_FAILURE**
- **XR_ERROR_RUNTIME_FAILURE**
- **XR_ERROR_HANDLE_INVALID**
- **XR_ERROR_INSTANCE_LOST**
- **XR_ERROR_SESSION_LOST**
- **XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB**
- **XR_ERROR_FEATURE_UNSUPPORTED**

The **xrGetSpaceRoomLayoutFB** function is defined as:
XrResult xrGetSpaceRoomLayoutFB(
    XrSession session,
    XrSpace space,
    XrRoomLayoutFB* roomLayoutOutput);

Parameter Descriptions

- **session** is a handle to an XrSession.
- **space** is the XrSpace handle to the spatial entity.
- **roomLayoutOutput** is an output parameter pointing to the structure containing the XrRoomLayoutFB for space.

Gets the room layout, specified by UUIDs for each surface, for a spatial entity with the XR_SPACE_COMPONENT_TYPE_ROOM_LAYOUT_FB component type enabled.

Valid Usage (Implicit)

- The XR_FB_scene extension must be enabled prior to calling xrGetSpaceRoomLayoutFB
- **session** must be a valid XrSession handle
- **space** must be a valid XrSpace handle
- **roomLayoutOutput** must be a pointer to an XrRoomLayoutFB structure
- **space** must have been created, allocated, or retrieved from session
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB
- XR_ERROR_FEATURE_UNSUPPORTED

Issues

Version History
- Revision 1, 2022-03-09 (John Schofield)
  - Initial draft

12.58. XR_FB_space_warp

Name String
XR_FB_space_warp

Extension Type
Instance extension

Registered Extension Number
172

Revision
2

Extension and Version Dependencies
- Requires OpenXR 1.0
Overview

This extension provides support to enable space warp technology on application. By feeding application generated motion vector and depth buffer images, the runtime can do high quality frame extrapolation and reprojection, allow applications to run at half fps but still providing smooth experience to users.

In order to enable the functionality of this extension, the application must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo::enabledExtensionNames` parameter as indicated in the Extensions section.

Note

This extension is independent of `XR_KHR_composition_layer_depth`, and both may be enabled and used at the same time, for different purposes. The `XrCompositionLayerSpaceWarpInfoFB::depthSubImage` depth data is dedicated for space warp, and its resolution is usually lower than `XrCompositionLayerDepthInfoKHR::subImage`. See `XrSystemSpaceWarpPropertiesFB` for suggested resolution of `depthSubImage`.

New Flag Types

typedef XrFlags64 XrCompositionLayerSpaceWarpInfoFlagsFB;

// Flag bits for XrCompositionLayerSpaceWarpInfoFlagsFB
static const XrCompositionLayerSpaceWarpInfoFlagsFB
    XR_COMPOSITION_LAYER_SPACE_WARP_INFO_FRAME_SKIP_BIT_FB = 0x00000001;

Flag Descriptions

- `XR_COMPOSITION_LAYER_SPACE_WARP_INFO_FRAME_SKIP_BIT_FB` requests that the runtime skips space warp frame extrapolation for a particular frame. This can be used when the application has better knowledge the particular frame will be not a good fit for space warp frame extrapolation.
New Enum Constants

**XrStructureType** enumeration is extended with:

- XR_TYPE_COMPOSITION_LAYER_SPACE_WARP_INFO_FB
- XR_TYPE_SYSTEM_SPACE_WARP_PROPERTIES_FB

New Enums

- XR_COMPOSITION_LAYER_SPACE_WARP_INFO_FRAME_SKIP_BIT_FB

New Structures

When submitting motion vector buffer and depth buffers along with projection layers, add an **XrCompositionLayerSpaceWarpInfoFB** structure to the **XrCompositionLayerProjectionView::next** chain, for each **XrCompositionLayerProjectionView** structure in the given layer.

The **XrCompositionLayerSpaceWarpInfoFB** structure is defined as:

```c
typedef struct XrCompositionLayerSpaceWarpInfoFB {
    XrStructureType                           type;
    const void*                               next;
    XrCompositionLayerSpaceWarpInfoFlagsFB    layerFlags;
    XrSwapchainSubImage                       motionVectorSubImage;
    XrPosef                                   appSpaceDeltaPose;
    XrSwapchainSubImage                       depthSubImage;
    float                                     minDepth;
    float                                     maxDepth;
    float                                     nearZ;
    float                                     farZ;
} XrCompositionLayerSpaceWarpInfoFB;
```
Member Descriptions

• **type** is the XrStructureType of this structure.

• **next** is NULL or a pointer to the next structure in a structure chain.

• **layerFlags** is a bitmask of XrCompositionLayerSpaceWarpInfoFlagsFB.

• **motionVectorSubImage** identifies the motion vector image XrSwapchainSubImage to be associated with the submitted layer XrCompositionLayerProjection.

• **appSpaceDeltaPose** is the incremental application-applied transform, if any, since the previous frame that affects the view. When artificial locomotion (scripted movement, teleportation, etc.) happens, the application might transform the whole XrCompositionLayerProjection::space from one application space pose to another pose between frames. The pose should be identity when there is no XrCompositionLayerProjection::space transformation in application.

• **depthSubImage** identifies the depth image XrSwapchainSubImage to be associated with motionVectorSubImage. The swapchain should be created with XR_SWAPCHAIN_USAGE_SAMPLED_BIT | XR_SWAPCHAIN_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT.

• **minDepth** and **maxDepth** are the range of depth values the depthSwapchain could have, in the range of [0.0,1.0]. This is akin to min and max values of OpenGL's glDepthRange, but with the requirement here that maxDepth \(\geq\) minDepth.

• **nearZ** is the positive distance in meters of the **minDepth** value in the depth swapchain. Applications may use a nearZ that is greater than **farZ** to indicate depth values are reversed. nearZ can be infinite.

• **farZ** is the positive distance in meters of the **maxDepth** value in the depth swapchain. farZ can be infinite.

The motion vector data is stored in the **motionVectorSubImage**'s RGB channels, defined in NDC (normalized device coordinates) space, for example, the same surface point's NDC is PrevNDC in previous frame, CurrNDC in current frame, then the motion vector value is "highp vec3 motionVector = (CurrNDC - PrevNDC).xyz;". Signed 16 bit float pixel format is recommended for this image.

The runtime **must** return error XR_ERROR_VALIDATION_FAILURE if nearZ == farZ.
Valid Usage (Implicit)

- The XR_FB_space_warp extension must be enabled prior to using XrCompositionLayerSpaceWarpInfoFB
- type must be XR_TYPE_COMPOSITION_LAYER_SPACE_WARP_INFO_FB
- next must be NULL or a valid pointer to the next structure in a structure chain
- layerFlags must be 0 or a valid combination of XrCompositionLayerSpaceWarpInfoFlagBitsFB values
- motionVectorSubImage must be a valid XrSwapchainSubImage structure
- depthSubImage must be a valid XrSwapchainSubImage structure

When this extension is enabled, an application can pass in an XrSystemSpaceWarpPropertiesFB structure in the XrSystemProperties::next chain when calling xrGetSystemProperties to acquire information about recommended motion vector buffer resolution. The XrSystemSpaceWarpPropertiesFB structure is defined as:

```c
typedef struct XrSystemSpaceWarpPropertiesFB {
    XrStructureType    type;
    void*              next;
    uint32_t           recommendedMotionVectorImageRectWidth;
    uint32_t           recommendedMotionVectorImageRectHeight;
} XrSystemSpaceWarpPropertiesFB;
```

Member Descriptions

- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain.
- recommendedMotionVectorImageRectWidth: recommended motion vector and depth image width
- recommendedMotionVectorImageRectHeight: recommended motion vector and depth image height
Valid Usage (Implicit)

- The **XR_FB_space_warp** extension must be enabled prior to using `XrSystemSpaceWarpPropertiesFB`
- **type** must be `XR_TYPE_SYSTEM_SPACE_WARP_PROPERTIES_FB`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

Issues

Version History

- Revision 1, 2021-08-04 (Jian Zhang)
  - Initial extension description
- Revision 2, 2022-02-07 (Jian Zhang)
  - Add `XR_COMPOSITION_LAYER_SPACE_WARP_INFO_FRAME_SKIP_BIT_FB`

12.59. XR_FB_spatial_entity

Name String

- **XR_FB_spatial_entity**

Extension Type

- Instance extension

Registered Extension Number

- 114

Revision

- 1

Extension and Version Dependencies

- Requires OpenXR 1.0
- Requires `XR_EXT_uuid`

Contributors

- John Schofield, Facebook
- Andrew Kim, Facebook
- Yuichi Taguchi, Facebook
- Cass Everitt, Facebook
- Curtis Arink, Facebook

Overview
This extension enables applications to use spatial entities to specify world-locked frames of reference. It enables applications to persist the real world location of content over time and contains definitions for the Entity-Component System. All Facebook spatial entity and scene extensions are dependent on this one.

We use OpenXR XrSpace handles to give applications access to spatial entities such as Spatial Anchors. In other words, any operation which involves spatial entities uses XrSpace handles to identify the affected spatial entities.

In order to enable the functionality of this extension, you must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo::enabledExtensionNames parameter as indicated in the Extensions section.

This extension allows:

- An application to create a Spatial Anchor (a type of spatial entity).
- An application to enumerate supported components for a given spatial entity.
- An application to enable or disable a component for a given spatial entity.
- An application to get the status of a component for a given spatial entity.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_SYSTEM_SPATIAL_ENTITY_PROPERTIES_FB
- XR_TYPE_SPATIAL_ANCHOR_CREATE_INFO_FB
- XR_TYPE_SPACE_COMPONENT_STATUS_SET_INFO_FB
- XR_TYPE_SPACE_COMPONENT_STATUS_FB
- XR_TYPE_EVENT_DATA_SPATIAL_ANCHOR_CREATE_COMPLETE_FB
- XR_TYPE_EVENT_DATA_SPACE_SET_STATUS_COMPLETE_FB

XrResult enumeration is extended with:

- XR_ERROR_SPACE_COMPONENT_NOT_SUPPORTED_FB
- XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB
- XR_ERROR_SPACE_COMPONENT_STATUS_PENDING_FB
- XR_ERROR_SPACE_COMPONENT_STATUS_ALREADY_SET_FB

New Enums
typedef enum XrSpaceComponentTypeFB {
    XR_SPACE_COMPONENT_TYPE_LOCATABLE_FB = 0,
    XR_SPACE_COMPONENT_TYPE_STORABLE_FB = 1,
    XR_SPACE_COMPONENT_TYPE_BOUNDED_2D_FB = 3,
    XR_SPACE_COMPONENT_TYPE_BOUNDED_3D_FB = 4,
    XR_SPACE_COMPONENT_TYPE_SEMANTIC_LABELS_FB = 5,
    XR_SPACE_COMPONENT_TYPE_ROOM_LAYOUT_FB = 6,
    XR_SPACE_COMPONENT_TYPE_SPACE_CONTAINER_FB = 7,
    XR_SPACE_COMPONENT_TYPE_MAX_ENUM_FB = 0x7FFFFFFF
} XrSpaceComponentTypeFB;

Specify the component interfaces attached to the spatial entity.

### Enumerant Descriptions

- **XR_SPACE_COMPONENT_TYPE_LOCATABLE_FB** — Enables tracking the 6 DOF pose of the XrSpace with xrLocateSpace.
- **XR_SPACE_COMPONENT_TYPE_STORABLE_FB** — Enables persistence operations: save and erase.
- **XR_SPACE_COMPONENT_TYPE_BOUNDED_2D_FB** — Bounded 2D component.
- **XR_SPACE_COMPONENT_TYPE_BOUNDED_3D_FB** — Bounded 3D component.
- **XR_SPACE_COMPONENT_TYPE_SEMANTIC_LABELS_FB** — Semantic labels component.
- **XR_SPACE_COMPONENT_TYPE_ROOM_LAYOUT_FB** — Room layout component.
- **XR_SPACE_COMPONENT_TYPE_SPACE_CONTAINER_FB** — Space container component.

### New Base Types

The XrAsyncRequestIdFB base type is defined as:

```c
XR_DEFINE_ATOM(XrAsyncRequestIdFB)
```

Represents a request to the spatial entity system. Several functions in this and other extensions will populate an output variable of this type so that an application can use it when referring to a specific request.

### New Structures

The XrSystemSpatialEntityPropertiesFB structure is defined as:
typedef struct XrSystemSpatialEntityPropertiesFB {
    XrStructureType    type;
    const void*        next;
    XrBool32           supportsSpatialEntity;
} XrSystemSpatialEntityPropertiesFB;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain.
- **supportsSpatialEntity** is a boolean value that determines if spatial entities are supported by the system.

An application can inspect whether the system is capable of spatial entity operations by extending the XrSystemProperties with XrSystemSpatialEntityPropertiesFB structure when calling xrGetSystemProperties.

If a runtime returns XR_FALSE for supportsSpatialEntity, the runtime must return XR_ERROR_FEATURE_UNSUPPORTED from xrGetSpaceUuidFB.

Valid Usage (Implicit)

- The XR_FB_spatial_entity extension must be enabled prior to using XrSystemSpatialEntityPropertiesFB
- **type** must be XR_TYPE_SYSTEM_SPATIAL_ENTITY_PROPERTIES_FB
- **next** must be NULL or a valid pointer to the next structure in a structure chain

The XrSpatialAnchorCreateInfoFB structure is defined as:

typedef struct XrSpatialAnchorCreateInfoFB {
    XrStructureType    type;
    const void*        next;
    XrSpace            space;
    XrPosef            poseInSpace;
    XrTime             time;
} XrSpatialAnchorCreateInfoFB;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **space** is the XrSpace handle to the reference space that defines the poseInSpace of the anchor to be defined.
- **poseInSpace** is the XrPosef location and orientation of the Spatial Anchor in the specified reference space.
- **time** is the XrTime timestamp associated with the specified pose.

Parameters to create a new spatial anchor.

Valid Usage (Implicit)

- The XR_FB_spatial_entity extension **must** be enabled prior to using XrSpatialAnchorCreateInfoFB
- **type** **must** be XR_TYPE_SPATIAL_ANCHOR_CREATE_INFO_FB
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain
- **space** **must** be a valid XrSpace handle

The XrSpaceComponentStatusSetInfoFB structure is defined as:

```c
typedef struct XrSpaceComponentStatusSetInfoFB {
    XrStructureType           type;
    const void*               next;
    XrSpaceComponentTypeFB    componentType;
    XrBool32                  enabled;
    XrDuration                timeout;
} XrSpaceComponentStatusSetInfoFB;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **componentType** is the component whose status is to be set.
- **enabled** is the value to set the component to.
- **timeout** is the number of nanoseconds before the operation should be cancelled. A value of XR_INFINITE_DURATION indicates to never time out. See Duration for more details.

Enables or disables the specified component for the specified spatial entity.

Valid Usage (Implicit)

- The XR_FB_spatial_entity extension must be enabled prior to using XrSpaceComponentStatusSetInfoFB
- **type** must be XR_TYPE_SPACE_COMPONENT_STATUS_SET_INFO_FB
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **componentType** must be a valid XrSpaceComponentTypeFB value

The XrSpaceComponentStatusFB structure is defined as:

```c
typedef struct XrSpaceComponentStatusFB {
    XrStructureType    type;
    void*              next;
    XrBool32           enabled;
    XrBool32           changePending;
} XrSpaceComponentStatusFB;
```
**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **enabled** is a boolean value that determines if a component is currently enabled or disabled.
- **changePending** is a boolean value that determines if the component's enabled state is about to change.

It holds information on the current state of a component.

**Valid Usage (Implicit)**

- The `XR_FB_spatial_entity` extension **must** be enabled prior to using `XrSpaceComponentStatusFB`
- **type** **must** be `XR_TYPE_SPACE_COMPONENT_STATUS_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain

The `XrEventDataSpatialAnchorCreateCompleteFB` structure is defined as:

```c
typedef struct XrEventDataSpatialAnchorCreateCompleteFB {
    XrStructureType       type;
    const void*           next;
    XrAsyncRequestIdFB    requestId;
    XrResult              result;
    XrSpace               space;
    XrUuidEXT             uuid;
} XrEventDataSpatialAnchorCreateCompleteFB;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **requestId** is the ID of the asynchronous request used to create a new spatial anchor.
- **result** is an `XrResult` that determines if the request succeeded or if an error occurred.
- **space** is the `XrSpace` handle to the newly created spatial anchor.
- **uuid** is the UUID of the newly created spatial anchor.

It describes the result of a request to create a new spatial anchor. Once this event is posted, it is the applications responsibility to take ownership of the `XrSpace`. The `XrSession` passed into `xrCreateSpatialAnchorFB` is the parent handle of the newly created `XrSpace`.

Valid Usage (Implicit)

- The `XR_FB_spatial_entity` extension must be enabled prior to using `XrEventDataSpatialAnchorCreateCompleteFB`
- **type** must be `XR_TYPE_EVENT_DATA_SPATIAL_ANCHOR_CREATE_COMPLETE_FB`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

The `XrEventDataSpaceSetStatusCompleteFB` structure is defined as:

```c
typedef struct XrEventDataSpaceSetStatusCompleteFB {
    XrStructureType           type;
    const void*               next;
    XrAsyncRequestIdFB        requestId;
    XrResult                  result;
    XrSpace                   space;
    XrUuidEXT                 uuid;
    XrSpaceComponentTypeFB    componentType;
    XrBool32                  enabled;
} XrEventDataSpaceSetStatusCompleteFB;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **requestId** is the ID of the asynchronous request used to enable or disable a component.
- **result** is an `XrResult` that describes whether the request succeeded or if an error occurred.
- **space** is the `XrSpace` handle to the spatial entity.
- **uuid** is the UUID of the spatial entity.
- **componentType** is the type of component being enabled or disabled.
- **enabled** is a boolean value indicating whether the component is now enabled or disabled.

It describes the result of a request to enable or disable a component of a spatial entity.

Valid Usage (Implicit)

- The `XR_FB_spatial_entity` extension **must** be enabled prior to using `XrEventDataSpaceSetStatusCompleteFB`
- **type** **must** be `XR_TYPE_EVENT_DATA_SPACE_SET_STATUS_COMPLETE_FB`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain

New Functions

The `xrCreateSpatialAnchorFB` function is defined as:

```c
XrResult xrCreateSpatialAnchorFB(
    XrSession                              session,  
    const XrSpatialAnchorCreateInfoFB*     info,    
    XrAsyncRequestIdFB*                    requestId);
```
Parameter Descriptions

- *session* is a handle to an *XrSession*.
- *info* is a pointer to an *XrSpatialAnchorCreateInfoFB* structure containing information about how to create the anchor.
- *requestId* is the output parameter that points to the ID of this asynchronous request.

Creates a Spatial Anchor using the specified tracking origin and pose relative to the specified tracking origin. The anchor will be locatable at the time of creation, and the 6 DOF pose relative to the tracking origin can be queried using the *xrLocateSpace* method. This operation is asynchronous and the runtime must post an *XrEventDataSpatialAnchorCreateCompleteFB* event when the operation completes successfully or encounters an error. The *requestId* can be used to later refer to the request, such as identifying which request has completed when an *XrEventDataSpatialAnchorCreateCompleteFB* is posted to the event queue.

Valid Usage (Implicit)

- The *XR_FB_spatial_entity* extension must be enabled prior to calling *xrCreateSpatialAnchorFB*
- *session* must be a valid *XrSession* handle
- *info* must be a pointer to a valid *XrSpatialAnchorCreateInfoFB* structure
- *requestId* must be a pointer to an *XrAsyncRequestIdFB* value
Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_LIMIT_REACHED
• XR_ERROR_TIME_INVALID
• XR_ERROR_POSE_INVALID
• XR_ERROR_FEATURE_UNSUPPORTED

The `xrGetSpaceUuidFB` function is defined as:

```c
XrResult xrGetSpaceUuidFB(
    XrSpace                                     space,
    XrUuidEXT*                                  uuid);
```

Parameter Descriptions

• `space` is the `XrSpace` handle of a spatial entity.
• `uuid` is an output parameter pointing to the entity’s UUID.

Gets the UUID for a spatial entity. If this space was previously created as a spatial anchor, `uuid` must be equal to the `XrEventDataSpatialAnchorCreateCompleteFB::uuid` in the event corresponding to the creation of that space. Subsequent calls to `xrGetSpaceUuidFB` using the same `XrSpace` must return the same `XrUuidEXT`. 
Valid Usage (Implicit)

- The XR_FB_spatial_entity extension **must** be enabled prior to calling `xrGetSpaceUuidFB`
- `space` **must** be a valid XrSpace handle
- `uuid` **must** be a pointer to an XrUuidEXT structure

Return Codes

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_FEATURE_UNSUPPORTED

The `xrEnumerateSpaceSupportedComponentsFB` function is defined as:

```c
XrResult xrEnumerateSpaceSupportedComponentsFB(
    XrSpace                                     space,
    uint32_t                                    componentTypeCapacityInput,
    uint32_t*                                   componentTypeCountOutput,
    XrSpaceComponentTypeFB*                     componentTypes);
```
**Parameter Descriptions**

- **space** is the XrSpace handle to the spatial entity.
- **componentTypeCapacityInput** is the capacity of the componentTypes array, or 0 to indicate a request to retrieve the required capacity.
- **componentTypeCountOutput** is a pointer to the count of componentTypes written, or a pointer to the required capacity in the case that componentTypeCapacityInput is insufficient.
- **componentTypes** is a pointer to an array of XrSpaceComponentTypeFB values, but can be NULL if componentTypeCapacityInput is 0.
- See [Buffer Size Parameters](#) chapter for a detailed description of retrieving the required componentTypes size.

Lists any component types that an entity supports. The list of component types available for an entity depends on which extensions are enabled. Component types **must** not be enumerated unless the corresponding extension that defines them is also enabled.

**Valid Usage (Implicit)**

- The XR_FB_spatial_entity extension **must** be enabled prior to calling `xrEnumerateSpaceSupportedComponentsFB`
- **space** **must** be a valid XrSpace handle
- **componentTypeCountOutput** **must** be a pointer to a `uint32_t` value
- If `componentTypeCapacityInput` is not 0, **componentTypes** **must** be a pointer to an array of `componentTypeCapacityInput` XrSpaceComponentTypeFB values
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_FEATURE_UNSUPPORTED

The `xrSetSpaceComponentStatusFB` function is defined as:

```c
XrResult xrSetSpaceComponentStatusFB(
    XrSpace                                     space,
    const XrSpaceComponentStatusSetInfoFB*      info,
    XrAsyncRequestIdFB*                         requestId);
```

Parameter Descriptions

• `space` is the `XrSpace` handle to the spatial entity.
• `info` is a pointer to an `XrSpaceComponentStatusSetInfoFB` structure containing information about the component to be enabled or disabled.
• `requestId` is the output parameter that points to the ID of this asynchronous request.

Enables or disables the specified component for the specified entity. This operation is asynchronous and always returns immediately, regardless of the value of `timeout`. The `requestId` can be used to later refer to the request, such as identifying which request has completed when an `XrEventDataSpaceSetStatusCompleteFB` is posted to the event queue. This function must return `XR_ERROR_SPACE_COMPONENT_NOT_SUPPORTED_FB` if the `XrSpace` does not support the specified component type.
Valid Usage (Implicit)

- The `XR_FB_spatial_entity` extension must be enabled prior to calling `xrSetSpaceComponentStatusFB`
- `space` must be a valid `XrSpace` handle
- `info` must be a pointer to a valid `XrSpaceComponentStatusSetInfoFB` structure
- `requestId` must be a pointer to an `XrAsyncRequestIdFB` value

Return Codes

Success
- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERRORVALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_SPACE_COMPONENT_STATUS_PENDING_FB`
- `XR_ERROR_SPACE_COMPONENT_STATUS_ALREADY_SET_FB`
- `XR_ERROR_SPACE_COMPONENT_NOT_SUPPORTED_FB`
- `XR_ERROR_FEATURE_UNSUPPORTED`

The `xrGetSpaceComponentStatusFB` function is defined as:

```c
XrResult xrGetSpaceComponentStatusFB(
    XrSpace                                    space,
    XrSpaceComponentTypeFB                     componentType,
    XrSpaceComponentStatusFB*                  status);
```
Parameter Descriptions

- `space` is the XrSpace handle of a spatial entity.
- `componentType` is the component type to query.
- `status` is an output parameter pointing to the structure containing the status of the component that was queried.

Gets the current status of the specified component for the specified entity. This function **must** return `XR_ERROR_SPACE_COMPONENT_NOT_SUPPORTED_FB` if the XrSpace does not support the specified component type.

Valid Usage (Implicit)

- The XR_FB_spatial_entity extension **must** be enabled prior to calling `xrGetSpaceComponentStatusFB`
- `space` **must** be a valid XrSpace handle
- `componentType` **must** be a valid XrSpaceComponentTypeFB value
- `status` **must** be a pointer to an XrSpaceComponentStatusFB structure

Return Codes

**Success**
- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_SPACE_COMPONENT_NOT_SUPPORTED_FB`
- `XR_ERROR_FEATURE_UNSUPPORTED`
12.60. XR_FB.spatial_entity_container

Name String
XR_FB.spatial_entity_container

Extension Type
Instance extension

Registered Extension Number
200

Revision
2

Extension and Version Dependencies
• Requires OpenXR 1.0
• Requires XR_FB.spatial_entity

Contributors
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Overview
This extension expands on the concept of spatial entities to include a way for one spatial entity to contain multiple child spatial entities, forming a hierarchy.

In order to enable the functionality of this extension, you must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo::enabledExtensionNames parameter as indicated in the Extensions section.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

• XR_TYPE_SPACE_CONTAINER_FB
New Enums

New Structures

The `XrSpaceContainerFB` structure is defined as:

```c
typedef struct XrSpaceContainerFB {
  XrStructureType    type;
  const void*        next;
  uint32_t           uuidCapacityInput;
  uint32_t           uuidCountOutput;
  XrUuidEXT*         uuids;
} XrSpaceContainerFB;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **uuidCapacityInput** is an input parameter for the application to specify a capacity for the output list
- **uuidCountOutput** is an output parameter which will hold the number of UUIDs included in the output list, or the required capacity in the case that `uuidCapacityInput` is insufficient
- **uuids** is an output parameter which will hold a list of space UUIDs contained by the space to which the component is attached.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required `uuids` size.

The `XrSpaceContainerFB` structure can be used by an application to perform the two calls required to obtain information about which spatial entities are contained by a specified spatial entity.
Valid Usage (Implicit)

- The `XR_FB_spatial_entity_container` extension must be enabled prior to using `XrSpaceContainerFB`
- `type` must be `XR_TYPE_SPACE_CONTAINER_FB`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- If `uuidCapacityInput` is not 0, `uuuids` must be a pointer to an array of `uuidCapacityInput` `XrUuidEXT` structures

New Functions

The `xrGetSpaceContainerFB` function is defined as:

```c
XrResult xrGetSpaceContainerFB(
    XrSession session,
    XrSpace space,
    XrSpaceContainerFB* spaceContainerOutput);
```

Parameter Descriptions

- `session` is a handle to an `XrSession`.
- `space` is a handle to an `XrSpace`.
- `spaceContainerOutput` is the output parameter that points to an `XrSpaceContainerFB` containing information about which spaces are contained by `space`.

The `xrGetSpaceContainerFB` function is used by an application to perform the two calls required to obtain information about which spatial entities are contained by a specified spatial entity.

The `XR_SPACE_COMPONENT_TYPE_SPACE_CONTAINER_FB` component type must be enabled, otherwise this function will return `XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB`. 
Valid Usage (Implicit)

- The `XR_FB.spatial_entity_container` extension must be enabled prior to calling `xrGetSpaceContainerFB`
- `session` must be a valid `XrSession` handle
- `space` must be a valid `XrSpace` handle
- `spaceContainerOutput` must be a pointer to an `XrSpaceContainerFB` structure
- `space` must have been created, allocated, or retrieved from `session`

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB`
- `XR_ERROR_FEATURE_UNSUPPORTED`

Issues

Version History

- Revision 1, 2022-03-09 (John Schofield)
  - Initial draft
- Revision 2, 2022-05-31 (John Schofield)
  - Fix types of `XrSpaceContainerFB` fields.
12.61. XR_FB_spatial_entity_query

Name String
XR_FB_spatial_entity_query

Extension Type
Instance extension

Registered Extension Number
157

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0
• Requires XR_FB_spatial_entity_storage

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Overview
This extension enables an application to discover persistent spatial entities in the area and restore them. Using the query system, the application can load persistent spatial entities from storage. The query system consists of a set of filters to define the spatial entity search query and an operation that needs to be performed on the search results.

In order to enable the functionality of this extension, you must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo::enabledExtensionNames parameter as indicated in the Extensions section.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

• XR_TYPE_SPACE_QUERY_INFO_FB
• XR_TYPE_SPACE_QUERY_RESULTS_FB
• XR_TYPE_SPACE_STORAGE_LOCATION_FILTER_INFO_FB
• XR_TYPE_SPACE_UUID_FILTER_INFO_FB
• XR_TYPE_SPACE_COMPONENT_FILTER_INFO_FB
• XR_TYPE_EVENT_DATA_SPACE_QUERY_RESULTS_AVAILABLE_FB
• XR_TYPE_EVENT_DATA_SPACE_QUERY_COMPLETE_FB

New Enums

typedef enum XrSpaceQueryActionFB {
    XR_SPACE_QUERY_ACTION_LOAD_FB = 0,
    XR_SPACE_QUERY_ACTION_MAX_ENUM_FB = 0x7FFFFFFF
} XrSpaceQueryActionFB;

Specify the type of query being performed.

Enumerant Descriptions

• XR_SPACE_QUERY_ACTION_ACTION_LOAD_FB — Tells the query to perform a load operation on any XrSpace returned by the query.

New Structures

The XrSpaceQueryInfoBaseHeaderFB structure is defined as:

typedef struct XrSpaceQueryInfoBaseHeaderFB {
    XrStructureType    type;
    const void*        next;
} XrSpaceQueryInfoBaseHeaderFB;

Member Descriptions

• type is the XrStructureType of this structure. This base structure itself has no associated XrStructureType value.
• next is NULL or a pointer to the next structure in a structure chain. This base structure itself has no associated XrStructureType value.
The **XrSpaceQueryInfoBaseHeaderFB** is a base structure that is not intended to be directly used, but forms a basis for specific query info types. All query info structures begin with the elements described in the **XrSpaceQueryInfoBaseHeaderFB**, and a query info pointer **must** be cast to a pointer to **XrSpaceQueryInfoBaseHeaderFB** when passing it to the **xrQuerySpacesFB** function.

### Valid Usage (Implicit)

- The **XR_FB_spatial_entity_query** extension **must** be enabled prior to using **XrSpaceQueryInfoBaseHeaderFB**
- **type** **must** be **XR_TYPE_SPACE_QUERY_INFO_FB**
- **next** **must** be **NULL** or a valid pointer to the next structure in a structure chain

The **XrSpaceFilterInfoBaseHeaderFB** structure is defined as:

```c
typedef struct XrSpaceFilterInfoBaseHeaderFB {
    XrStructureType    type;
    const void*        next;
} XrSpaceFilterInfoBaseHeaderFB;
```

### Member Descriptions

- **type** is the **XrStructureType** of this structure.
- **next** is **NULL** or a pointer to the next structure in a structure chain. This base structure itself has no associated **XrStructureType** value.

The **XrSpaceFilterInfoBaseHeaderFB** is a base structure that is not intended to be directly used, but forms a basis for specific filter info types. All filter info structures begin with the elements described in the **XrSpaceFilterInfoBaseHeaderFB**, and a filter info pointer **must** be cast to a pointer to **XrSpaceFilterInfoBaseHeaderFB** when populating **XrSpaceQueryInfoFB::filter** and **XrSpaceQueryInfoFB::excludeFilter** to pass to the **xrQuerySpacesFB** function.
Valid Usage (Implicit)

- The **XR_FB_spatial_entity_query** extension must be enabled prior to using `XrSpaceFilterInfoBaseHeaderFB`
- **type** must be one of the following `XrStructureType` values: `XR_TYPE_SPACE_COMPONENT_FILTER_INFO_FB`, `XR_TYPE_SPACE_UUID_FILTER_INFO_FB`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrSpaceStorageLocationFilterInfoFB`

The **XrSpaceQueryInfoFB** structure is defined as:

```c
typedef struct XrSpaceQueryInfoFB {
    XrStructureType                         type;
    const void*                             next;
    XrSpaceQueryActionFB                    queryAction;
    uint32_t                                maxResultCount;
    XrDuration                              timeout;
    const XrSpaceFilterInfoBaseHeaderFB*    filter;
    const XrSpaceFilterInfoBaseHeaderFB*    excludeFilter;
} XrSpaceQueryInfoFB;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **queryAction** is the type of query to perform.
- **maxResultCount** is the maximum number of entities to be found.
- **timeout** is the number of nanoseconds before the operation should time out. A value of `XR_INFINITE_DURATION` indicates no timeout.
- **filter** is NULL or a pointer to a valid structure based on `XrSpaceFilterInfoBaseHeaderFB`.
- **excludeFilter** is NULL or a pointer to a valid structure based on `XrSpaceFilterInfoBaseHeaderFB`.

May be used to query for spaces and perform a specific action on the spaces returned. The available actions are enumerated in `XrSpaceQueryActionFB`. The filter info provided to the `filter` member of the struct is used as an inclusive filter. The filter info provided to the `excludeFilter` member of the...
structure is used to exclude spaces from the results returned from the filter. All spaces that match the criteria in \texttt{filter}, and that do not match the criteria in \texttt{excludeFilter}, \textbf{must} be included in the results returned. This is to allow for a more selective style query.

### Valid Usage (Implicit)

- The \texttt{XR_FB_spatial_entity_query} extension \textbf{must} be enabled prior to using \texttt{XrSpaceQueryInfoFB}
- \texttt{type} \textbf{must} be \texttt{XR_TYPE_SPACE_QUERY_INFO_FB}
- \texttt{next} \textbf{must} be \texttt{NULL} or a valid pointer to the next structure in a structure chain
- \texttt{queryAction} \textbf{must} be a valid \texttt{XrSpaceQueryActionFB} value
- If \texttt{filter} is not \texttt{NULL}, \texttt{filter} \textbf{must} be a pointer to a valid \texttt{XrSpaceFilterInfoBaseHeaderFB}-based structure. See also: \texttt{XrSpaceComponentFilterInfoFB}, \texttt{XrSpaceUuidFilterInfoFB}
- If \texttt{excludeFilter} is not \texttt{NULL}, \texttt{excludeFilter} \textbf{must} be a pointer to a valid \texttt{XrSpaceFilterInfoBaseHeaderFB}-based structure. See also: \texttt{XrSpaceComponentFilterInfoFB}, \texttt{XrSpaceUuidFilterInfoFB}

The \texttt{XrSpaceStorageLocationFilterInfoFB} structure is defined as:

```c
typedef struct XrSpaceStorageLocationFilterInfoFB {
    XrStructureType             type;
    const void*                 next;
    XrSpaceStorageLocationFB    location;
} XrSpaceStorageLocationFilterInfoFB;
```

### Member Descriptions

- \texttt{type} is the \texttt{XrStructureType} of this structure.
- \texttt{next} is \texttt{NULL} or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- \texttt{location} is the location to limit the query to.

Extends a query filter to limit a query to a specific storage location. Set the \texttt{next} pointer of an \texttt{XrSpaceFilterInfoBaseHeaderFB} to chain this extra filtering functionality.
Valid Usage (Implicit)

- The XR_FB_spatial_entity_query extension must be enabled prior to using XrSpaceStorageLocationFilterInfoFB
- type must be XR_TYPE_SPACE_STORAGE_LOCATION_FILTER_INFO_FB
- next must be NULL or a valid pointer to the next structure in a structure chain
- location must be a valid XrSpaceStorageLocationFB value

The XrSpaceUuidFilterInfoFB structure is defined as:

```c
typedef struct XrSpaceUuidFilterInfoFB {
    XrStructureType type;
    const void* next;
    uint32_t uuidCount;
    XrUuidEXT* uuids;
} XrSpaceUuidFilterInfoFB;
```

Member Descriptions

- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- uuidCount is the number of UUIDs to be matched.
- uuids is an array of XrUuidEXT that contains the UUIDs to be matched.

The XrSpaceUuidFilterInfoFB structure is a filter an application can use to find XrSpace entities that match specified UUIDs, to include or exclude them from a query.
Valid Usage (Implicit)

• The `XR_FB.spatial_entity_query` extension must be enabled prior to using `XrSpaceUuidFilterInfoFB`

• `type` must be `XR_TYPE_SPACE_UUID_FILTER_INFO_FB`

• `next` must be `NULL` or a valid pointer to the next structure in a structure chain

• `uuids` must be a pointer to an array of `uuidCount` `XrUuidEXT` structures

• The `uuidCount` parameter must be greater than 0

The `XrSpaceComponentFilterInfoFB` structure is defined as:

```c
typedef struct XrSpaceComponentFilterInfoFB {
    XrStructureType           type;
    const void*               next;
    XrSpaceComponentTypeFB    componentType;
} XrSpaceComponentFilterInfoFB;
```

Member Descriptions

• `type` is the `XrStructureType` of this structure.

• `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

• `componentType` is the `XrSpaceComponentTypeFB` to query for.

The `XrSpaceComponentFilterInfoFB` structure is a filter an application can use to find `XrSpace` entities which have the `componentType` enabled, to include or exclude them from a query.

Valid Usage (Implicit)

• The `XR_FB.spatial_entity_query` extension must be enabled prior to using `XrSpaceComponentFilterInfoFB`

• `type` must be `XR_TYPE_SPACE_COMPONENT_FILTER_INFO_FB`

• `next` must be `NULL` or a valid pointer to the next structure in a structure chain

• `componentType` must be a valid `XrSpaceComponentTypeFB` value

The `XrSpaceQueryResultFB` structure is defined as:
typedef struct XrSpaceQueryResultFB {
    XrSpace space;
    XrUuidEXT uuid;
} XrSpaceQueryResultFB;

**Member Descriptions**

- **space** is the `XrSpace` handle to the spatial entity found by the query.
- **uuid** is the UUID that identifies the entity.

The `XrSpaceQueryResultFB` structure is a query result returned in the `results` output parameter of the `xrRetrieveSpaceQueryResultsFB` function.

**Valid Usage (Implicit)**

- The `XR_FB_spatial_entity_query` extension must be enabled prior to using `XrSpaceQueryResultFB`

The `XrSpaceQueryResultsFB` structure is defined as:

typedef struct XrSpaceQueryResultsFB {
    XrStructureType type;
    void* next;
    uint32_t resultCapacityInput;
    uint32_t resultCountOutput;
    XrSpaceQueryResultFB* results;
} XrSpaceQueryResultsFB;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **resultCapacityInput** is the capacity of the results array, or 0 to indicate a request to retrieve the required capacity.
- **resultCountOutput** is an output parameter containing the count of results retrieved, or returns the required capacity in the case that resultCapacityInput is insufficient.
- **results** is a pointer to an array of results, but can be NULL if resultCapacityInput is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required results size.

The XrSpaceQueryResultsFB structure is used by the xrRetrieveSpaceQueryResultsFB function to retrieve query results.

Valid Usage (Implicit)

- The XR_FB_spatial_entity_query extension must be enabled prior to using XrSpaceQueryResultsFB
- **type** must be XR_TYPE_SPACE_QUERY_RESULTS_FB
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- If resultCapacityInput is not 0, **results** must be a pointer to an array of resultCapacityInput XrSpaceQueryResultFB structures

The XrEventDataSpaceQueryResultsAvailableFB structure is defined as:

```c
typedef struct XrEventDataSpaceQueryResultsAvailableFB {
    XrStructureType       type;
    const void*           next;
    XrAsyncRequestIdFB    requestId;
} XrEventDataSpaceQueryResultsAvailableFB;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **requestId** is the ID of the asynchronous query request.

It indicates a query request has produced some number of results. If a query yields results this event **must** be delivered before the XrEventDataSpaceQueryCompleteFB event is delivered. Call xrQuerySpacesFB to retrieve those results.

Valid Usage (Implicit)

- The XR_FB_spatial_entity_query extension **must** be enabled prior to using XrEventDataSpaceQueryResultsAvailableFB
- **type** **must** be XR_TYPE_EVENT_DATA_SPACE_QUERY_RESULTS_AVAILABLE_FB
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain

The XrEventDataSpaceQueryCompleteFB structure is defined as:

typedef struct XrEventDataSpaceQueryCompleteFB {
    XrStructureType type;
    const void* next;
    XrAsyncRequestIdFB requestId;
    XrResult result;
} XrEventDataSpaceQueryCompleteFB;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **requestId** is the ID of the asynchronous query request.
- **result** is an XrResult that determines if the request succeeded or if an error occurred.

It indicates a query request has completed and specifies the request result. This event **must** be
delivered when a query has completed, regardless of the number of results found. If any results have been found, then this event must be delivered after any XrEventDataSpaceQueryResultsAvailableFB events have been delivered.

Valid Usage (Implicit)

- The XR_FB.spatial_entity_query extension must be enabled prior to using XrEventDataSpaceQueryCompleteFB
- type must be XR_TYPE_EVENT_DATA_SPACE_QUERY_COMPLETE_FB
- next must be NULL or a valid pointer to the next structure in a structure chain

New Functions

The xrQuerySpacesFB function is defined as:

```c
XrResult xrQuerySpacesFB(
    XrSession session,
    const XrSpaceQueryInfoBaseHeaderFB* info,
    XrAsyncRequestIdFB* requestId);
```

Parameter Descriptions

- session is a handle to an XrSession.
- info is a pointer to the XrSpaceQueryInfoBaseHeaderFB structure.
- requestId is an output parameter, and the variable it points to will be populated with the ID of this asynchronous request.

The xrQuerySpacesFB function enables an application to find and retrieve spatial entities from storage. Cast an XrSpaceQueryInfoFB pointer to a XrSpaceQueryInfoBaseHeaderFB pointer to pass as info. The application should keep the returned requestId for the duration of the request as it is used to refer to the request when calling xrRetrieveSpaceQueryResultsFB and is used to map completion events to the request. This operation is asynchronous and the runtime must post an XrEventDataSpaceQueryCompleteFB event when the operation completes successfully or encounters an error. The runtime must post an XrEventDataSpaceQueryResultsAvailableFB if any results are found. Once an XrEventDataSpaceQueryResultsAvailableFB event has been posted, the application may call xrRetrieveSpaceQueryResultsFB to retrieve the available results.
Valid Usage (Implicit)

- The `XR_FBSpatialEntityQuery` extension **must** be enabled prior to calling `xrQuerySpacesFB`.
- `session` **must** be a valid `XrSession` handle.
- `info` **must** be a pointer to a valid `XrSpaceQueryInfoBaseHeaderFB`-based structure. See also: `XrSpaceQueryInfoFB`.
- `requestId` **must** be a pointer to an `XrAsyncRequestIdFB` value.

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION LOSS_PENDING`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_FEATURE_UNSUPPORTED`

The `xrRetrieveSpaceQueryResultsFB` function is defined as:

```c
XrResult xrRetrieveSpaceQueryResultsFB(
  XrSession                                   session,
  XrAsyncRequestIdFB                          requestId,
  XrSpaceQueryResultsFB*                      results);
```
# Parameter Descriptions

- **session** is the XrSession for which the in-progress query is valid.
- **requestId** is the XrAsyncRequestIdFB to enumerate results for.
- **results** is a pointer to an XrSpaceQueryResultsFB to populate with results.
- See [Buffer Size Parameters](#) chapter for a detailed description of retrieving the required size of the results in this parameter.

Allows an application to retrieve all available results for a specified query. Call this function once to get the number of results found and then once more to copy the results into a buffer provided by the application. The number of results will not change between the two calls used to retrieve results. This function **must** only retrieve each query result once. After the application has used this function to retrieve a query result, the runtime frees its copy. The runtime **must** return XR_ERROR_VALIDATION_FAILURE if **requestId** refers to a request that is not yet complete, a request for which results have already been retrieved, or if **requestId** does not refer to a known request.

## Valid Usage (Implicit)

- The XR_FB_spatial_entity_query extension **must** be enabled prior to calling xrRetrieveSpaceQueryResultsFB
- **session** **must** be a valid XrSession handle
- **results** **must** be a pointer to an XrSpaceQueryResultsFB structure
Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_FEATURE_UNSUPPORTED

Issues

Version History
• Revision 1, 2022-01-22 (John Schofield)
  ◦ Initial draft

12.62. XR_FB_spatial_entity_storage

Name String
XR_FB_spatial_entity_storage

Extension Type
Instance extension

Registered Extension Number
159

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0
• Requires XR_FB_spatial_entity
Overview

This extension enables spatial entities to be stored and persisted across sessions. If the `XR_SPACE_COMPONENT_TYPE_STORABLE_FB` component has been enabled on the spatial entity, application developers may save, load, and erase persisted `XrSpace` entities.

In order to enable the functionality of this extension, you must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo::enabledExtensionNames` parameter as indicated in the Extensions section.

New Object Types

New Flag Types

New Enum Constants

`XrStructureType` enumeration is extended with:

- `XR_TYPE_SPACE_SAVE_INFO_FB`
- `XR_TYPE_SPACE_ERASE_INFO_FB`
- `XR_TYPE_EVENT_DATA_SPACE_SAVE_COMPLETE_FB`
- `XR_TYPE_EVENT_DATA_SPACE_ERASE_COMPLETE_FB`

New Enums

```c
typedef enum XrSpaceStorageLocationFB {
    XR_SPACE_STORAGE_LOCATION_INVALID_FB = 0,
    XR_SPACE_STORAGE_LOCATION_LOCAL_FB = 1,
    XR_SPACE_STORAGE_LOCATION_MAX_ENUM_FB = 0x7FFFFFFF
} XrSpaceStorageLocationFB;
```

The `XrSpaceStorageLocationFB` enumeration contains the storage locations used to store, erase, and query spatial entities.
The XrSpacePersistenceModeFB enumeration specifies the persistence mode for the save operation.

New Structures

The XrSpaceSaveInfoFB structure is defined as:

typedef struct XrSpaceSaveInfoFB {
    XrStructureType              type;
    const void*                  next;
    XrSpace                      space;
    XrSpaceStorageLocationFB     location;
    XrSpacePersistenceModeFB     persistenceMode;
} XrSpaceSaveInfoFB;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **space** is the `XrSpace` handle to the reference space that defines the `poseInSpace` of the entity to be saved.
- **location** is the storage location.
- **persistenceMode** is the persistence mode.

The `XrSpaceSaveInfoFB` structure contains information used to save the spatial entity.

Valid Usage (Implicit)

- The `XR_FB_spatial_entity_storage` extension must be enabled prior to using `XrSpaceSaveInfoFB`
- **type** must be `XR_TYPE_SPACE_SAVE_INFO_FB`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- **space** must be a valid `XrSpace` handle
- **location** must be a valid `XrSpaceStorageLocationFB` value
- **persistenceMode** must be a valid `XrSpacePersistenceModeFB` value

The `XrSpaceEraseInfoFB` structure is defined as:

```c
typedef struct XrSpaceEraseInfoFB {
    XrStructureType             type;
    const void*                 next;
    XrSpace                     space;
    XrSpaceStorageLocationFB    location;
} XrSpaceEraseInfoFB;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **space** is the `XrSpace` handle to the reference space that defines the entity to be erased.
- **location** is the storage location.

The `XrSpaceEraseInfoFB` structure contains information used to erase the spatial entity.

Valid Usage (Implicit)

- The `XR_FB_spatial_entity_storage` extension must be enabled prior to using `XrSpaceEraseInfoFB`.
- **type** must be `XR_TYPE_SPACE_ERASE_INFO_FB`.
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain.
- **space** must be a valid `XrSpace` handle.
- **location** must be a valid `XrSpaceStorageLocationFB` value.

The `XrEventDataSpaceSaveCompleteFB` structure is defined as:

```c
typedef struct XrEventDataSpaceSaveCompleteFB {
    XrStructureType type;
    const void* next;
    XrAsyncRequestIdFB requestId;
    XrResult result;
    XrSpace space;
    XrUuidEXT uuid;
    XrSpaceStorageLocationFB location;
} XrEventDataSpaceSaveCompleteFB;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **requestId** is the ID of the asynchronous request to save an entity.
- **result** is an XrResult that describes whether the request succeeded or if an error occurred.
- **space** is the spatial entity being saved.
- **uuid** is the UUID for the spatial entity being saved.
- **location** is the location of the spatial entity being saved.

The save result event contains the success of the save/write operation to the specified location, as well as the XrSpace handle on which the save operation was attempted on, the unique UUID, and the triggered async request ID from the initial calling function.

Valid Usage (Implicit)

- The XR_FB_spatial_entity_storage extension must be enabled prior to using XrEventDataSpaceSaveCompleteFB
- **type** must be XR_TYPE_EVENT_DATA_SPACE_SAVE_COMPLETE_FB
- **next** must be NULL or a valid pointer to the next structure in a structure chain

The XrEventDataSpaceEraseCompleteFB structure is defined as:

typedef struct XrEventDataSpaceEraseCompleteFB {
    XrStructureType             type;
    const void*                 next;
    XrAsyncRequestIdFB          requestId;
    XrResult                    result;
    XrSpace                     space;
    XrUuidEXT                   uuid;
    XrSpaceStorageLocationFB    location;
} XrEventDataSpaceEraseCompleteFB;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **requestId** is the ID of the asynchronous request to erase an entity.
- **result** is an `XrResult` that describes whether the request succeeded or if an error occurred.
- **space** is the spatial entity being erased.
- **uuid** is the UUID for the spatial entity being erased.
- **location** is the location of the spatial entity being erased.

The erase result event contains the success of the erase operation from the specified storage location. It also provides the UUID of the entity and the async request ID from the initial calling function.

Valid Usage (Implicit)

- The `XR_FB_spatial_entity_storage` extension must be enabled prior to using `XrEventDataSpaceEraseCompleteFB`.
- **type** must be `XR_TYPE_EVENT_DATA_SPACE_ERASE_COMPLETE_FB`.
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain.

New Functions

The `xrSaveSpaceFB` function is defined as:

```c
XrResult xrSaveSpaceFB(
    XrSession session,
    const XrSpaceSaveInfoFB* info,
    XrAsyncRequestIdFB* requestId);
```
Parameter Descriptions

• **session** is a handle to an XrSession.
• **info** contains the parameters for the save operation.
• **requestId** is an output parameter, and the variable it points to will be populated with the ID of this asynchronous request.

The `xrSaveSpaceFB` function persists the spatial entity at the specified location with the specified mode. The runtime **must** return `XR_ERROR_VALIDATION_FAILURE` if `XrSpaceSaveInfoFB::space` is `XR_NULL_HANDLE` or otherwise invalid. The runtime **must** return `XR_ERROR_VALIDATION_FAILURE` if `XrSpaceSaveInfoFB::location` or `XrSpaceSaveInfoFB::persistenceMode` is invalid. This operation is asynchronous and the runtime **must** post an XrEventDataSpaceSaveCompleteFB event when the operation completes successfully or encounters an error.

Valid Usage (Implicit)

• The `XR_FB.spatial_entity_storage` extension **must** be enabled prior to calling `xrSaveSpaceFB`
• **session** **must** be a valid XrSession handle
• **info** **must** be a pointer to a valid XrSpaceSaveInfoFB structure
• **requestId** **must** be a pointer to an XrAsyncRequestIdFB value

Return Codes

**Success**

• `XR_SUCCESS`
• `XR_SESSION_LOSS_PENDING`

**Failure**

• `XR_ERROR_FUNCTION_UNSUPPORTED`
• `XR_ERROR_VALIDATION_FAILURE`
• `XR_ERROR_RUNTIME_FAILURE`
• `XR_ERROR_HANDLE_INVALID`
• `XR_ERROR_INSTANCE_LOST`
• `XR_ERROR_SESSION_LOST`
• `XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB`
• `XR_ERROR_FEATURE_UNSUPPORTED`
The `xrEraseSpaceFB` function is defined as:

```c
XrResult xrEraseSpaceFB(
    XrSession                                   session,
    const XrSpaceEraseInfoFB*                   info,
    XrAsyncRequestIdFB*                         requestId);
```

**Parameter Descriptions**

- `session` is a handle to an `XrSession`.
- `info` contains the parameters for the erase operation.
- `requestId` is an output parameter, and the variable it points to will be populated with the ID of this asynchronous request.

The `xrEraseSpaceFB` function erases a spatial entity from storage at the specified location. The `XrSpace` remains valid in the current session until the application destroys it or the session ends. The runtime must return `XR_ERROR_VALIDATION_FAILURE` if `XrSpaceEraseInfoFB::space` is `XR_NULL_HANDLE` or otherwise invalid. The runtime must return `XR_ERROR_VALIDATION_FAILURE` if `XrSpaceEraseInfoFB::location` is invalid. This operation is asynchronous and the runtime must post an `XrEventDataSpaceEraseCompleteFB` event when the operation completes successfully or encounters an error.

**Valid Usage (Implicit)**

- The `XR_FB_spatial_entity_storage` extension must be enabled prior to calling `xrEraseSpaceFB`
- `session` must be a valid `XrSession` handle
- `info` must be a pointer to a valid `XrSpaceEraseInfoFB` structure
- `requestId` must be a pointer to an `XrAsyncRequestIdFB` value
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_SPACE_COMPONENT_NOT_ENABLED_FB
• XR_ERROR_FEATURE_UNSUPPORTED

Issues

Version History

• Revision 1, 2022-01-22 (John Schofield)
  ◦ Initial draft

12.63. XR_FB_swapchain_update_state

Name String

XR_FB_swapchain_update_state

Extension Type

Instance extension

Registered Extension Number

72

Revision

3

Extension and Version Dependencies

• Requires OpenXR 1.0
Contributors

Cass Everitt, Facebook
Gloria Kennickell, Facebook

Overview

This extension enables the application to modify and query specific mutable state associated with a swapchain.

In order to enable the functionality of this extension, the application must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo::enabledExtensionNames` parameter as indicated in the Extensions section.

New Object Types

New Flag Types

New Enum Constants

New Enums

New Structures

The `XrSwapchainStateBaseHeaderFB` structure is defined as:

```c
typedef struct XrSwapchainStateBaseHeaderFB {
    XrStructureType type;
    void* next;
} XrSwapchainStateBaseHeaderFB;
```

Member Descriptions

- `type` is the `XrStructureType` of this structure. This base structure itself has no associated `XrStructureType` value.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

The `XrSwapchainStateBaseHeaderFB` is a base structure that can be overridden by a specific `XrSwapchainState*` child structure.
Valid Usage (Implicit)

- The `XR_FB_swapchain_update_state` extension must be enabled prior to using `XrSwapchainStateBaseHeaderFB`.
- `type` must be one of the following `XrStructureType` values:
  - `XR_TYPE_SWAPCHAIN_STATE_ANDROID_SURFACE_DIMENSIONS_FB`
  - `XR_TYPE_SWAPCHAIN_STATE_FOVEATION_FB`
  - `XR_TYPE_SWAPCHAIN_STATE_SAMPLER_OPENGL_ES_FB`
  - `XR_TYPE_SWAPCHAIN_STATE_SAMPLER_VULKAN_FB`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain.

New Functions

The `xrUpdateSwapchainFB` function is defined as:

```c
XrResult xrUpdateSwapchainFB(
    XrSwapchain swapchain,
    const XrSwapchainStateBaseHeaderFB* state);
```

Parameter Descriptions

- `swapchain` is the `XrSwapchain` to update state for.
- `state` is a pointer to a `XrSwapchainState` structure based off of `XrSwapchainStateBaseHeaderFB`.

`xrUpdateSwapchainFB` provides support for an application to update specific mutable state associated with an `XrSwapchain`.

Valid Usage (Implicit)

- The `XR_FB_swapchain_update_state` extension must be enabled prior to calling `xrUpdateSwapchainFB`.
- `swapchain` must be a valid `XrSwapchain` handle.
- `state` must be a pointer to a valid `XrSwapchainStateBaseHeaderFB`-based structure. See also:
  - `XrSwapchainStateAndroidSurfaceDimensionsFB`
  - `XrSwapchainStateFoveationFB`
  - `XrSwapchainStateSamplerOpenGLESFB`
  - `XrSwapchainStateSamplerVulkanFB`
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST

The `xrGetSwapchainStateFB` function is defined as:

```c
XrResult xrGetSwapchainStateFB(
    XrSwapchain swapchain,
    XrSwapchainStateBaseHeaderFB* state);
```

Parameter Descriptions

• `swapchain` is the `XrSwapchain` to update state for.
• `state` is a pointer to a `XrSwapchainState` structure based off of `XrSwapchainStateBaseHeaderFB`.

`xrGetSwapchainStateFB` provides support for an application to query specific mutable state associated with an `XrSwapchain`.
**Valid Usage (Implicit)**

- The `XR_FB_swapchain_update_state` extension must be enabled prior to calling `xrGetSwapchainStateFB`.
- `swapchain` must be a valid `XrSwapchain` handle.
- `state` must be a pointer to an `XrSwapchainStateBaseHeaderFB`-based structure. See also: `XrSwapchainStateAndroidSurfaceDimensionsFB`, `XrSwapchainStateFoveationFB`, `XrSwapchainStateSamplerOpenGLESFB`, `XrSwapchainStateSamplerVulkanFB`.

**Return Codes**

**Success**
- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`

**Issues**

- Should we add a method to query the current state?
  - Yes. Given that we allow mutable state to be updated by the application, it is useful to have a query mechanism to get the current state for all state structures.

**Version History**

- Revision 1, 2021-04-16 (Gloria Kennickell)
  - Initial extension description
- Revision 2, 2021-05-13 (Gloria Kennickell)
  - Add mechanism to query current state for all state structures.
- Revision 3, 2021-05-27 (Gloria Kennickell)
  - Move platform and graphics API specific structs into separate extensions.
12.64. XR_FB_swapchain_update_state_android_surface

Name String
XR_FB_swapchain_update_state_android_surface

Extension Type
Instance extension

Registered Extension Number
162

Revision
1

Extension and Version Dependencies
- Requires OpenXR 1.0
- Requires XR_KHR_android_surface_swapchain
- Requires XR_FB_swapchain_update_state

Contributors
Cass Everitt, Facebook
Gloria Kennickell, Facebook

Overview

This extension enables the application to modify and query specific mutable state associated with an Android surface swapchain, examples include:

- A video application may need to update the default size of the image buffers associated with an Android Surface Swapchain.
- A video application may need to communicate a new width and height for an Android Surface Swapchain, as the surface dimensions may be implicitly updated by the producer during the life of the Swapchain. This is important for correct application of the non-normalized imageRect specified via XrSwapchainSubImage.

In order to enable the functionality of this extension, the application must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo enabledExtensionNames parameter as indicated in the Extensions section.

New Object Types

New Flag Types

New Enum Constants
XrStructureType enumeration is extended with:

- XR_TYPE_SWAPCHAIN_STATE_ANDROID_SURFACE_DIMENSIONS_FB

New Enums

New Structures

The XrSwapchainStateAndroidSurfaceDimensionsFB structure is defined as:

```c
typedef struct XrSwapchainStateAndroidSurfaceDimensionsFB {
    XrStructureType type;
    void* next;
    uint32_t width;
    uint32_t height;
} XrSwapchainStateAndroidSurfaceDimensionsFB;
```

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **width** is the width of the image buffer, must not be greater than the graphics API’s maximum limit.
- **height** is the height of the image buffer, must not be greater than the graphics API’s maximum limit.

When XrSwapchainStateAndroidSurfaceDimensionsFB is specified in the call to xrUpdateSwapchainFB, the dimensions provided will be used to update the default size of the image buffers associated with the Android Surface swapchain.

Additionally, the dimensions provided will become the new source of truth for the swapchain width and height, affecting operations such as computing the normalized imageRect for the swapchain.

When XrSwapchainStateAndroidSurfaceDimensionsFB is specified in the call to xrGetSwapchainStateFB, the dimensions will be populated with the current swapchain width and height.

To use XrSwapchainStateAndroidSurfaceDimensionsFB, XR_USE_PLATFORM_ANDROID must be defined before including openxr_platform.h.
Valid Usage (Implicit)

- The `XR_FB_swapchain_update_state_android_surface` extension **must** be enabled prior to using `XrSwapchainStateAndroidSurfaceDimensionsFB`
- **type** must be `XR_TYPE_SWAPCHAIN_STATE_ANDROID_SURFACE_DIMENSIONS_FB`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

New Functions

Issues

Version History

- Revision 1, 2021-05-27 (Gloria Kennickell)
  - Initial draft

12.65. XR_FB_swapchain_update_state_state_opengl_es

Name String

- `XR_FB_swapchain_update_state_opengl_es`

Extension Type

- Instance extension

Registered Extension Number

- 163

Revision

- 1

Extension and Version Dependencies

- Requires OpenXR 1.0
- Requires `XR_KHR_opengl_es_enable`
- Requires `XR_FB_swapchain_update_state`

Contributors

- Cass Everitt, Facebook
- Gloria Kennickell, Facebook

Overview

This extension enables the application to modify and query OpenGL ES-specific mutable state.
associated with a swapchain, examples include:

- On platforms where composition runs in a separate process from the application, swapchains must be created in a cross-process friendly way. In such cases, the texture image memory may be shared between processes, but the texture state may not; and, an explicit mechanism to synchronize this texture state between the application and the compositor is required.

In order to enable the functionality of this extension, the application must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo enabledExtensionNames` parameter as indicated in the Extensions section.

**New Object Types**

**New Flag Types**

**New Enum Constants**

`XrStructureType` enumeration is extended with:

- `XR_TYPE_SWAPCHAIN_STATE_SAMPLER_OPENGL_ES_FB`

**New Enums**

**New Structures**

The `XrSwapchainStateSamplerOpenGLESFB` structure is defined as:

```c
typedef struct XrSwapchainStateSamplerOpenGLESFB {
    XrStructureType type;
    void* next;
    EGLenum minFilter;
    EGLenum magFilter;
    EGLenum wrapModeS;
    EGLenum wrapModeT;
    EGLenum swizzleRed;
    EGLenum swizzleGreen;
    EGLenum swizzleBlue;
    EGLenum swizzleAlpha;
    float maxAnisotropy;
    XrColor4f borderColor;
} XrSwapchainStateSamplerOpenGLESFB;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **minFilter** is a valid Android OpenGL ES `EGLenum`.
- **magFilter** is a valid Android OpenGL ES `EGLenum`.
- **wrapModeS** is a valid Android OpenGL ES `EGLenum`.
- **wrapModeT** is a valid Android OpenGL ES `EGLenum`.
- **swizzleRed** is a valid Android OpenGL ES `EGLenum`.
- **swizzleGreen** is a valid Android OpenGL ES `EGLenum`.
- **swizzleBlue** is a valid Android OpenGL ES `EGLenum`.
- **swizzleAlpha** is a valid Android OpenGL ES `EGLenum`.
- **maxAnisotropy** is a valid float used to represent max anisotropy.
- **borderColor** is an RGBA color to be used as border texels.

When `XrSwapchainStateSamplerOpenGLESFB` is specified in the call to `xrUpdateSwapchainFB`, texture sampler state for all images in the `XrSwapchain` will be updated for both the application and compositor processes.

For most cases, the sampler state update is only required compositor-side, as that is where the swapchain images are sampled. For completeness, the application-side sampler state is additionally updated to support cases where the application may choose to directly sample the swapchain images.

Applications are expected to handle synchronization of the sampler state update with application-side rendering. Similarly, the compositor will synchronize the sampler state update with rendering of the next compositor frame.

An `EGLContext`, either the `EGLContext` bound during `XrSwapchain` creation or an `EGLContext` in the same share group, is required to be bound on the application calling thread. Current texture bindings may be altered by the call, including the active texture.

When `XrSwapchainStateSamplerOpenGLESFB` is specified in the call to `xrGetSwapchainStateFB`, the sampler state will be populated with the current swapchain sampler state.

To use `XrSwapchainStateSamplerOpenGLESFB`, `XR_USE_GRAPHICS_API_OPENGL_ES` must be defined before including `openxr_platform.h`. 
Valid Usage (Implicit)

- The `XR_FB_swapchain_update_state_opengl_es` extension **must** be enabled prior to using `XrSwapchainStateSamplerOpenGLESFB`
- `type` **must** be `XR_TYPE_SWAPCHAIN_STATE_SAMPLER_OPENGL_ES_FB`
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain
- `minFilter` **must** be a valid `EGLenum` value
- `magFilter` **must** be a valid `EGLenum` value
- `wrapModeS` **must** be a valid `EGLenum` value
- `wrapModeT` **must** be a valid `EGLenum` value
- `swizzleRed` **must** be a valid `EGLenum` value
- `swizzleGreen` **must** be a valid `EGLenum` value
- `swizzleBlue` **must** be a valid `EGLenum` value
- `swizzleAlpha` **must** be a valid `EGLenum` value

New Functions

Issues

Version History

- Revision 1, 2021-05-27 (Gloria Kennickell)
  - Initial draft

12.66. XR_FB_swapchain_update_state_state_vulkan

Name String

- `XR_FB_swapchain_update_state_state_vulkan`

Extension Type

- Instance extension

Registered Extension Number

- 164

Revision

- 1

Extension and Version Dependencies

- Requires OpenXR 1.0
Requires `XR_KHR_vulkan_enable`
Requires `XR_FB_swapchain_update_state`

Contributors
Cass Everitt, Facebook
Gloria Kennickell, Facebook

Overview
This extension enables the application to modify and query Vulkan-specific mutable state associated with a swapchain, examples include:

- On platforms where composition runs in a separate process from the application, swapchains must be created in a cross-process friendly way. In such cases, the texture image memory may be shared between processes, but the texture state may not; and, an explicit mechanism to synchronize this texture state between the application and the compositor is required.

In order to enable the functionality of this extension, the application must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo enabledExtensionNames` parameter as indicated in the Extensions section.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

- `XR_TYPE_SWAPCHAIN_STATE_SAMPLER_VULKAN_FB`

New Enums

New Structures

The `XrSwapchainStateSamplerVulkanFB` structure is defined as:
typedef struct XrSwapchainStateSamplerVulkanFB {
    XrStructureType         type;
    void*                   next;
    VkFilter                minFilter;
    VkFilter                magFilter;
    VkSamplerMipmapMode     mipmapMode;
    VkSamplerAddressMode    wrapModeS;
    VkSamplerAddressMode    wrapModeT;
    VkComponentSwizzle      swizzleRed;
    VkComponentSwizzle      swizzleGreen;
    VkComponentSwizzle      swizzleBlue;
    VkComponentSwizzle      swizzleAlpha;
    float                   maxAnisotropy;
    XrColor4f               borderColor;
} XrSwapchainStateSamplerVulkanFB;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **minFilter** is a valid Vulkan VkFilter.
- **magFilter** is a valid Vulkan VkFilter.
- **mipmapMode** is a valid Vulkan VkSamplerMipmapMode.
- **wrapModeS** is a valid Vulkan VkSamplerAddressMode.
- **wrapModeT** is a valid Vulkan VkSamplerAddressMode.
- **swizzleRed** is a valid Vulkan VkComponentSwizzle.
- **swizzleGreen** is a valid Vulkan VkComponentSwizzle.
- **swizzleBlue** is a valid Vulkan VkComponentSwizzle.
- **swizzleAlpha** is a valid Vulkan VkComponentSwizzle.
- **maxAnisotropy** is a valid float used to represent max anisotropy.
- **borderColor** is an RGBA color to be used as border texels.

When XrSwapchainStateSamplerVulkanFB is specified in the call to xrUpdateSwapchainFB, texture sampler state for all images in the XrSwapchain will be updated for the compositor process. For most cases, the sampler state update is only required compositor-side, as that is where the swapchain images are sampled. If the application requires sampling of the swapchain images, the application will be responsible for updating the texture state using normal Vulkan mechanisms and synchronizing appropriately with application-side rendering.
When `XrSwapchainStateSamplerVulkanFB` is specified in the call to `xrGetSwapchainStateFB`, the sampler state will be populated with the current swapchain sampler state.

To use `XrSwapchainStateSamplerVulkanFB`, `XR_USE_GRAPHICS_API_VULKAN` must be defined before including `openxr_platform.h`.

### Valid Usage (Implicit)

- The `XR_FB_swapchain_update_state_vulkan` extension **must** be enabled prior to using `XrSwapchainStateSamplerVulkanFB`
- `type` **must** be `XR_TYPE_SWAPCHAIN_STATE_SAMPLER_VULKAN_FB`
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain
- `minFilter` **must** be a valid `VkFilter` value
- `magFilter` **must** be a valid `VkFilter` value
- `mipmapMode` **must** be a valid `VkSamplerMipmapMode` value
- `wrapModeS` **must** be a valid `VkSamplerAddressMode` value
- `wrapModeT` **must** be a valid `VkSamplerAddressMode` value
- `swizzleRed` **must** be a valid `VkComponentSwizzle` value
- `swizzleGreen` **must** be a valid `VkComponentSwizzle` value
- `swizzleBlue` **must** be a valid `VkComponentSwizzle` value
- `swizzleAlpha` **must** be a valid `VkComponentSwizzle` value

### New Functions

### Issues

### Version History

- Revision 1, 2021-05-27 (Gloria Kennickell)
  - Initial draft

### 12.67. XR_FB_triangle_mesh

#### Name String

`XR_FB_triangle_mesh`

#### Extension Type

Instance extension
Overview

Meshes may be useful in XR applications when representing parts of the environment. In particular, application may provide the surfaces of real-world objects tagged manually to the runtime, or obtain automatically detected environment contents.

This extension allows:

• An application to create a triangle mesh and specify the mesh data.
• An application to update mesh contents if a mesh is mutable.

In order to enable the functionality of this extension, the application must pass the name of the extension into `xrCreateInstance` via the `XrInstanceCreateInfo::enabledExtensionNames` parameter as indicated in the Extensions section.

New Object Types

```c
XR_DEFINE_HANDLE(XrTriangleMeshFB)
```

`XrTriangleMeshFB` represents a triangle mesh with its corresponding mesh data: a vertex buffer and an index buffer.

New Flag Types

```c
typedef XrFlags64 XrTriangleMeshFlagsFB;
```
// Flag bits for XrTriangleMeshFlagsFB
static const XrTriangleMeshFlagsFB XR_TRIANGLE_MESH_MUTABLE_BIT_FB = 0x00000001;

**Flag Descriptions**

- **XR_TRIANGLE_MESH_MUTABLE_BIT_FB** — The triangle mesh is mutable (can be modified after it is created).

**New Enum Constants**

XrStructureType enumeration is extended with:

- **XR_TYPE_TRIANGLE_MESH_CREATE_INFO_FB**

**New Enums**

Applications may specify the triangle winding order of a mesh - whether the vertices of an outward-facing side of a triangle appear in clockwise or counter-clockwise order - using XrWindingOrderFB enumeration.

```c
typedef enum XrWindingOrderFB {
    XR_WINDING_ORDER_UNKNOWN_FB = 0,
    XR_WINDING_ORDER_CW_FB = 1,
    XR_WINDING_ORDER_CCW_FB = 2,
    XR_WINDING_ORDER_MAX_ENUM_FB = 0x7FFFFFFF
} XrWindingOrderFB;
```

**Enumerant Descriptions**

- **XR_WINDING_ORDER_UNKNOWN_FB** — Winding order is unknown and the runtime cannot make any assumptions on the triangle orientation
- **XR_WINDING_ORDER_CW_FB** — Clockwise winding order
- **XR_WINDING_ORDER_CCW_FB** — Counter-clockwise winding order

**New Structures**

XrTriangleMeshCreateInfoFB must be provided when calling xrCreateTriangleMeshFB.
The `XrTriangleMeshCreateInfoFB` structure is defined as:

```c
typedef struct XrTriangleMeshCreateInfoFB {
    XrStructureType          type;
    const void*              next;
    XrTriangleMeshFlagsFB    flags;
    XrWindingOrderFB         windingOrder;
    uint32_t                 vertexCount;
    const XrVector3f*        vertexBuffer;
    uint32_t                 triangleCount;
    const uint32_t*          indexBuffer;
} XrTriangleMeshCreateInfoFB;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **flags** is a bitmask of `XrTriangleMeshFlagBitsFB` that specify behavior.
- **windingOrder** is the `XrWindingOrderFB` value defining the winding order of the mesh triangles.
- **vertexCount** is the number of vertices in the mesh. In the case of the mutable mesh, the value is treated as the maximum number of vertices the mesh will be able to represent at any time in its lifecycle. The actual number of vertices can vary and is defined when `xrTriangleMeshEndUpdateFB` is called.
- **vertexBuffer** is a pointer to the vertex data. The size of the array must be `vertexCount` elements. When the mesh is mutable `((flags & XR_TRIANGLE_MESH_MUTABLE_BIT_FB) != 0)`, the `vertexBuffer` parameter **must** be `NULL` and mesh data **must** be populated separately.
- **triangleCount** is the number of triangles in the mesh. In the case of the mutable mesh, the value is treated as the maximum number of triangles the mesh will be able to represent at any time in its lifecycle. The actual number of triangles can vary and is defined when `xrTriangleMeshEndUpdateFB` is called.
- **indexBuffer** the triangle indices. The size of the array must be `triangleCount` elements. When the mesh is mutable `((flags & XR_TRIANGLE_MESH_MUTABLE_BIT_FB) != 0)`, the `indexBuffer` parameter **must** be `NULL` and mesh data **must** be populated separately.

Mesh buffers can be updated between `xrTriangleMeshBeginUpdateFB` and `xrTriangleMeshEndUpdateFB` calls.
If the mesh is non-mutable, `vertexBuffer` must be a pointer to an array of `vertexCount` `XrVector3f` structures. If the mesh is non-mutable, `indexBuffer` must be a pointer to an array of `3 * triangleCount` `uint32_t` vertex indices.

### Valid Usage (Implicit)

- The `XR_FB_triangle_mesh` extension must be enabled prior to using `XrTriangleMeshCreateInfoFB`
- `type` must be `XR_TYPE_TRIANGLE_MESH_CREATE_INFO_FB`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `flags` must be `0` or a valid combination of `XrTriangleMeshFlagBitsFB` values
- `windingOrder` must be a valid `XrWindingOrderFB` value

### Mutable Mesh Update States

Mutable meshes have a state machine controlling how they may be updated.

![Mutable Triangle Mesh States Diagram](image)

**Figure 8. Mutable Triangle Mesh States**

The states are as follows:
Undefined Topology
The default state immediately after creation of a mutable mesh. Move to Defining Topology by calling xrTriangleMeshBeginUpdateFB.

Defining Topology
The application must set the initial vertex buffer and index buffer before moving to Ready by calling xrTriangleMeshEndUpdateFB.

Ready
In this state, the buffer contents/size must not be modified. To move to Updating Mesh call xrTriangleMeshBeginUpdateFB. To move to Updating Vertices call xrTriangleMeshBeginVertexBufferUpdateFB.

Updating Mesh
The application may modify the vertex buffer contents and/or the vertex count. The application may modify the index buffer contents and/or the index buffer element count. Move to Ready and commit changes by calling xrTriangleMeshEndUpdateFB.

Updating Vertices
The application may modify the vertex buffer contents, but not the vertex count. Move to Ready and commit changes by calling xrTriangleMeshEndVertexBufferUpdateFB.

New Functions
The xrCreateTriangleMeshFB function is defined as:

```
XrResult xrCreateTriangleMeshFB(
    XrSession session,
    const XrTriangleMeshCreateInfoFB* createInfo,
    XrTriangleMeshFB* outTriangleMesh);
```

Parameter Descriptions
- **session** is the XrSession to which the mesh will belong.
- **createInfo** is a pointer to an XrTriangleMeshCreateInfoFB structure containing parameters to be used to create the mesh.
- **outTriangleMesh** is a pointer to a handle in which the created XrTriangleMeshFB is returned.

This creates an XrTriangleMeshFB handle. The returned triangle mesh handle may be subsequently used in API calls.
When the mesh is mutable (the `XR_TRIANGLE_MESH_MUTABLE_BIT_FB` bit is set in `createInfo→flags`), the created triangle mesh starts in the **Undefined Topology** state.

Immutable meshes have no state machine; they may be considered to be in state **Ready** with no valid edges leaving that state.

### Valid Usage (Implicit)
- The `XR_FB_triangle_mesh` extension **must** be enabled prior to calling `xrCreateTriangleMeshFB`
- `session` **must** be a valid `XrSession` handle
- `createInfo` **must** be a pointer to a valid `XrTriangleMeshCreateInfoFB` structure
- `outTriangleMesh` **must** be a pointer to an `XrTriangleMeshFB` handle

### Return Codes

**Success**
- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_LIMIT_REACHED`
- `XR_ERROR_INSUFFICIENT_RESOURCES_PASSTHROUGH_FB`
- `XR_ERROR_FEATURE_UNSUPPORTED`

The `xrDestroyTriangleMeshFB` function is defined as:

```c
XrResult xrDestroyTriangleMeshFB(  XrTriangleMeshFB  mesh);
```
Parameter Descriptions

- `mesh` is the `XrTriangleMeshFB` to destroy.

**XrTriangleMeshFB** handles and their associated data are destroyed by `xrDestroyTriangleMeshFB`. The mesh buffers retrieved by `xrTriangleMeshGetVertexBufferFB` and `xrTriangleMeshGetIndexBufferFB` must not be accessed anymore after their parent mesh object has been destroyed.

Valid Usage (Implicit)

- The `XR_FB_triangle_mesh` extension must be enabled prior to calling `xrDestroyTriangleMeshFB`
- `mesh` must be a valid `XrTriangleMeshFB` handle

Thread Safety

- Access to `mesh`, and any child handles, must be externally synchronized
- Access to the buffers returned from calls to `xrTriangleMeshGetVertexBufferFB` and `xrTriangleMeshGetIndexBufferFB` on `mesh` must be externally synchronized

Return Codes

**Success**

- XR_SUCCESS

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_FEATURE_UNSUPPORTED

The `xrTriangleMeshGetVertexBufferFB` function is defined as:
XrResult xrTriangleMeshGetVertexBufferFB(
    XrTriangleMeshFB mesh,
    XrVector3f** outVertexBuffer);

Parameter Descriptions

- **mesh** is the XrTriangleMeshFB to get the vertex buffer for.
- **outVertexBuffer** is a pointer to return the vertex buffer into.

Retrieves a pointer to the vertex buffer. The vertex buffer is structured as an array of XrVector3f. The size of the buffer is XrTriangleMeshCreateInfoFB::vertexCount elements. The buffer location is guaranteed to remain constant over the lifecycle of the mesh object.

A mesh **must** be mutable and in a specific state for the application to modify it through the retrieved vertex buffer.

- A mutable triangle mesh **must** be in state Defining Topology, Updating Mesh, or Updating Vertices to modify the contents of the vertex buffer retrieved by this function.
- A mutable triangle mesh **must** be in state Defining Topology or Updating Mesh to modify the count of elements in the vertex buffer retrieved by this function. The new count is passed as a parameter to xrTriangleMeshEndUpdateFB.

Valid Usage (Implicit)

- The XR_FB_triangle_mesh extension **must** be enabled prior to calling xrTriangleMeshGetVertexBufferFB
- **mesh** must be a valid XrTriangleMeshFB handle
- **outVertexBuffer** must be a pointer to a pointer to an XrVector3f structure
## Return Codes

### Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

### Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_FEATURE_UNSUPPORTED

The `xrTriangleMeshGetIndexBufferFB` function is defined as:

```c
XrResult xrTriangleMeshGetIndexBufferFB(
    XrTriangleMeshFB mesh,
    uint32_t** outIndexBuffer);
```

### Parameter Descriptions
- **mesh** is the `XrTriangleMeshFB` to get the index buffer for.
- **outIndexBuffer** is a pointer to return the index buffer into.

Retrieves a pointer to the index buffer that defines the topology of the triangle mesh. Each triplet of consecutive elements points to three vertices in the vertex buffer and thus form a triangle. The size of the buffer is `XrTriangleMeshCreateInfoFB::indexCount` elements. The buffer location is guaranteed to remain constant over the lifecycle of the mesh object.

A triangle mesh **must** be mutable and in state **Defining Topology** or **Updating Mesh** for the application to **modify** the contents and/or triangle count in the index buffer retrieved by this function.
Valid Usage (Implicit)

- The `XR_FB_triangle_mesh` extension must be enabled prior to calling `xrTriangleMeshGetIndexBufferFB`
- `mesh` must be a valid `XrTriangleMeshFB` handle
- `outIndexBuffer` must be a pointer to a pointer to a `uint32_t` value

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_FEATURE_UNSUPPORTED`

The `xrTriangleMeshBeginUpdateFB` function is defined as:

```c
XrResult xrTriangleMeshBeginUpdateFB(
    XrTriangleMeshFB mesh);
```

Parameter Descriptions

- `mesh` is the `XrTriangleMeshFB` to update.

Begins updating the mesh buffer data. The application must call this function before it makes any modifications to the buffers retrieved by `xrTriangleMeshGetVertexBufferFB` and `xrTriangleMeshGetIndexBufferFB`. If only the vertex buffer contents need to be updated, and the mesh is in state `[fb_triangle_mesh_ready]`, `xrTriangleMeshBeginVertexBufferUpdateFB` may be used instead.
To commit the modifications, the application must call `xrTriangleMeshEndUpdateFB`.

The triangle mesh must be mutable. The runtime must return `XR_ERROR_VALIDATION_FAILURE` if the mesh is immutable.

The triangle mesh must be in state `[fb_triangle_mesh_topology_undefined]` or `[fb_triangle_mesh_ready]`.

- If the triangle mesh is in state `[fb_triangle_mesh_topology_undefined]` before this call, a successful call moves it to state Defining Topology.
- If the triangle mesh is in state `[fb_triangle_mesh_ready]` before this call, a successful call moves it to state Updating Mesh.

### Valid Usage (Implicit)

- The `XR_FB_triangle_mesh` extension must be enabled prior to calling `xrTriangleMeshBeginUpdateFB`
- mesh must be a valid XrTriangleMeshFB handle

### Return Codes

**Success**
- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_FEATURE_UNSUPPORTED`
- `XR_ERROR_CALL_ORDER_INVALID`

The `xrTriangleMeshEndUpdateFB` function is defined as:
XrResult xrTriangleMeshEndUpdateFB(
    XrTriangleMeshFB mesh,
    uint32_t vertexCount,
    uint32_t triangleCount);

**Parameter Descriptions**

- **mesh** is the XrTriangleMeshFB to update.
- **vertexCount** is the vertex count after the update.
- **triangleCount** is the triangle count after the update.

Signals to the runtime that the application has finished initially populating or updating the mesh buffers. **vertexCount** and **triangleCount** specify the actual number of primitives that make up the mesh after the update. They **must** be larger than zero but smaller or equal to the maximum counts defined at create time. The runtime **must** return XR_ERROR_VALIDATION_FAILURE if an invalid count is passed.

The triangle mesh **mesh** **must** be mutable. The runtime **must** return XR_ERROR_VALIDATION_FAILURE if the mesh is immutable.

The triangle mesh **mesh** **must** be in state Defining Topology or Updating Mesh.

A successful call moves **mesh** to state [fb_triangle_mesh_ready].

**Valid Usage (Implicit)**

- The XR_FB_triangle_mesh extension **must** be enabled prior to calling xrTriangleMeshEndUpdateFB
- **mesh** **must** be a valid XrTriangleMeshFB handle
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_FEATURE_UNSUPPORTED
- XR_ERROR_CALL_ORDER_INVALID

The `xrTriangleMeshBeginVertexBufferUpdateFB` function is defined as:

```c
XrResult xrTriangleMeshBeginVertexBufferUpdateFB(
    XrTriangleMeshFB mesh,
    uint32_t* outVertexCount);
```

Parameter Descriptions

- `mesh` is the `XrTriangleMeshFB` to update.
- `outVertexCount` is a pointer to a value to populate with the current vertex count. The updated data must have the exact same number of vertices.

Begins an update of the vertex positions of a mutable triangle mesh. The vertex count returned through `outVertexCount` is defined by the last call to `xrTriangleMeshEndUpdateFB`. Once the modification is done, call `xrTriangleMeshEndVertexBufferUpdateFB` to commit the changes and move to state `[fb_triangle_mesh_ready]`.

The triangle mesh `mesh` must be mutable. The runtime must return `XR_ERROR_VALIDATION_FAILURE` if the mesh is immutable.

The triangle mesh `mesh` must be in state `[fb_triangle_mesh_ready]`. 
A successful call moves mesh to state Updating Vertices.

Valid Usage (Implicit)

- The XR_FB_triangle_mesh extension must be enabled prior to calling xrTriangleMeshBeginVertexBufferUpdateFB
- mesh must be a valid XrTriangleMeshFB handle
- outVertexCount must be a pointer to a uint32_t value

Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_FEATURE_UNSUPPORTED
- XR_ERROR_CALL_ORDER_INVALID

The xrTriangleMeshEndVertexBufferUpdateFB function is defined as:

```c
XrResult xrTriangleMeshEndVertexBufferUpdateFB(
    XrTriangleMeshFB mesh);
```

Parameter Descriptions

- mesh is the XrTriangleMeshFB to update.
to `xrTriangleMeshBeginVertexBufferUpdateFB`.

The triangle mesh must be mutable. The runtime must return `XR_ERROR_VALIDATION_FAILURE` if the mesh is immutable.

The triangle mesh must be in state `Updating Vertices`.

A successful call moves mesh to state `[fb_triangle_mesh_ready]`.

**Valid Usage (Implicit)**

- The `XR_FB_triangle_mesh` extension must be enabled prior to calling `xrTriangleMeshEndVertexBufferUpdateFB`
- mesh must be a valid `XrTriangleMeshFB` handle

**Return Codes**

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_FEATURE_UNSUPPORTED`
- `XR_ERROR_CALL_ORDER_INVALID`

**Issues**

**Version History**

- Revision 1, 2021-09-01 (Anton Vaneev)
  - Initial extension description
- Revision 2, 2022-01-07 (Ryan Pavlik, Collabora, Ltd.)
  - Add a state diagram to clarify valid usage, and allow `XR_ERROR_CALL_ORDER_INVALID`.
12.68. XR_HTC_facial_tracking

Name String
XR_HTC_facial_tracking

Extension Type
Instance extension

Registered Extension Number
105

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2021-12-16

IP Status
No known IP claims.

Contributors
Kyle Chen, HTC
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Overview
This extension allows an application to track and integrate users' eye and lip movements, empowering developers to read intention and model facial expressions.

Inspect system capability

XrSystemFacialTrackingPropertiesHTC is defined as:

```c
typedef struct XrSystemFacialTrackingPropertiesHTC {
    XrStructureType    type;
    void*              next;
    XrBool32           supportEyeFacialTracking;
    XrBool32           supportLipFacialTracking;
} XrSystemFacialTrackingPropertiesHTC;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **supportEyeFacialTracking** indicates if the current system is capable of generating eye expressions.
- **supportLipFacialTracking** indicates if the current system is capable of generating lip expressions.

An application **can** inspect whether the system is capable of two of the facial tracking by extending the `XrSystemProperties` with `XrSystemFacialTrackingPropertiesHTC` structure when calling `xrGetSystemProperties`.

Valid Usage (Implicit)

- The `XR_HTC_facial_tracking` extension **must** be enabled prior to using `XrSystemFacialTrackingPropertiesHTC`
- **type** **must** be `XR_TYPE_SYSTEM_FACIAL_TRACKING_PROPERTIES_HTC`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain

If a runtime returns `XR_FALSE` for `supportEyeFacialTracking`, the runtime **must** return `XR_ERROR_FEATURE_UNSUPPORTED` from `xrCreateFacialTrackerHTC` with `XR_FACIAL_TRACKING_TYPE_EYE_DEFAULT_HTC` set for `XrFacialTrackingTypeHTC` in `XrFacialTrackerCreateInfoHTC`. Similarly, if a runtime returns `XR_FALSE` for `supportLipFacialTracking` the runtime **must** return `XR_ERROR_FEATURE_UNSUPPORTED` from `xrCreateFacialTrackerHTC` with `XR_FACIAL_TRACKING_TYPE_LIP_DEFAULT_HTC` set for `XrFacialTrackingTypeHTC` in `XrFacialTrackerCreateInfoHTC`.

Create a facial tracker handle

The `XrFacialTrackerHTC` handle represents the resources for an facial tracker of the specific facial tracking type.

```c
XR_DEFINE_HANDLE(XrFacialTrackerHTC)
```

An application creates separate `XrFacialTrackerHTC` handles for eye tracker or lip tracker. This handle can be used to retrieve corresponding facial expressions using `xrGetFacialExpressionsHTC` function.
The `xrCreateFacialTrackerHTC` function is defined as

```c
XrResult xrCreateFacialTrackerHTC(
    XrSession                                   session,
    const XrFacialTrackerCreateInfoHTC*         createInfo,
    XrFacialTrackerHTC*                         facialTracker);
```

### Parameter Descriptions

- **session** is an `XrSession` in which the facial expression will be active.
- **createInfo** is the `XrFacialTrackerCreateInfoHTC` used to specify the facial tracking type.
- **facialTracker** is the returned `XrFacialTrackerHTC` handle.

An application **can** create an `XrFacialTrackerHTC` handle using `xrCreateFacialTrackerHTC`.

If the system does not support eye tracking or lip tracking, runtime **must** return `XR_ERROR_FEATURE_UNSUPPORTED` from `xrCreateFacialTrackerHTC` according to the corresponding case. In this case, the runtime **must** return `XR_FALSE` for `supportEyeFacialTracking` or `supportLipFacialTracking` in `XrSystemFacialTrackingPropertiesHTC` when the function `xrGetSystemProperties` is called, so that the application **may** avoid creating a facial tracker.

### Valid Usage (Implicit)

- The `XR_HTC_facial_tracking` extension **must** be enabled prior to calling `xrCreateFacialTrackerHTC`
- **session** **must** be a valid `XrSession` handle
- **createInfo** **must** be a pointer to a valid `XrFacialTrackerCreateInfoHTC` structure
- **facialTracker** **must** be a pointer to an `XrFacialTrackerHTC` handle
Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_LIMIT_REACHED
• XR_ERROR_FEATURE_UNSUPPORTED

The XrFacialTrackerCreateInfoHTC structure is defined as:

typedef struct XrFacialTrackerCreateInfoHTC {
  XrStructureType type;
  const void* next;
  XrFacialTrackingTypeHTC facialTrackingType;
} XrFacialTrackerCreateInfoHTC;

Member Descriptions

• type is the XrStructureType of this structure.
• next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
• facialTrackingType is an XrFacialTrackingTypeHTC which describes which type of facial tracking should be used for this handle.

The XrFacialTrackerCreateInfoHTC structure describes the information to create an XrFacialTrackerHTC handle.
Valid Usage (Implicit)

- The XR_HTC_facial_tracking extension must be enabled prior to using XrFacialTrackerCreateInfoHTC
- type must be XR_TYPE_FACIAL_TRACKER_CREATE_INFO_HTC
- next must be NULL or a valid pointer to the next structure in a structure chain
- facialTrackingType must be a valid XrFacialTrackingTypeHTC value

The XrFacialTrackingTypeHTC describes which type of tracking the XrFacialTrackerHTC is using.

typedef enum XrFacialTrackingTypeHTC {
    XR_FACIAL_TRACKING_TYPE_EYE_DEFAULT_HTC = 1,
    XR_FACIAL_TRACKING_TYPE_LIP_DEFAULT_HTC = 2,
    XR_FACIAL_TRACKING_TYPE_MAX_ENUM_HTC = 0x7FFFFFFF
} XrFacialTrackingTypeHTC;

Enumerant Descriptions

- XR_FACIAL_TRACKING_TYPE_EYE_DEFAULT_HTC — Specifies this handle will observe eye expressions, with values indexed by XrEyeExpressionHTC whose count is XR_FACIAL_EXPRESSION_EYE_COUNT_HTC.
- XR_FACIAL_TRACKING_TYPE_LIP_DEFAULT_HTC — Specifies this handle will observe lip expressions, with values indexed by XrLipExpressionHTC whose count is XR_FACIAL_EXPRESSION_LIP_COUNT_HTC.

The xrDestroyFacialTrackerHTC function is defined as:

XrResult xrDestroyFacialTrackerHTC( XrFacialTrackerHTC facialTracker);

Parameter Descriptions

- facialTracker is an XrFacialTrackerHTC previously created by xrCreateFacialTrackerHTC.

xrDestroyFacialTrackerHTC releases the facialTracker and the underlying resources when finished
with facial tracking experiences.

**Valid Usage (Implicit)**

- The `XR_HTC_facial_tracking` extension must be enabled prior to calling `xrDestroyFacialTrackerHTC`
- `facialTracker` must be a valid `XrFacialTrackerHTC` handle

**Thread Safety**

- Access to `facialTracker`, and any child handles, must be externally synchronized

**Return Codes**

**Success**

- `XR_SUCCESS`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_HANDLE_INVALID`

**Retrieve facial expressions**

The `xrGetFacialExpressionsHTC` function is defined as:

```c
XrResult xrGetFacialExpressionsHTC(
    XrFacialTrackerHTC facialTracker,
    XrFacialExpressionsHTC* facialExpressions);
```

**Parameter Descriptions**

- `facialTracker` is an `XrFacialTrackerHTC` previously created by `xrCreateFacialTrackerHTC`.
- `facialExpressions` is a pointer to `XrFacialExpressionsHTC` receiving the returned facial expressions.

`xrGetFacialExpressionsHTC` retrieves an array of values of blend shapes for a facial expression on a given time.
Valid Usage (Implicit)

• The XR_HTC_facial_tracking extension must be enabled prior to calling xrGetFacialExpressionsHTC

• facialTracker must be a valid XrFacialTrackerHTC handle

• facialExpressions must be a pointer to an XrFacialExpressionsHTC structure

Return Codes

Success

• XR_SUCCESS

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED

• XR_ERROR_VALIDATION_FAILURE

• XR_ERROR_RUNTIME_FAILURE

• XR_ERROR_HANDLE_INVALID

• XR_ERROR_INSTANCE_LOST

• XR_ERROR_TIME_INVALID

The XrFacialExpressionsHTC structure is defined as:

typedef struct XrFacialExpressionsHTC {
    XrStructureType     type;
    const void*         next;
    XrBool32             isActive;
    XrTime               sampleTime;
    uint32_t             expressionCount;
    float*               expressionWeightings;
} XrFacialExpressionsHTC;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **isActive** is an XrBool32 indicating if the facial tracker is active.
- **sampleTime** is when in time the expression is expressed.
- **expressionCount** is a uint32_t describing the count of elements in expressionWeightings array.
- **expressionWeightings** is a float array filled in by the runtime, specifying the weightings for each blend shape.

XrFacialExpressionsHTC structure returns data of a lip facial expression or an eye facial expression.

An application **must** preallocate the output expressionWeightings array that can contain at least expressionCount of float. expressionCount **must** be at least XR_FACIAL_EXPRESSION_LIP_COUNT_HTC for XR_FACIAL_TRACKING_TYPE_LIP_DEFAULT_HTC, and at least XR_FACIAL_EXPRESSION_EYE_COUNT_HTC for XR_FACIAL_TRACKING_TYPE_EYE_DEFAULT_HTC.

The application **must** set expressionCount as described by the XrFacialTrackingTypeHTC when creating the XrFacialTrackerHTC otherwise the runtime **must** return XR_ERROR_VALIDATION_FAILURE.

The runtime **must** update the expressionWeightings array ordered so that the application can index elements using the corresponding facial tracker enum (e.g. XrEyeExpressionHTC or XrLipExpressionHTC) as described by XrFacialTrackingTypeHTC when creating the XrFacialTrackerHTC. For example, when the XrFacialTrackerHTC is created with facialTrackingType set to XR_FACIAL_TRACKING_TYPE_EYE_DEFAULT_HTC, the application **must** set the expressionCount to XR_FACIAL_EXPRESSION_EYE_COUNT_HTC, and the runtime **must** fill the expressionWeightings array ordered with eye expression data so that it can be indexed by the XrEyeExpressionHTC enum.

If the returned isActive is true, the runtime **must** fill the expressionWeightings array ordered.

If the returned isActive is false, it indicates the facial tracker did not detect the corresponding facial input or the application lost input focus.

If the input expressionCount is not sufficient to contain all output indices, the runtime **must** return XR_ERROR_SIZE_INSUFFICIENT on calls to xrGetFacialExpressionsHTC and not change the content in expressionWeightings.
Valid Usage (Implicit)

- The XR_HTC_facial_tracking extension must be enabled prior to using XrFacialExpressionsHTC.
- type must be XR_TYPE_FACIAL_EXPRESSIONS_HTC
- next must be NULL or a valid pointer to the next structure in a structure chain
- expressionWeightings must be a pointer to a float value

#define XR_FACIAL_EXPRESSION_EYE_COUNT_HTC 14

The number of blend shapes in an expression of type XR_FACIAL_TRACKING_TYPE_EYE_DEFAULT_HTC.

#define XR_FACIAL_EXPRESSION_LIP_COUNT_HTC 37

The number of blend shapes in an expression of type XR_FACIAL_TRACKING_TYPE_LIP_DEFAULT_HTC.

Facial Expression List

- Eye Blend Shapes

Through feeding the blend shape values of eye expression to an avatar, its facial expression can be animated with the player's eye movement. The following pictures show how the facial expression acts on the avatar according to each set of eye blend shape values.
typedef enum XrEyeExpressionHTC {
    XR_EYE_EXPRESSION_LEFT_BLINK_HTC = 0,
    XR_EYE_EXPRESSION_LEFT_WIDE_HTC = 1,
    XR_EYE_EXPRESSION_RIGHT_BLINK_HTC = 2,
    XR_EYE_EXPRESSION_RIGHT_WIDE_HTC = 3,
    XR_EYE_EXPRESSION_LEFT_SQUEEZE_HTC = 4,
    XR_EYE_EXPRESSION_RIGHT_SQUEEZE_HTC = 5,
    XR_EYE_EXPRESSION_LEFT_DOWN_HTC = 6,
    XR_EYE_EXPRESSION_RIGHT_DOWN_HTC = 7,
    XR_EYE_EXPRESSION_LEFT_OUT_HTC = 8,
    XR_EYE_EXPRESSION_RIGHT_IN_HTC = 9,
    XR_EYE_EXPRESSION_LEFT_IN_HTC = 10,
    XR_EYE_EXPRESSION_RIGHT_OUT_HTC = 11,
    XR_EYE_EXPRESSION_LEFT_UP_HTC = 12,
    XR_EYE_EXPRESSION_RIGHT_UP_HTC = 13,
    XR_EYE_EXPRESSION_MAX_ENUM_HTC = 0x7FFFFFFF
} XrEyeExpressionHTC;

<table>
<thead>
<tr>
<th>XR_EYE_EXPRESSION_LEFT_WIDE_HTC</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>This blend shape keeps left eye wide and at that time XR_EYE_EXPRESSION_LEFT_BLINK_HTC value is 0.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>XR_EYE_EXPRESSION_RIGHT_WIDE_HTC</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>This blend shape keeps right eye wide and at that time XR_EYE_EXPRESSION_RIGHT_BLINK_HTC value is 0.</td>
</tr>
<tr>
<td>Blend Shape</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_LEFT_BLINK_HTC</td>
<td>This blend shape influences blinking of the right eye. When this value goes higher, left eye approaches close.</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_RIGHT_BLINK_HTC</td>
<td>This blend shape influences blinking of the right eye. When this value goes higher, right eye approaches close.</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_LEFT_SQUEEZE_HTC</td>
<td>The blend shape closes eye tightly and at that time, XR_EYE_EXPRESSION_LEFT_BLINK_HTC value is 100.</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_RIGHT_SQUEEZE_HTC</td>
<td>The blend shape closes eye tightly and at that time, XR_EYE_EXPRESSION_RIGHT_BLINK_HTC value is 100.</td>
</tr>
<tr>
<td>Expression Code</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_LEFT_DOWN_HTC</td>
<td>This blendShape influences the muscles around the left eye, moving these muscles further downward with a higher value.</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_RIGHT_DOWN_HTC</td>
<td>This blendShape influences the muscles around the right eye, moving these muscles further downward with a higher value.</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_LEFT_OUT_HTC</td>
<td>This blendShape influences the muscles around the left eye, moving these muscles further leftward with a higher value.</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_RIGHT_IN_HTC</td>
<td>This blendShape influences the muscles around the right eye, moving these muscles further leftward with a higher value.</td>
</tr>
<tr>
<td>Blend Shape Name</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_LEFT_IN_HTC</td>
<td>This blendShape influences the muscles around the left eye, moving these muscles further rightward with a higher value.</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_RIGHT_OUT_HTC</td>
<td>This blendShape influences the muscles around the right eye, moving these muscles further rightward with a higher value.</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_LEFT_UP_HTC</td>
<td>This blendShape influences the muscles around the left eye, moving these muscles further upward with a higher value.</td>
</tr>
<tr>
<td>XR_EYE_EXPRESSION_RIGHT_UP_HTC</td>
<td>This blendShape influences the muscles around the right eye, moving these muscles further upward with a higher value.</td>
</tr>
</tbody>
</table>

- **Lip Blend Shapes**

Through feeding the blend shape values of lip expression to an avatar, its facial expression can be
animated with the player's lip movement. The following pictures show how the facial expression acts on the avatar according to each set of lip blend shape values.

```c
typedef enum XrLipExpressionHTC {
    XR_LIP_EXPRESSION_JAW_RIGHT_HTC = 0,
    XR_LIP_EXPRESSION_JAW_LEFT_HTC = 1,
    XR_LIP_EXPRESSION_JAW_FORWARD_HTC = 2,
    XR_LIP_EXPRESSION_JAW_OPEN_HTC = 3,
    XR_LIP_EXPRESSION_MOUTH_APE_SHAPE_HTC = 4,
    XR_LIP_EXPRESSION_MOUTH_UPPER_RIGHT_HTC = 5,
    XR_LIP_EXPRESSION_MOUTH_UPPER_LEFT_HTC = 6,
    XR_LIP_EXPRESSION_MOUTH_LOWER_RIGHT_HTC = 7,
    XR_LIP_EXPRESSION_MOUTH_LOWER_LEFT_HTC = 8,
    XR_LIP_EXPRESSION_MOUTH_UPPER_OVERTURN_HTC = 9,
    XR_LIP_EXPRESSION_MOUTH_LOWER_OVERTURN_HTC = 10,
    XR_LIP_EXPRESSION_MOUTH_POUT_HTC = 11,
    XR_LIP_EXPRESSION_MOUTH_SMILE_RIGHT_HTC = 12,
    XR_LIP_EXPRESSION_MOUTH_SMILE_LEFT_HTC = 13,
    XR_LIP_EXPRESSION_MOUTH_SAD_RIGHT_HTC = 14,
    XR_LIP_EXPRESSION_MOUTH_SAD_LEFT_HTC = 15,
    XR_LIP_EXPRESSION_CHEEK_PUFF_RIGHT_HTC = 16,
    XR_LIP_EXPRESSION_CHEEK_PUFF_LEFT_HTC = 17,
    XR_LIP_EXPRESSION_CHEEK_SUCK_HTC = 18,
    XR_LIP_EXPRESSION_MOUTH_UPPER_UPRIGHT_HTC = 19,
    XR_LIP_EXPRESSION_MOUTH_UPPER_UPLEFT_HTC = 20,
    XR_LIP_EXPRESSION_MOUTH_LOWER_DOWNRIGHT_HTC = 21,
    XR_LIP_EXPRESSION_MOUTH_LOWER_DOWNLEFT_HTC = 22,
    XR_LIP_EXPRESSION_MOUTH_UPPER_INSIDE_HTC = 23,
    XR_LIP_EXPRESSION_MOUTH_LOWER_INSIDE_HTC = 24,
    XR_LIP_EXPRESSION_MOUTH_LOWER_OVERLAY_HTC = 25,
    XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC = 26,
    XR_LIP_EXPRESSION_TONGUE_LEFT_HTC = 27,
    XR_LIP_EXPRESSION_TONGUE_RIGHT_HTC = 28,
    XR_LIP_EXPRESSION_TONGUE_UP_HTC = 29,
    XR_LIP_EXPRESSION_TONGUE_DOWN_HTC = 30,
    XR_LIP_EXPRESSION_TONGUE_ROLL_HTC = 31,
    XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC = 32,
    XR_LIP_EXPRESSION_TONGUE_UPRIGHT_MORPH_HTC = 33,
    XR_LIP_EXPRESSION_TONGUE_UPLEFT_MORPH_HTC = 34,
    XR_LIP_EXPRESSION_TONGUE_DOWNRIGHT_MORPH_HTC = 35,
    XR_LIP_EXPRESSION_TONGUE_DOWNLEFT_MORPH_HTC = 36,
    XR_LIP_EXPRESSION_MAX_ENUM_HTC = 0x7FFFFFFF
} XrLipExpressionHTC;
```
<table>
<thead>
<tr>
<th>Blend Shape</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_LIP_EXPRESSION_JAW_LEFT_HTC</td>
<td>This blend shape moves the jaw further leftward with a higher value.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_JAW_RIGHT_HTC</td>
<td>This blend shape moves the jaw further rightward with a higher value.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_JAW_FORWARD_HTC</td>
<td>This blend shape moves the jaw forward with a higher value.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_JAW_OPEN_HTC</td>
<td>This blend shape opens the mouth further with a higher value.</td>
</tr>
<tr>
<td>Blend Shape</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_APE_SHAPE_HTC</td>
<td>This blend shape stretches the jaw further with a higher value.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_UPPER_LEFT_HTC</td>
<td>This blend shape moves your upper lip leftward.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_UPPER_RIGHT_HTC</td>
<td>This blend shape moves your upper lip rightward.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_LOWER_LEFT_HTC</td>
<td>This blend shape moves your lower lip leftward.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_LOWER_RIGHT_HTC</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td></td>
</tr>
<tr>
<td>This blend shape moves your lower lip</td>
<td></td>
</tr>
<tr>
<td>rightward.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>XR_LIP_EXPRESSION_MOUTH_UPPER_OVERTURN_HTC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>This blend shape pouts your upper lip.</td>
</tr>
<tr>
<td>Can be used with</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_UPPER_UPRIGHT_HTC</td>
</tr>
<tr>
<td>and</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_UPPER_UPLEFT_HTC</td>
</tr>
<tr>
<td>to complete upper O mouth shape.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>XR_LIP_EXPRESSION_MOUTH_LOWER_OVERTURN_HTC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>This blend shape pouts your lower lip.</td>
</tr>
<tr>
<td>Can be used with</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_UPPER_UPRIGHT_HTC</td>
</tr>
<tr>
<td>and</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_LOWER_DOWNRIGHT_HTC to complete upper O mouth shape.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>XR_LIP_EXPRESSION_MOUTH_POUT_HTC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>This blend shape allows the lips to pout</td>
</tr>
<tr>
<td>more with a higher value.</td>
</tr>
<tr>
<td>Blend Shape</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_SMILE_LEFT_HTC</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_SMILE_RIGHT_HTC</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_SAD_LEFT_HTC</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_SAD_RIGHT_HTC</td>
</tr>
</tbody>
</table>
### XR_LIP_EXPRESSION_CHEEK_PUFF_RIGHT_HTC

**Description**
This blend shape puffs up the right side of the cheek further with a higher value.

### XR_LIP_EXPRESSION_CHEEK_PUFF_LEFT_HTC

**Description**
This blend shape puffs up the left side of the cheek further with a higher value.

### XR_LIP_EXPRESSION_CHEEK_SUCK_HTC

**Description**
This blend shape sucks in the cheeks on both sides further with a higher value.

### XR_LIP_EXPRESSION_MOUTH_UPPER_UPLEFT_HTC

**Description**
This blend shape raises the left upper lip further with a higher value.
<table>
<thead>
<tr>
<th>Blend Shape</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_UPPER_UPRIGHT_HTC</td>
<td>This blend shape raises the right upper lip further with a higher value.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_LOWER_DOWNLEFT_HTC</td>
<td>This blend shape lowers the left lower lip further with a higher value.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_LOWER_DOWNRIGHT_HTC</td>
<td>This blend shape lowers the right lower lip further with a higher value.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_LOWER_INSIDE_HTC</td>
<td>This blend shape rolls in the lower lip further with a higher value.</td>
</tr>
<tr>
<td>Blend Shape</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_UPPER_INSIDE_HTC</td>
<td>This blend shape rolls in the upper lip further with a higher value.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_LOWER_OVERLAY_HTC</td>
<td>This blend shape stretches the lower lip further and lays it on the upper lip further with a higher value.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC</td>
<td>This blend shape sticks the tongue out slightly. In step 1 of extending the tongue, the main action of the tongue is to lift up, and the elongated length only extends to a little bit beyond the teeth.</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC</td>
<td>This blend shape sticks the tongue out extremely. Continuing the step 1, it extends the tongue to the longest.</td>
</tr>
<tr>
<td>Blend Shape</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_TONGUE_DOWN_HTC</td>
<td>This blend shape sticks the tongue out and down extremely. This example contains (XR_LIP_EXPRESSION_TONGUE_DOWN_HTC XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC).</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_TONGUE_UP_HTC</td>
<td>This blend shape sticks the tongue out and up extremely. This example contains (XR_LIP_EXPRESSION_TONGUE_UP_HTC XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC).</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_TONGUE_RIGHT_HTC</td>
<td>This blend shape sticks the tongue out and right extremely. This example contains (XR_LIP_EXPRESSION_TONGUE_RIGHT_HTC XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC).</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_TONGUE_LEFT_HTC</td>
<td>This blend shape sticks the tongue out and left extremely. This example contains (XR_LIP_EXPRESSION_TONGUE_LEFT_HTC XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC).</td>
</tr>
<tr>
<td>Blend Shape</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>XR_LIP_EXPRESSION_TONGUE_ROLL_HTC</strong></td>
<td>This blend shape sticks the tongue out with roll type. This example contains (XR_LIP_EXPRESSION_TONGUE_ROLL_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC).</td>
</tr>
<tr>
<td><strong>XR_LIP_EXPRESSION_TONGUE_UPRIGHT_MORPH_HTC</strong></td>
<td>This blend shape doesn't make sense. When both the right and up blend shapes appear at the same time, the tongue will be deformed. (XR_LIP_EXPRESSION_TONGUE_RIGHT_HTC + XR_LIP_EXPRESSION_TONGUE_UP_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC)</td>
</tr>
<tr>
<td></td>
<td>This blend shape fixes the deformation illustrated above. (XR_LIP_EXPRESSION_TONGUE_RIGHT_HTC + XR_LIP_EXPRESSION_TONGUE_UP_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC + XR_LIP_EXPRESSION_TONGUE_UPRIGHT_MORPH_HTC)</td>
</tr>
<tr>
<td>Blend Shape</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
</tr>
</tbody>
</table>
| **XR_LIP_EXPRESSION_TONGUE_UPLEFT_MORPH_HTC** | This blend shape doesn’t make sense. When both the left and up blend shapes appear at the same time, the tongue will be deformed.  
\[(XR\_LIP\_EXPRESSION\_TONGUE\_LEFT\_HTC \ XR\_LIP\_EXPRESSION\_TONGUE\_UP\_HTC + XR\_LIP\_EXPRESSION\_TONGUE\_LONGSTEP1\_HTC \ XR\_LIP\_EXPRESSION\_TONGUE\_LONGSTEP2\_HTC)\] |
| **XR_LIP_EXPRESSION_TONGUE_DOWNRIGHT_MORPH_HTC** | This blend shape doesn’t make sense. When both the right and down blend shapes appear at the same time, the tongue will be deformed.  
\[(XR\_LIP\_EXPRESSION\_TONGUE\_RIGHT\_HTC \ XR\_LIP\_EXPRESSION\_TONGUE\_DOWN\_HTC + XR\_LIP\_EXPRESSION\_TONGUE\_LONGSTEP1\_HTC \ XR\_LIP\_EXPRESSION\_TONGUE\_LONGSTEP2\_HTC)\] |
**XR_LIP_EXPRESSION_TONGUE_DOWNRIGHT_MORPH_HTC**

**Description**  
This blend shape fixes the deformation illustrated above.  
(XR_LIP_EXPRESSION_TONGUE_RIGHT_HTC + XR_LIP_EXPRESSION_TONGUE_DOWN_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC + XR_LIP_EXPRESSION_TONGUE_DOWNRIGHT_MORPH_HTC)

**XR_LIP_EXPRESSION_TONGUE_DOWNLEFT_MORPH_HTC**

**Description**  
This blend shape doesn't make sense. When both the left and down blend shapes appear at the same time, the tongue will be deformed.  
(XR_LIP_EXPRESSION_TONGUE_LEFT_HTC + XR_LIP_EXPRESSION_TONGUE_DOWN_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC)

**Description**  
This blend shape fixes the deformation illustrated above.  
(XR_LIP_EXPRESSION_TONGUE_LEFT_HTC + XR_LIP_EXPRESSION_TONGUE_DOWN_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP1_HTC + XR_LIP_EXPRESSION_TONGUE_LONGSTEP2_HTC + XR_LIP_EXPRESSION_TONGUE_DOWNLEFT_MORPH_HTC)
### O shape

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The entire O-shaped mouth is formed by the combination of 6 blend shapes:</td>
</tr>
<tr>
<td>(XR_LIP_EXPRESSION_MOUTH_UPPER_OVERTURN_HTC</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_LOWER_OVERTURN_HTC</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_UPPER_UPLEFT_HTC</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_UPPER_UPRIGHT_HTC</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_LOWER_DOWNLEFT_HTC</td>
</tr>
<tr>
<td>XR_LIP_EXPRESSION_MOUTH_LOWER_DOWNRIGHT_HTC)</td>
</tr>
</tbody>
</table>

### New Object Types

- XrFacialTrackerHTC

### New Flag Types

### New Enum Constants

- `XR_OBJECT_TYPE_FACIAL_TRACKER_HTC`

### XrStructureType enumeration is extended with:

- `XR_TYPE_SYSTEM_FACIAL_TRACKING_PROPERTIES_HTC`
- `XR_TYPE_FACIAL_TRACKER_CREATE_INFO_HTC`
- `XR_TYPE_FACIAL_EXPRESSIONS_HTC`

### New Enums

- `XrFacialTrackingTypeHTC`
- `XrEyeExpressionHTC`
- `XrLipExpressionHTC`

### New Structures

- `XrSystemFacialTrackingPropertiesHTC`
- `XrFacialTrackerCreateInfoHTC`
New Functions

- xrCreateFacialTrackerHTC
- xrDestroyFacialTrackerHTC
- xrGetFacialExpressionsHTC

Issues

Version History

- Revision 1, 2021-12-16 (Kyle Chen)
  - Initial extension description

12.69. XR_HTC_hand_interaction

Name String

XR_HTC_hand_interaction

Extension Type

Instance extension

Registered Extension Number

107

Revision

1

Extension and Version Dependencies

- Requires OpenXR 1.0

Last Modified Date

2022-05-27

IP Status

No known IP claims.

Contributors

Ria Hsu, HTC
Bill Chang, HTC

Overview

This extension defines a new interaction profile for tracked hands.
Hand interaction profile

Interaction profile path:

• /interaction_profiles/htc/hand_interaction

Valid for user paths:

• /user/hand_htc/left
• /user/hand_htc/right

This interaction profile represents basic pose and actions for interaction of tracked hands.

Supported component paths for far interaction:

• .../input/select/value
• .../input/aim/pose

The application should use .../input/aim/pose path to aim at objects in the world and use .../input/select/value path to decide user selection from pinch shape strength which the range of value is 0.0f to 1.0f, with 1.0f meaning pinch fingers touched.

Supported component paths for near interaction:

• .../input/squeeze/value
• .../input/grip/pose

The application should use .../input/grip/pose path to interact with the nearby objects and locate the position of handheld objects, and use .../input/squeeze/value path to decide the hand picking up or holding the nearby objects from grip shape strength which the range of value is 0.0f to 1.0f, with 1.0f meaning hand grip shape is closed.

Note

Far and near interaction depends on the support capabilities of hand tracking engine. The application can check isActive of XrActionStatePose of aim and grip to know far and near interaction supported or not then decide the interaction behavior in content.

Version History

• Revision 1, 2022-05-27 (Ria Hsu)
  ◦ Initial extension description

12.70. XR_HTC_vive_cosmos_controller_interaction
Name String
    XR_HTC_vive_cosmos_controller_interaction

Extension Type
    Instance extension

Registered Extension Number
    103

Revision
    1

Extension and Version Dependencies
    • Requires OpenXR 1.0

Last Modified Date
    2020-09-28

IP Status
    No known IP claims.

Contributors
    Chris Kuo, HTC
    Kyle Chen, HTC

Overview
    This extension defines a new interaction profile for the VIVE Cosmos Controller.

VIVE Cosmos Controller interaction profile

Interaction profile path:
    • /interaction_profiles/htc/vive_cosmos_controller

Valid for user paths:
    • /user/hand/left
    • /user/hand/right

This interaction profile represents the input sources and haptics on the VIVE Cosmos Controller.

Supported component paths:
    • On /user/hand/left only:
        • ../input/x/click
• On /user/hand/right only:
  ◦ ../input/a/click
  ◦ ../input/b/click
  ◦ ../input/system/click (may not be available for application use)
• ../input/shoulder/click
• ../input/squeeze/click
• ../input/trigger/click
• ../input/trigger/value
• ../input/thumbstick/x
• ../input/thumbstick/y
• ../input/thumbstick/click
• ../input/thumbstick/touch
• ../input/grip/pose
• ../input/aim/pose
• ../output/haptic

New Object Types

New Flag Types

New Enum Constants

New Enums

New Structures

New Functions

Issues

Version History

• Revision 1, 2020-09-28 (Chris Kuo)
  ◦ Initial extension description


12.71. XR_HTC_vive_focus3_controller_interaction

Name String

XR_HTC_vive_focus3_controller_interaction

Extension Type

Instance extension

Registered Extension Number

106

Revision

2

Extension and Version Dependencies

• Requires OpenXR 1.0

Last Modified Date

2022-04-29

IP Status

No known IP claims.

Contributors

Ria Hsu, HTC

Overview

This extension defines a new interaction profile for the VIVE Focus 3 Controller.

VIVE Focus 3 Controller interaction profile

Interaction profile path:

• /interaction_profiles/htc/vive_focus3_controller

Valid for user paths:

• /user/hand/left

• /user/hand/right

This interaction profile represents the input sources and haptics on the VIVE Focus 3 Controller.

Supported component paths:

• On /user/hand/left only:
• /input/x/click
• /input/y/click
• /input/menu/click

• On /user/hand/right only:
  • /input/a/click
  • /input/b/click
  • /input/system/click (may not be available for application use)

• /input/squeeze/click
• /input/squeeze/touch
• /input/squeeze/value
• /input/trigger/click
• /input/trigger/touch
• /input/trigger/value
• /input/thumbstick/x
• /input/thumbstick/y
• /input/thumbstick/click
• /input/thumbstick/touch
• /input/thumbrest/touch
• /input/grip/pose
• /input/aim/pose
• /output/haptic

New Object Types

New Flag Types

New Enum Constants

New Enums

New Structures

New Functions

Issues

Version History
• Revision 1, 2022-01-03 (Ria Hsu)
12.72. XR_HTC_vive_wrist_tracker_interaction

Name String
XR_HTC_vive_wrist_tracker_interaction

Extension Type
Instance extension

Registered Extension Number
108

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2022-05-27

IP Status
No known IP claims.

Contributors
Ria Hsu, HTC
Bill Chang, HTC

Overview
This extension provides an XrPath for getting device input from a VIVE wrist tracker to enable its interactions. VIVE wrist tracker is a tracked device mainly worn on user's wrist for pose tracking. Besides this use case, user also can tie it to a physical object to track its object pose, e.g. tie on a gun.

VIVE Wrist Tracker input
This extension exposes a new interaction profile path /interaction_profiles/htc/vive_wrist_tracker that is valid for the user path

• /user/wrist_htc/left
• /user/wrist_htc/right
The entity_htc pose allows the applications to recognize the origin of a tracked input device, especially for the wearable devices which are not held in the user's hand. The entity_htc pose is defined as follows:

- The entity position: The center position of the tracked device.
- The entity orientation: Oriented with +Y up, +X to the right, and -Z forward.

**Version History**

- Revision 1, 2022-05-27 (Ria Hsu)
  - Initial extension description

### 12.73. XR_HUAWEI_controller_interaction

**Name String**

XR_HUAWEI_controller_interaction

**Extension Type**

Instance extension

**Registered Extension Number**

70

**Revision**

1

**Extension and Version Dependencies**

- Requires OpenXR 1.0

**Last Modified Date**

2020-05-26
IP Status
No known IP claims.

Contributors
Guodong Chen, Huawei
Kai Shao, Huawei
Yang Tao, Huawei
Gang Shen, Huawei
Yihong Huang, Huawei

Overview
This extension defines a new interaction profile for the Huawei Controller, including but not limited to Huawei VR Glasses Controller.

Huawei Controller interaction profile

Interaction profile path:

• /interaction_profiles/huawei/controller

Valid for user paths:

• /user/hand/left
• /user/hand/right

This interaction profile represents the input sources and haptics on the Huawei Controller.

Supported component paths:

• .../input/home/click
• .../input/back/click
• .../input/volume_up/click
• .../input/volume_down/click
• .../input/trigger/value
• .../input/trigger/click
• .../input/trackpad/x
• .../input/trackpad/y
• .../input/trackpad/click
• .../input/trackpad/touch
• .../input/aim/pose
• .../input/grip/pose
New Object Types

New Flag Types

New Enum Constants

New Enums

New Structures

New Functions

Issues

Version History

• Revision 1, 2020-04-28 (Yihong Huang)
  ◦ Initial extension description

12.74. XR_META_performance_metrics

Name String

XR_META_performance_metrics

Extension Type

Instance extension

Registered Extension Number

233

Revision

1

Extension and Version Dependencies

• Requires OpenXR 1.0

Contributors

Xiang Wei, Meta Platforms

Overview

This extension provides APIs to enumerate and query performance metrics counters of the current XR device and XR application. Developers can perform performance analysis and do targeted optimization to the XR application using the performance metrics counters being collected. The
application **should** not change its behavior based on the counter reads.

The performance metrics counters are organized into predefined **XrPath**, under the root path /perfmetrics_meta. You **can** query the available counters through *xrEnumeratePerformanceMetricsCounterPathsMETA*. Here is a list of the performance metrics counter paths that **may** be provided on Meta devices:

- /perfmetrics_meta/app/cpu_frametime
- /perfmetrics_meta/app/gpu_frametime
- /perfmetrics_meta/app/motion_to_photon_latency
- /perfmetrics_meta/compositor/cpu_frametime
- /perfmetrics_meta/compositor/gpu_frametime
- /perfmetrics_meta/compositor/dropped_frame_count
- /perfmetrics_meta/compositor/spacewarp_mode
- /perfmetrics_meta/device/cpu_utilization_average
- /perfmetrics_meta/device/cpu_utilization_worst
- /perfmetrics_meta/device/gpu_utilization
- /perfmetrics_meta/device/cpu0_utilization through /perfmetrics_meta/device/cpuX_utilization

After a session is created, you **can** use *xrSetPerformanceMetricsStateMETA* to enable the performance metrics system for that session. You **can** use *xrQueryPerformanceMetricsCounterMETA* to query performance metrics counter on a session that has performance metrics system enabled, or use *xrGetPerformanceMetricsStateMETA* to get the enablement state.

Note: the measurement intervals of individual performance metrics counters are defined by the OpenXR runtime. The application **must** not make assumptions or change its behavior at runtime by measuring them.

In order to enable the functionality of this extension, the application **must** pass the name of the extension into *xrCreateInstance* via the *XrInstanceCreateInfo::enabledExtensionNames* parameter as indicated in the Extensions section.

**New Flag Types**

typedef XrFlags64 XrPerformanceMetricsCounterFlagsMETA;
// Flag bits for XrPerformanceMetricsCounterFlagsMETA
static const XrPerformanceMetricsCounterFlagsMETA
XR_PERFORMANCE_METRICS_COUNTER_ANY_VALUE_VALID_BIT_META = 0x00000001;
static const XrPerformanceMetricsCounterFlagsMETA
XR_PERFORMANCE_METRICS_COUNTER_UINT_VALUE_VALID_BIT_META = 0x00000002;
static const XrPerformanceMetricsCounterFlagsMETA
XR_PERFORMANCE_METRICS_COUNTER_FLOAT_VALUE_VALID_BIT_META = 0x00000004;

Flag Descriptions

- **XR_PERFORMANCE_METRICS_COUNTER_ANY_VALUE_VALID_BIT_META**—Indicates any of the values in XrPerformanceMetricsCounterMETA is valid.
- **XR_PERFORMANCE_METRICS_COUNTER_UINT_VALUE_VALID_BIT_META**—Indicates the uintValue in XrPerformanceMetricsCounterMETA is valid.
- **XR_PERFORMANCE_METRICS_COUNTER_FLOAT_VALUE_VALID_BIT_META**—Indicates the floatValue in XrPerformanceMetricsCounterMETA is valid.

New Enum Constants

**XrStructureType** enumeration is extended with:

- **XR_TYPE_PERFORMANCE_METRICS_STATE_META**
- **XR_TYPE_PERFORMANCE_METRICS_COUNTER_META**

New Enums

typedef enum XrPerformanceMetricsCounterUnitMETA {
    XR_PERFORMANCE_METRICS_COUNTER_UNIT_GENERIC_META = 0,
    XR_PERFORMANCE_METRICS_COUNTER_UNIT_PERCENTAGE_META = 1,
    XR_PERFORMANCE_METRICS_COUNTER_UNIT_MILLISECONDS_META = 2,
    XR_PERFORMANCE_METRICS_COUNTER_UNIT(Bytes META = 3,
    XR_PERFORMANCE_METRICS_COUNTER_UNIT_HERTZ_META = 4,
    XR_PERFORMANCE_METRICS_COUNTER_UNIT_MAX_ENUM_META = 0x7FFFFFFF
} XrPerformanceMetricsCounterUnitMETA;

<table>
<thead>
<tr>
<th>Enum</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_PERFORMANCE_METRICS_COUNTER_UNIT_GENERIC_META</td>
<td>the performance counter unit is generic (unspecified).</td>
</tr>
<tr>
<td>Enum</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_PERFORMANCE_METRICS_COUNTER_UNIT_PERCENTAGE_META</td>
<td>the performance counter unit is percentage (%)</td>
</tr>
<tr>
<td>XR_PERFORMANCE_METRICS_COUNTER_UNIT_MILLISECONDS_META</td>
<td>the performance counter unit is millisecond</td>
</tr>
<tr>
<td>XR_PERFORMANCE_METRICS_COUNTER_UNIT_BYTES_META</td>
<td>the performance counter unit is byte</td>
</tr>
<tr>
<td>XR_PERFORMANCE_METRICS_COUNTER_UNIT_HERTZ_META</td>
<td>the performance counter unit is hertz (Hz)</td>
</tr>
</tbody>
</table>

**New Structures**

The `XrPerformanceMetricsStateMETA` structure is defined as:

```c
typedef struct XrPerformanceMetricsStateMETA {
    XrStructureType type;
    const void* next;
    XrBool32 enabled;
} XrPerformanceMetricsStateMETA;
```

**Member Descriptions**

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `enabled` is set to `XR_TRUE` to indicate the performance metrics system is enabled, `XR_FALSE` otherwise, when getting state. When setting state, set to `XR_TRUE` to enable the performance metrics system and `XR_FALSE` to disable it.

`XrPerformanceMetricsStateMETA` is provided as input when calling `xrSetPerformanceMetricsStateMETA` to enable or disable the performance metrics system. `XrPerformanceMetricsStateMETA` is populated as an output parameter when calling `xrGetPerformanceMetricsStateMETA` to query the enablement status of the performance metrics system.
Valid Usage (Implicit)

• The `XR_META_performance_metrics` extension must be enabled prior to using `XrPerformanceMetricsStateMETA`
• `type` must be `XR_TYPE_PERFORMANCE_METRICS_STATE_META`
• `next` must be `NULL` or a valid pointer to the next structure in a structure chain

The `XrPerformanceMetricsCounterMETA` structure is defined as:

```c
typedef struct XrPerformanceMetricsCounterMETA {
    XrStructureType                         type;
    const void*                             next;
    XrPerformanceMetricsCounterFlagsMETA    counterFlags;
    XrPerformanceMetricsCounterUnitMETA     counterUnit;
    uint32_t                                uintValue;
    float                                   floatValue;
} XrPerformanceMetricsCounterMETA;
```

Member Descriptions

• `type` is the `XrStructureType` of this structure.
• `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
• `counterFlags` is a bitmask of `XrPerformanceMetricsCounterFlagBitsMETA` describing the validity of value members.
• `counterUnit` is a enum of `XrPerformanceMetricsCounterUnitMETA` describing the measurement unit.
• `uintValue` is the counter value in `uint32_t` format. It is valid if `counterFlags` contains `XR_PERFORMANCE_METRICS_COUNTER_UINT_VALUE_VALID_BIT_META`.
• `floatValue` is the counter value in `float` format. It is valid if `counterFlags` contains `XR_PERFORMANCE_METRICS_COUNTER_FLOAT_VALUE_VALID_BIT_META`.

`XrPerformanceMetricsCounterMETA` is populated by calling `xrQueryPerformanceMetricsCounterMETA` to query real-time performance metrics counter information.
Valid Usage (Implicit)

- The `XR_META_performance_metrics` extension must be enabled prior to using `XrPerformanceMetricsCounterMETA`.
- `type` must be `XR_TYPE_PERFORMANCE_METRICS_COUNTER_META`.
- `next` must be `null` or a valid pointer to the next structure in a structure chain.
- `counterFlags` must be `0` or a valid combination of `XrPerformanceMetricsCounterFlagBitsMETA` values.
- `counterUnit` must be a valid `XrPerformanceMetricsCounterUnitMETA` value.

New Functions

The `xrEnumeratePerformanceMetricsCounterPathsMETA` function enumerate all performance metrics counter paths that supported by the runtime, it is defined as:

```c
XrResult xrEnumeratePerformanceMetricsCounterPathsMETA(
    XrInstance                                  instance,
    uint32_t                                    counterPathCapacityInput,
    uint32_t*                                   counterPathCountOutput,
    XrPath*                                     counterPaths);
```

Parameter Descriptions

- `instance` is an `XrInstance` handle previously created with `xrCreateInstance`.
- `counterPathCapacityInput` is the capacity of the `counterPaths` array, or `0` to indicate a request to retrieve the required capacity.
- `counterPathCountOutput` is filled in by the runtime with the count of `counterPaths` written or the required capacity in the case that `counterPathCapacityInput` is insufficient.
- `counterPaths` is an array of `XrPath` filled in by the runtime which contains all the available performance metrics counters, but can be `null` if `counterPathCapacityInput` is `0`.
- See the `Buffer Size Parameters` section for a detailed description of retrieving the required `counterPaths` size.
Valid Usage (Implicit)

- The `XR_META_performance_metrics` extension **must** be enabled prior to calling `xrEnumeratePerformanceMetricsCounterPathsMETA`.
- `instance` **must** be a valid `XrInstance` handle.
- `counterPathCountOutput` **must** be a pointer to a `uint32_t` value.
- If `counterPathCapacityInput` is not `0`, `counterPaths` **must** be a pointer to an array of `counterPathCapacityInput XrPath` values.

Return Codes

**Success**

- `XR_SUCCESS`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SIZE_INSUFFICIENT`

The `xrSetPerformanceMetricsStateMETA` function is defined as:

```c
XrResult xrSetPerformanceMetricsStateMETA(
    XrSession                                   session,
    const XrPerformanceMetricsStateMETA*        state);
```

Parameter Descriptions

- `session` is an `XrSession` handle previously created with `xrCreateSession`.
- `state` is a pointer to an `XrPerformanceMetricsStateMETA` structure.

The `xrSetPerformanceMetricsStateMETA` function enables or disables the performance metrics system.
Valid Usage (Implicit)

- The XR_META_performance_metrics extension must be enabled prior to calling xrSetPerformanceMetricsStateMETA
- session must be a valid XrSession handle
- state must be a pointer to a valid XrPerformanceMetricsStateMETA structure

Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST

The xrGetPerformanceMetricsStateMETA function is defined as:

```c
XrResult xrGetPerformanceMetricsStateMETA(
    XrSession                                   session,
    XrPerformanceMetricsStateMETA*              state);
```

Parameter Descriptions

- session is an XrSession handle previously created with xrCreateSession.
- state is a pointer to an XrPerformanceMetricsStateMETA structure.

The xrGetPerformanceMetricsStateMETA function gets the current state of the performance metrics system.
Valid Usage (Implicit)

- The `XR_META_performance_metrics` extension must be enabled prior to calling `xrGetPerformanceMetricsStateMETA`.
- `session` must be a valid `XrSession` handle.
- `state` must be a pointer to an `XrPerformanceMetricsStateMETA` structure.

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`

The `xrQueryPerformanceMetricsCounterMETA` function is defined as:

```c
XrResult xrQueryPerformanceMetricsCounterMETA(
    XrSession session,
    XrPath counterPath,
    XrPerformanceMetricsCounterMETA* counter);
```

Parameter Descriptions

- `session` is an `XrSession` handle previously created with `xrCreateSession`.
- `counterPath` is a valid performance metrics counter path.
- `counter` is a pointer to an `XrPerformanceMetricsCounterMETA` structure.

The `xrQueryPerformanceMetricsCounterMETA` function queries a performance metrics counter.
Valid Usage (Implicit)

- The `XR_META_performance_metrics` extension must be enabled prior to calling `xrQueryPerformanceMetricsCounterMETA`.
- `session` must be a valid `XrSession` handle.
- `counter` must be a pointer to an `XrPerformanceMetricsCounterMETA` structure.

Return Codes

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_PATH_INVALID

Issues

Version History

- Revision 1, 2022-04-28 (Xiang Wei)
  - Initial extension description

12.75. XR_META_vulkan_swapchain_create_info

Name String

`XR_META_vulkan_swapchain_create_info`

Extension Type

Instance extension
Registered Extension Number
228

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2022-05-19

IP Status
No known IP claims.

Contributors
John Kearney, Meta Platforms
Andreas L. Selvik, Meta Platforms
Jakob Bornecrantz, Collabora
Ross Ning, Meta Platforms

Overview
Using this extension, a Vulkan-based application can pass through additional VkImageCreateFlags or VkImageUsageFlags by chaining an XrVulkanSwapchainCreateInfoMETA structure to the XrSwapchainCreateInfo when calling xrCreateSwapchain. The application is still encouraged to use the common bits like XR_SWAPCHAIN_USAGE_TRANSFER_SRC_BIT defined in XrSwapchainUsageFlags. However, the application may present both XR_SWAPCHAIN_USAGE_TRANSFER_SRC_BIT in XrSwapchainUsageFlags and VK_IMAGE_USAGE_TRANSFER_SRC_BIT in VkImageUsageFlags at the same time.

The application must enable the corresponding Vulkan extensions before requesting additional Vulkan flags. For example, VK_EXT_fragment_density_map device extension must be enabled if an application requests VK_IMAGE_CREATE_SUBSAMPLED_BIT_EXT bit. Otherwise, it may cause undefined behavior, including an application crash.

Runtimes that implement this extension must support the XR_KHR_vulkan_enable or the XR_KHR_vulkan_enable2 extension.

New Object Types

New Flag Types

New Enum Constants

New Enums
typedef struct XrVulkanSwapchainCreateInfoMETA {
    XrStructureType       type;
    const void*           next;
    VkImageCreateFlags    additionalCreateFlags;
    VkImageUsageFlags     additionalUsageFlags;
} XrVulkanSwapchainCreateInfoMETA;

**Member Descriptions**

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `additionalCreateFlags` is a bitmask of `VkImageCreateFlags` describing additional parameters of an image.
- `additionalUsageFlags` is a bitmask of `VkImageUsageFlags` describing additional parameters of an image.

The runtime **must** return `XR_ERROR_FEATURE_UNSUPPORTED` if any bit of either `additionalCreateFlags` or `additionalUsageFlags` is not supported.

**Valid Usage (Implicit)**

- The `XR_META_vulkan_swapchain_create_info` extension **must** be enabled prior to using `XrVulkanSwapchainCreateInfoMETA`
- `type` **must** be `XR_TYPE_VULKAN_SWAPCHAIN_CREATE_INFO_META`
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain
- `additionalCreateFlags` **must** be a valid `VkImageCreateFlags` value
- `additionalUsageFlags` **must** be a valid `VkImageUsageFlags` value

**New Functions**

**Issues**

**Version History**

- Revision 1, 2022-05-05 (Ross Ning)
12.76. XR_MND_headless

Name String
XR_MND_headless

Extension Type
Instance extension

Registered Extension Number
43

Revision
2

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2019-10-22

IP Status
No known IP claims.

Contributors
Ryan Pavlik, Collabora

Overview

Some applications may wish to access XR interaction devices without presenting any image content on the display(s). This extension provides a mechanism for writing such an application using the OpenXR API. It modifies the specification in the following ways, without adding any new named entities.

• When this extension is enabled, an application may call `xrCreateSession` without an `XrGraphicsBinding*` structure in its next chain. In this case, the runtime must create a "headless" session that does not interact with the display.

• In a headless session, the session state should proceed to `XR_SESSION_STATE_READY` directly from `XR_SESSION_STATE_IDLE`.

• In a headless session, the `XrSessionBeginInfo::primaryViewConfigurationType` must be ignored and may be 0.

• In a headless session, the session state proceeds to `XR_SESSION_STATE_SYNCHRONIZED`, then `XR_SESSION_STATE_VISIBLE` and `XR_SESSION_STATE_FOCUSED`, after the call to `xrBeginSession`. The application does not need to call `xrWaitFrame`, `xrBeginFrame`, or `xrEndFrame`, unlike with non-
headless sessions.

- In a headless session, `xrEnumerateSwapchainFormats` must return `XR_SUCCESS` but enumerate 0 formats.

- `xrWaitFrame` must set `XrFrameState::shouldRender` to `XR_FALSE` in a headless session. The VISIBLE and FOCUSED states are only used for their input-related semantics, not their rendering-related semantics, and these functions are permitted to allow minimal change between headless and non-headless code if desired.

Because `xrWaitFrame` is not required, an application using a headless session should sleep periodically to avoid consuming all available system resources in a busy-wait loop.

New Object Types

New Flag Types

New Enum Constants

New Enums

New Structures

New Functions

Issues

- Not all devices with which this would be useful fit into one of the existing `XrFormFactor` values.

Version History

- Revision 1, 2019-07-25 (Ryan Pavlik)
  - Initial version reflecting Monado prototype.
- Revision 2, 2019-10-22 (Ryan Pavlik)
  - Clarify that `xrWaitFrame` is permitted and should set `shouldRender` to false.

12.77. XR_MSFT_composition_layer_reprojection

Name String

`XR_MSFT_composition_layer_reprojection`

Extension Type

Instance extension

Registered Extension Number

67
Overview

This extension enables an application to provide additional reprojection information for a projection composition layer to help the runtime produce better hologram stability and visual quality.

First, the application uses `xrEnumerateReprojectionModesMSFT` to inspect what reprojection mode the view configuration supports.

The `xrEnumerateReprojectionModesMSFT` function returns the supported reprojection modes of the view configuration.

```c
XrResult xrEnumerateReprojectionModesMSFT(
    XrInstance instance,
    XrSystemId systemId,
    XrViewConfigurationType viewConfigurationType,
    uint32_t modeCapacityInput,
    uint32_t* modeCountOutput,
    XrReprojectionModeMSFT* modes);
```
Parameter Descriptions

- **instance** is the instance from which **systemId** was retrieved.
- **systemId** is the **XrSystemId** whose reprojection modes will be enumerated.
- **viewConfigurationType** is the **XrViewConfigurationType** to enumerate.
- **modeCapacityInput** is the capacity of the array, or 0 to indicate a request to retrieve the required capacity.
- **modeCountOutput** is a pointer to the count of the array, or a pointer to the required capacity in the case that **modeCapacityInput** is insufficient.
- **modes** is a pointer to an application-allocated array that will be filled with the **XrReprojectionModeMSFT** values that are supported by the runtime. It can be **NULL** if **modeCapacityInput** is 0.
- See **Buffer Size Parameters** chapter for a detailed description of retrieving the required mode size.

Valid Usage (Implicit)

- The **XR_MSFT_composition_layer_reprojection** extension **must** be enabled prior to calling **xrEnumerateReprojectionModesMSFT**
- **instance** **must** be a valid **XrInstance** handle
- **viewConfigurationType** **must** be a valid **XrViewConfigurationType** value
- **modeCountOutput** **must** be a pointer to a **uint32_t** value
- If **modeCapacityInput** is not 0, **modes** **must** be a pointer to an array of **modeCapacityInput** **XrReprojectionModeMSFT** values
Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED
- XR_ERROR_SYSTEM_INVALID

A system may support different sets of reprojection modes for different view configuration types.

Then, the application can provide reprojection mode for the projection composition layer to inform the runtime that the XR experience may benefit from the provided reprojection mode.

An XrCompositionLayerReprojectionInfoMSFT structure can be added to the next chain of XrCompositionLayerProjection structure when calling xrEndFrame.

typedef struct XrCompositionLayerReprojectionInfoMSFT {
    XrStructureType           type;
    const void*               next;
    XrReprojectionModeMSFT    reprojectionMode;
} XrCompositionLayerReprojectionInfoMSFT;

Parameter Descriptions

- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain.
- reprojectionMode is an XrReprojectionModeMSFT enum providing a hint to the reprojection mode to the corresponding projection layer.
Valid Usage (Implicit)

- The `XR_MSFT_composition_layer_reprojection` extension **must** be enabled prior to using `XrCompositionLayerReprojectionInfoMSFT`
- `type` **must** be `XR_TYPE_COMPOSITION_LAYER_REPROJECTION_INFO_MSFT`
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain
- `reprojectionMode` **must** be a valid `XrReprojectionModeMSFT` value

When the application chained this structure when calling `xrEndFrame`, the `mode` **must** be one of the supported `XrReprojectionModeMSFT` returned by `xrEnumerateReprojectionModesMSFT` function for the corresponding `XrViewConfigurationType`. Otherwise, the runtime **must** return error `XR_ERROR_REPROJECTION_MODE_UNSUPPORTED_MSFT` on the `xrEndFrame` function.

The runtime **must** only use the given information for the corresponding frame in `xrEndFrame` function, and it **must** not affect other frames.

The `XrReprojectionModeMSFT` describes the reprojection mode of a projection composition layer.

```c
typedef enum XrReprojectionModeMSFT {
    XR_REPROJECTION_MODE_DEPTH_MSFT = 1,
    XR_REPROJECTION_MODE_PLANAR_FROM_DEPTH_MSFT = 2,
    XR_REPROJECTION_MODE_PLANAR_MANUAL_MSFT = 3,
    XR_REPROJECTION_MODE_ORIENTATION_ONLY_MSFT = 4,
    XR_REPROJECTION_MODE_MAX_ENUM_MSFT = 0x7FFFFFFF
} XrReprojectionModeMSFT;
```
• **XR_REPROJECTION_MODE_DEPTH_MSFT** indicates the corresponding layer *may* benefit from per-pixel depth reprojection provided by XrCompositionLayerDepthInfoKHR to the projection layer. This mode is typically used for world-locked content that should remain physically stationary as the user walks around.

• **XR_REPROJECTION_MODE_PLANAR_FROM_DEPTH_MSFT** indicates the corresponding layer *may* benefit from planar reprojection and the plane *can* be calculated from the corresponding depth information provided by XrCompositionLayerDepthInfoKHR to the projection layer. This mode works better when the application knows the content is mostly placed on a plane.

• **XR_REPROJECTION_MODE_PLANAR_MANUAL_MSFT** indicates that the corresponding layer *may* benefit from planar reprojection. The application *can* customize the plane by chaining an XrCompositionLayerReprojectionPlaneOverrideMSFT structure to the same layer. The app *can* also omit the plane override, indicating the runtime should use the default reprojection plane settings. This mode works better when the application knows the content is mostly placed on a plane, or when it cannot afford to submit depth information.

• **XR_REPROJECTION_MODE_ORIENTATION_ONLY_MSFT** indicates the layer should be stabilized only for changes to orientation, ignoring positional changes. This mode works better for body-locked content that should follow the user as they walk around, such as 360-degree video.

When the application passes **XR_REPROJECTION_MODE_DEPTH_MSFT** or **XR_REPROJECTION_MODE_PLANAR_FROM_DEPTH_MSFT** mode, it *should* also provide the depth buffer for the corresponding layer using XrCompositionLayerDepthInfoKHR in XR_KHR_composition_layer_depth extension. However, if the application does not submit this depth buffer, the runtime *must* apply a runtime defined fallback reprojection mode, and *must* not fail the xrEndFrame function because of this missing depth.

When the application passes **XR_REPROJECTION_MODE_PLANAR_MANUAL_MSFT** or **XR_REPROJECTION_MODE_ORIENTATION_ONLY_MSFT** mode, it *should* avoid providing a depth buffer for the corresponding layer using XrCompositionLayerDepthInfoKHR in XR_KHR_composition_layer_depth extension. However, if the application does submit this depth buffer, the runtime *must* not fail the xrEndFrame function because of this unused depth data.

When the application is confident that overriding the reprojection plane can benefit hologram stability, it *can* provide XrCompositionLayerReprojectionPlaneOverrideMSFT structure to further help the runtime to fine tune the reprojection details.

An application *can* add an XrCompositionLayerReprojectionPlaneOverrideMSFT structure to the next chain of XrCompositionLayerProjection structure.

The runtime *must* only use the given plane override for the corresponding frame in xrEndFrame function, and it *must* not affect other frames.
typedef struct XrCompositionLayerReprojectionPlaneOverrideMSFT {
    XrStructureType type;
    const void* next;
    XrVector3f position;
    XrVector3f normal;
    XrVector3f velocity;
} XrCompositionLayerReprojectionPlaneOverrideMSFT;

Parameter Descriptions

- **position** describes the position of the focus plane represented in the corresponding `XrCompositionLayerProjection::space`.
- **normal** is a unit vector describes the focus plane normal represented in the corresponding `XrCompositionLayerProjection::space`.
- **velocity** is a velocity of the position in the corresponding `XrCompositionLayerProjection::space` measured in meters per second.

A runtime **must** return `XR_ERROR_VALIDATION_FAILURE` if the `normal` vector deviates by more than 1% from unit length.

Adding a reprojection plane override **may** benefit various reprojection modes including `XR_REPROJECTION_MODE_DEPTH_MSFT`, `XR_REPROJECTION_MODE_PLANAR_FROM_DEPTH_MSFT` and `XR_REPROJECTION_MODE_PLANAR_MANUAL_MSFT`.

When application choose `XR_REPROJECTION_MODE_ORIENTATION_ONLY_MSFT` mode, the reprojection plane override **may** be ignored by the runtime.

Valid Usage (Implicit)

- The `XR_MSFT_composition_layer_reprojection` extension **must** be enabled prior to using `XrCompositionLayerReprojectionPlaneOverrideMSFT`
- `type` **must** be `XR_TYPE_COMPOSITION_LAYER_REPROJECTION_PLANE_OVERRIDE_MSFT`
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain

New Object Types

New Flag Types

New Enum Constants

`XrStructureType` enumeration is extended with:
• XR_TYPE_COMPOSITION_LAYER_REPROJECTION_INFO_MSFT
• XR_TYPE_COMPOSITION_LAYER_REPROJECTION_PLANE_OVERRIDE_MSFT

XrResult enumeration is extended with:
• XR_ERROR_REPROJECTION_MODE_UNSUPPORTED_MSFT

New Enums
• XrReprojectionModeMSFT

New Structures
• XrCompositionLayerReprojectionInfoMSFT
• XrCompositionLayerReprojectionPlaneOverrideMSFT

New Functions
• xrEnumerateReprojectionModesMSFT

Issues

Version History
• Revision 1, 2020-06-20 (Yin Li)
  ◦ Initial extension proposal

12.78. XR_MSFT_controller_model

Name String
XR_MSFT_controller_model

Extension Type
Instance extension

Registered Extension Number
56

Revision
2

Extension and Version Dependencies
• Requires OpenXR 1.0

Contributors
Bryce Hutchings, Microsoft
Overview

This extension provides a mechanism to load a GLTF model for controllers. An application can render the controller model using the real time pose input from controller's grip action pose and animate controller parts representing the user's interactions, such as pressing a button, or pulling a trigger.

This extension supports any controller interaction profile that supports `.../grip/pose`. The returned controller model represents the physical controller held in the user's hands, and it may be different from the current interaction profile.

Query controller model key

`xrGetControllerModelKeyMSFT` retrieves the `XrControllerModelKeyMSFT` for a controller. This model key may later be used to retrieve the model data.

The `xrGetControllerModelKeyMSFT` function is defined as:

```c
XrResult xrGetControllerModelKeyMSFT(
    XrSession session,
    XrPath topLevelUserPath,
    XrControllerModelKeyStateMSFT* controllerModelKeyState);
```

Parameter Descriptions

- **session** is the specified `XrSession`.
- **topLevelUserPath** is the top level user path corresponding to the controller render model being queried (e.g. `/user/hand/left` or `/user/hand/right`).
- **controllerModelKeyState** is a pointer to the `XrControllerModelKeyStateMSFT` to write the model key state to.
Valid Usage (Implicit)

- The `XR_MSFT_controller_model` extension **must** be enabled prior to calling `xrGetControllerModelKeyMSFT`
- `session` **must** be a valid `XrSession` handle
- `controllerModelKeyState` **must** be a pointer to an `XrControllerModelKeyStateMSFT` structure

Return Codes

**Success**
- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_CONTROLLER_MODEL_KEY_INVALID_MSFT`

The `XrControllerModelKeyStateMSFT` structure is defined as:

```c
typedef struct XrControllerModelKeyStateMSFT {
    XrStructureType             type;
    void*                       next;
    XrControllerModelKeyMSFT    modelKey;
} XrControllerModelKeyStateMSFT;
```
Parameter Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain.
- **modelKey** is the model key corresponding to the controller render model being queried.

The **modelKey** value for the session represents a unique controller model that can be retrieved from `xrLoadControllerModelMSFT` function. Therefore, the application can use `modelKey` to cache the returned data from `xrLoadControllerModelMSFT` for the session.

A **modelKey** value of `XR_NULL_CONTROLLER_MODEL_KEY_MSFT`, represents an invalid model key and indicates there is no controller model yet available. The application **should** keep calling `xrGetControllerModelKeyMSFT` because the model **may** become available at a later point.

Valid Usage (Implicit)

- The `XR_MSFT_controller_model` extension must be enabled prior to using `XrControllerModelKeyStateMSFT`
- **type** must be `XR_TYPE_CONTROLLER_MODEL_KEY_STATE_MSFT`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

```c
#define XR_NULL_CONTROLLER_MODEL_KEY_MSFT 0
```

`XR_NULL_CONTROLLER_MODEL_KEY_MSFT` defines an invalid model key value.

```c
XR_DEFINE_ATOM(XrControllerModelKeyMSFT)
```

The controller model key used to retrieve the data for the renderable controller model and associated properties and state.

**Load controller model as glTF 2.0 data**

Once the application obtained a valid `modelKey`, it can use the `xrLoadControllerModelMSFT` function to load the GLB data for the controller model.

The `xrLoadControllerModelMSFT` function loads the controller model as a byte buffer containing a
binary form of glTF (a.k.a GLB file format) for the controller. The binary glTF data must conform to glTF 2.0 format defined at https://github.com/KhronosGroup/glTF/tree/master/specification/2.0.

```c
XrResult xrLoadControllerModelMSFT(
    XrSession session,
    XrControllerModelKeyMSFT modelKey,
    uint32_t bufferCapacityInput,
    uint32_t* bufferCountOutput,
    uint8_t* buffer);
```

### Parameter Descriptions

- **session** is the specified XrSession.
- **modelKey** is the model key corresponding to the controller render model being queried.
- **bufferCapacityInput** is the capacity of the buffer array, or 0 to indicate a request to retrieve the required capacity.
- **bufferCountOutput** filled in by the runtime with the count of elements in buffer array, or returns the required capacity in the case that bufferCapacityInput is insufficient.
- **buffer** is a pointer to an application-allocated array of the model for the device that will be filled with the uint8_t values by the runtime. It can be NULL if bufferCapacityInput is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required buffer size.

The xrLoadControllerModelMSFT function may be a slow operation and therefore should be invoked from a non-timing critical thread.

If the input modelKey is invalid, i.e. it is XR_NULL_CONTROLLER_MODEL_KEY_MSFT or not a key returned from XrControllerModelKeyStateMSFT, the runtime must return XR_ERROR_CONTROLLER_MODEL_KEY_INVALID_MSFT.
Valid Usage (Implicit)

- The `XR_MSFT_controller_model` extension must be enabled prior to calling `xrLoadControllerModelMSFT`
- `session` must be a valid `XrSession` handle
- `bufferCountOutput` must be a pointer to a `uint32_t` value
- If `bufferCapacityInput` is not 0, `buffer` must be a pointer to an array of `bufferCapacityInput` `uint8_t` values

Return Codes

Success

- XR_SUCCESS
- XR_SESSION LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_CONTROLLER_MODEL_KEY_INVALID_MSFT

Animate controller parts

The application can animate parts of the glTF model to represent the user's interaction on the controller, such as pressing a button or pulling a trigger.

Once the application loads the glTF model of the controller, it should first get `XrControllerModelPropertiesMSFT` containing an array of node names in the glTF model that can be animated. These properties, including the order of these node names in the array, must be immutable for a valid `modelKey` in the session, and therefore can be cached. In the frame loop, the application should get `XrControllerModelStateMSFT` to retrieve the pose of each node representing user's interaction on the controller and apply the transform to the corresponding node in the glTF model using application’s glTF renderer.

The `xrGetControllerModelPropertiesMSFT` function returns the controller model properties for a given
XrResult xrGetControllerModelPropertiesMSFT(
    XrSession                        session,
    XrControllerModelKeyMSFT         modelKey,
    XrControllerModelPropertiesMSFT* properties);

**Parameter Descriptions**

- **session** is the specified `XrSession`.
- **modelKey** is a valid model key obtained from `XrControllerModelKeyStateMSFT`.
- **properties** is an `XrControllerModelPropertiesMSFT` returning the properties of the controller model.

The runtime must return the same data in `XrControllerModelPropertiesMSFT` for a valid `modelKey`. Therefore, the application can cache the returned `XrControllerModelPropertiesMSFT` using `modelKey` and reuse the data for each frame.

If the input `modelKey` is invalid, i.e. it is `XR_NULL_CONTROLLER_MODEL_KEY_MSFT` or not a key returned from `XrControllerModelKeyStateMSFT`, the runtime must return `XR_ERROR_CONTROLLER_MODEL_KEY_INVALID_MSFT`.

**Valid Usage (Implicit)**

- The `XR_MSFT_controller_model` extension must be enabled prior to calling `xrGetControllerModelPropertiesMSFT`.
- **session** must be a valid `XrSession` handle.
- **properties** must be a pointer to an `XrControllerModelPropertiesMSFT` structure.
Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_CONTROLLER_MODEL_KEY_INVALID_MSFT

The XrControllerModelPropertiesMSFT structure describes the properties of a controller model including an array of XrControllerModelNodePropertiesMSFT.

typedef struct XrControllerModelPropertiesMSFT {
    XrStructureType                         type;
    void*                                   next;
    uint32_t                                nodeCapacityInput;
    uint32_t                                nodeCountOutput;
    XrControllerModelNodePropertiesMSFT*    nodeProperties;
} XrControllerModelPropertiesMSFT;
Parameter Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain.
- **nodeCapacityInput** is the capacity of the `nodeProperties` array, or 0 to indicate a request to retrieve the required capacity.
- **nodeCountOutput** filled in by the runtime with the count of elements in `nodeProperties` array, or returns the required capacity in the case that `nodeCapacityInput` is insufficient.
- **nodeProperties** is a pointer to an application-allocated array that will be filled with the `XrControllerModelNodePropertiesMSFT` values. It can be `NULL` if `nodeCapacityInput` is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required `nodeProperties` size.

Valid Usage (Implicit)

- The `XR_MSFT_controller_model` extension must be enabled prior to using `XrControllerModelPropertiesMSFT`
- **type** must be `XR_TYPE_CONTROLLER_MODEL_PROPERTIES_MSFT`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- If `nodeCapacityInput` is not 0, `nodeProperties` must be a pointer to an array of `nodeCapacityInput` `XrControllerModelNodePropertiesMSFT` structures

The `XrControllerModelNodePropertiesMSFT` structure describes properties of animatable nodes, including the node name and parent node name to locate a glTF node in the controller model that can be animated based on user's interactions on the controller.

typedef struct XrControllerModelNodePropertiesMSFT {
    XrStructureType    type;
    void*              next;
    char               parentNodeName[XR_MAX_CONTROLLER_MODEL_NODE_NAME_SIZE_MSFT];
    char               nodeName[XR_MAX_CONTROLLER_MODEL_NODE_NAME_SIZE_MSFT];
} XrControllerModelNodePropertiesMSFT;
Parameter Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain.
- **parentNodeName** is the name of the parent node in the provided glTF file. The parent name **may** be empty if it should not be used to locate this node.
- **nodeName** is the name of this node in the provided glTF file.

The node can be located in the glTF node hierarchy by finding the node(s) with the matching node name and parent node name. If the **parentNodeName** is empty, the matching will be solely based on the **nodeName**.

If there are multiple nodes in the glTF file matches the condition above, the first matching node using depth-first traversal in the glTF scene **should** be animated and the rest **should** be ignored.

The runtime **must** not return any **nodeName** or **parentName** that doesn't match any glTF nodes in the corresponding controller model.

Valid Usage (Implicit)

- The **XR_MSFT_controller_model** extension **must** be enabled prior to using `XrControllerModelNodePropertiesMSFT`
- **type** **must** be `XR_TYPE_CONTROLLER_MODEL_NODE_PROPERTIES_MSFT`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **parentNodeName** **must** be a null-terminated UTF-8 string whose length is less than or equal to `XR_MAX_CONTROLLER_MODEL_NODE_NAME_SIZE_MSFT`
- **nodeName** **must** be a null-terminated UTF-8 string whose length is less than or equal to `XR_MAX_CONTROLLER_MODEL_NODE_NAME_SIZE_MSFT`

The **xrGetControllerModelStateMSFT** function returns the current state of the controller model representing user's interaction to the controller, such as pressing a button or pulling a trigger.

```c
XrResult xrGetControllerModelStateMSFT(
    XrSession                                   session,
    XrControllerModelKeyMSFT                    modelKey,
    XrControllerModelStateMSFT*                 state);
```
Parameter Descriptions

• **session** is the specified *XrSession*.
• **modelKey** is the model key corresponding to the controller model being queried.
• **state** is a pointer to *XrControllerModelNodeStateMSFT* returns the current controller model state.

The runtime *may* return different state for a model key after each call to *xrSyncActions*, which represents the latest state of the user interactions.

If the input **modelKey** is invalid, i.e. it is *XR_NULL_CONTROLLER_MODEL_KEY_MSFT* or not a key returned from *XrControllerModelKeyStateMSFT*, the runtime *must* return *XR_ERROR_CONTROLLER_MODEL_KEY_INVALID_MSFT*.

Valid Usage (Implicit)

• The *XR_MSFT_controller_model* extension *must* be enabled prior to calling *xrGetControllerModelStateMSFT*
• **session** *must* be a valid *XrSession* handle
• **state** *must* be a pointer to an *XrControllerModelStateMSFT* structure

Return Codes

**Success**

• *XR_SUCCESS*
• *XR_SESSION_LOSS_PENDING*

**Failure**

• *XR_ERROR_FUNCTION_UNSUPPORTED*
• *XR_ERROR_VALIDATION_FAILURE*
• *XR_ERROR_HANDLE_INVALID*
• *XR_ERROR_INSTANCE_LOST*
• *XR_ERROR_SESSION_LOST*
• *XR_ERROR_OUT_OF_MEMORY*
• *XR_ERROR_CONTROLLER_MODEL_KEY_INVALID_MSFT*
The `XrControllerModelNodeStateMSFT` structure describes the state of a node in a controller model.

```c
typedef struct XrControllerModelStateMSFT {
    XrStructureType type;
    void* next;
    uint32_t nodeCapacityInput;
    uint32_t nodeCountOutput;
    XrControllerModelNodeStateMSFT* nodeStates;
} XrControllerModelStateMSFT;
```

### Parameter Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain.
- **nodeCapacityInput** is the capacity of the `nodeStates` array, or 0 to indicate a request to retrieve the required capacity.
- **nodeCountOutput** filled in by the runtime with the count of elements in `nodeStates` array, or returns the required capacity in the case that `nodeCapacityInput` is insufficient.
- **nodeStates** is a pointer to an application-allocated array that will be filled with the `XrControllerModelNodeStateMSFT` values. It can be `NULL` if `sourceCapacityInput` is 0.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required `nodeStates` size.

### Valid Usage (Implicit)

- The `XR_MSFT_controller_model` extension must be enabled prior to using `XrControllerModelStateMSFT`
- **type** must be `XR_TYPE_CONTROLLER_MODEL_STATE_MSFT`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- If `nodeCapacityInput` is not 0, `nodeStates` must be a pointer to an array of `nodeCapacityInput` `XrControllerModelNodeStateMSFT` structures
typedef struct XrControllerModelNodeStateMSFT {
    XrStructureType    type;
    void*              next;
    XrPosef            nodePose;
} XrControllerModelNodeStateMSFT;

Parameter Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain.
- **nodePose** is an XrPosef of the node in its parent node space.

The state is corresponding to the glTF node identified by the **nodeName** and **nodeParentName** of the node property at the same array index in the nodeProperties in XrControllerModelPropertiesMSFT.

The **nodePose** is based on the user's interaction on the controller at the latest xrSyncActions, represented as the XrPosef of the node in it's parent node space.

Valid Usage (Implicit)

- The XR_MSFT_controller_model extension must be enabled prior to using XrControllerModelNodeStateMSFT
- **type** must be XR_TYPE_CONTROLLER_MODEL_NODE_STATE_MSFT
- **next** must be NULL or a valid pointer to the next structure in a structure chain

New Object Types

New Flag Types

New Enum Constants

- XR_MAX_CONTROLLER_MODEL_NODE_NAME_SIZE_MSFT
- XR_TYPE_CONTROLLER_MODEL_NODE_PROPERTIES_MSFT
- XR_TYPE_CONTROLLER_MODEL_PROPERTIES_MSFT
- XR_TYPE_CONTROLLER_MODEL_NODE_STATE_MSFT
- XR_TYPE_CONTROLLER_MODEL_STATE_MSFT
- XR_ERROR_CONTROLLER_MODEL_KEY_INVALID_MSFT

New Enums
New Structures

- XrControllerModelKeyStateMSFT
- XrControllerModelNodePropertiesMSFT
- XrControllerModelPropertiesMSFT
- XrControllerModelNodeStateMSFT
- XrControllerModelStateMSFT

New Functions

- xrGetControllerModelKeyMSFT
- xrLoadControllerModelMSFT
- xrGetControllerModelPropertiesMSFT
- xrGetControllerModelStateMSFT

Issues

Version History

- Revision 1, 2020-03-12 (Yin Li)
  - Initial extension description
- Revision 2, 2020-08-12 (Bryce Hutchings)
  - Remove a possible error condition

12.79. XR_MSFT_first_person_observer

Name String

XR_MSFT_first_person_observer

Extension Type

Instance extension

Registered Extension Number

55

Revision

1

Extension and Version Dependencies

- Requires OpenXR 1.0
- Requires XR_MSFT_secondary_view_configuration
12.79.1. Overview

This first-person observer view configuration enables the runtime to request the application to render an additional first-person view of the scene to be composed onto video frames being captured from a camera attached to and moved with the primary display on the form factor, which is generally for viewing on a 2D screen by an external observer. This first-person camera will be facing forward with roughly the same perspective as the primary views, and so the application should render its view to show objects that surround the user and avoid rendering the user’s body avatar. The runtime is responsible for composing the application’s rendered observer view onto the camera frame based on the chosen environment blend mode for this view configuration, as this extension does not provide the associated camera frame to the application.

This extension requires the XR_MSFT_secondary_view_configuration extension to also be enabled. XR_VIEW_CONFIGURATION_TYPE_SECONDARY_MONO_FIRST_PERSON_OBSERVER_MSFT requires one element in XrViewConfigurationProperties and one projection in each XrCompositionLayerProjection layer.

Runtimes should only make this view configuration active when the user or the application activates a runtime feature that will make use of the resulting composed camera frames, for example taking a mixed reality photo. Otherwise, the runtime should leave this view configuration inactive to avoid the application wasting CPU and GPU resources rendering unnecessarily for this extra view.

Because this is a first-person view of the scene, applications can share a common culling and instanced rendering pass with their primary view renders. However, the view state (pose and FOV) of the first-person observer view will not match the view state of any of the primary views. Applications enabling this view configuration must call xrLocateViews a second time each frame to explicitly query the view state for the XR_VIEW_CONFIGURATION_TYPE_SECONDARY_MONO_FIRST_PERSON_OBSERVER_MSFT configuration.

This secondary view configuration may support a different set of environment blend modes than the primary view configuration. For example, a device that only supports additive blending for its primary display may support alpha-blending when composing the first-person observer view with camera frames. The application should render with assets and shaders that produce output acceptable to both the primary and observer view configuration’s environment blend modes when sharing render passes across both view configurations.
New Object Types

New Flag Types

New Enum Constants

XrViewConfigurationType enumeration is extended with:

- XR_VIEW_CONFIGURATION_TYPE_SECONDARY_MONO_FIRST_PERSON_OBSERVER_MSFT

New Enums

New Structures

New Functions

Issues

Version History

- Revision 1, 2019-07-30 (Yin LI)
  - Initial extension description

12.80. XR_MSFT_hand_interaction

Name String

XR_MSFT_hand_interaction

Extension Type

Instance extension

Registered Extension Number

51

Revision

1

Extension and Version Dependencies

- Requires OpenXR 1.0

Contributors

Yin Li, Microsoft
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Overview
This extension defines a new interaction profile for near interactions and far interactions driven by directly-tracked hands.

**Hand interaction profile**

Interaction profile path:

- `/interaction_profiles/microsoft/hand_interaction`

Valid for top level user path:

- `/user/hand/left`
- `/user/hand/right`

This interaction profile provides basic pose and actions for near and far interactions using hand tracking input.

Supported component paths:

- `../input/select/value`
- `../input/squeeze/value`
- `../input/aim/pose`
- `../input/grip/pose`

The application **should** use the `../select/value` and `../aim/pose` paths for far hand interactions, such as using a virtual laser pointer to target and click a button on the wall. Here, `../select/value can` be used as either a boolean or float action type, where the value `XR_TRUE` or `1.0f` represents a closed hand shape.

The application **should** use the `../squeeze/value` and `../grip/pose` for near hand interactions, such as picking up a virtual object within the user's reach from a table. Here, `../squeeze/value can` be used as either a boolean or float action type, where the value `XR_TRUE` or `1.0f` represents a closed hand shape.

The runtime **may** trigger both "select" and "squeeze" actions for the same hand gesture if the user's hand gesture is able to trigger both near and far interactions. The application **should** not assume they are as independent as two buttons on a controller.

**New Object Types**

**New Flag Types**

**New Enum Constants**

**New Enums**

**New Structures**

**New Functions**
12.81. XR_MSFT_hand_tracking_mesh

Name String
XR_MSFT_hand_tracking_mesh

Extension Type
Instance extension

Registered Extension Number
53

Revision
4

Extension and Version Dependencies
- Requires OpenXR 1.0
- Requires XR_EXT_hand_tracking

Last Modified Date
2021-10-20

IP Status
No known IP claims.

Contributors
Yin Li, Microsoft
Lachlan Ford, Microsoft
Alex Turner, Microsoft
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12.81.1. Overview

This extension enables hand tracking inputs represented as a dynamic hand mesh. It enables applications to render hands in XR experiences and interact with virtual objects using hand meshes.

The application must also enable the XR_EXT_hand_tracking extension in order to use this extension.

Inspect system capability
An application can inspect whether the system is capable of hand tracking meshes by chaining an `XrSystemHandTrackingMeshPropertiesMSFT` structure to the `XrSystemProperties` when calling `xrGetSystemProperties`.

```c
typedef struct XrSystemHandTrackingMeshPropertiesMSFT {
    XrStructureType type;
    void* next;
    XrBool32 supportsHandTrackingMesh;
    uint32_t maxHandMeshIndexCount;
    uint32_t maxHandMeshVertexCount;
} XrSystemHandTrackingMeshPropertiesMSFT;
```

### Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **supportsHandTrackingMesh** is an `XrBool32`, indicating if current system is capable of hand tracking mesh input.
- **maxHandMeshIndexCount** is a `uint32_t` returns the maximum count of indices that will be returned from the hand tracker.
- **maxHandMeshVertexCount** is a `uint32_t` returns the maximum count of vertices that will be returned from the hand tracker.

If a runtime returns `XR_FALSE` for `supportsHandTrackingMesh`, the system does not support hand tracking mesh input, and therefore must return `XR_ERROR_FEATURE_UNSUPPORTED` from `xrCreateHandMeshSpaceMSFT` and `xrUpdateHandMeshMSFT`. The application should avoid using hand mesh functionality when `supportsHandTrackingMesh` is `XR_FALSE`.

If a runtime returns `XR_TRUE` for `supportsHandTrackingMesh`, the system supports hand tracking mesh input. In this case, the runtime must return a positive number for `maxHandMeshIndexCount` and `maxHandMeshVertexCount`. An application should use `maxHandMeshIndexCount` and `maxHandMeshVertexCount` to preallocate hand mesh buffers and reuse them in their render loop when calling `xrUpdateHandMeshMSFT` every frame.
Valid Usage (Implicit)

- The `XR_MSFT_hand_tracking_mesh` extension must be enabled prior to using `XrSystemHandTrackingMeshPropertiesMSFT`
- `type` must be `XR_TYPE_SYSTEM_HAND_TRACKING_MESH_PROPERTIES_MSFT`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain

12.81.2. Obtain a hand tracker handle

An application first creates an `XrHandTrackerEXT` handle using the `xrCreateHandTrackerEXT` function for each hand. The application can also reuse the same `XrHandTrackerEXT` handle previously created for the hand joint tracking. When doing so, the hand mesh input is always in sync with hand joints input with the same `XrHandTrackerEXT` handle.

12.81.3. Create a hand mesh space

The application creates a hand mesh space using function `xrCreateHandMeshSpaceMSFT`. The position and normal of hand mesh vertices will be represented in this space.

```c
XrResult xrCreateHandMeshSpaceMSFT(
    XrHandTrackerEXT                            handTracker,  // handTracker is an XrHandTrackerEXT handle previously created with the xrCreateHandTrackerEXT function.
    const XrHandMeshSpaceCreateInfoMSFT*        createInfo,  // createInfo is the XrHandMeshSpaceCreateInfoMSFT used to specify the hand mesh space.
    XrSpace*                                    space);  // space is the returned XrSpace handle of the new hand mesh space.
```

A hand mesh space location is specified by runtime preference to effectively represent hand mesh vertices without unnecessary transformations. For example, an optical hand tracking system can define the hand mesh space origin at the depth camera’s optical center.

An application should create separate hand mesh space handles for each hand to retrieve the corresponding hand mesh data. The runtime may use the lifetime of this hand mesh space handle to manage the underlying device resources. Therefore, the application should destroy the hand mesh handle after it is finished using the hand mesh.
The hand mesh space can be related to other spaces in the session, such as view reference space, or grip action space from the `/interaction_profiles/khr/simple_controller` interaction profile. The hand mesh space may be not locatable when the hand is outside of the tracking range, or if focus is removed from the application. In these cases, the runtime must not set the `XR_SPACE_LOCATION_POSITION_VALID_BIT` and `XR_SPACE_LOCATION_ORIENTATION_VALID_BIT` bits on calls to `xrLocateSpace` with the hand mesh space, and the application should avoid using the returned poses or query for hand mesh data.

If the underlying `XrHandTrackerEXT` is destroyed, the runtime must continue to support `xrLocateSpace` using the hand mesh space, and it must return space location with `XR_SPACE_LOCATION_POSITION_VALID_BIT` and `XR_SPACE_LOCATION_ORIENTATION_VALID_BIT` unset.

The application may create a mesh space for the reference hand by setting `handPoseType` to `XR_HAND_POSE_TYPE_REFERENCE_OPEN_PALM_MSFT`. Hand mesh spaces for the reference hand must only be locatable in reference to mesh spaces or joint spaces of the reference hand.

### Valid Usage (Implicit)

- The `XR_MSFT_hand_tracking_mesh` extension must be enabled prior to calling `xrCreateHandMeshSpaceMSFT`
- `handTracker` must be a valid `XrHandTrackerEXT` handle
- `createInfo` must be a pointer to a valid `XrHandMeshSpaceCreateInfoMSFT` structure
- `space` must be a pointer to an `XrSpace` handle
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_POSE_INVALID
- XR_ERROR_FEATURE_UNSUPPORTED

typedef struct XrHandMeshSpaceCreateInfoMSFT {
    XrStructureType       type;
    const void*           next;
    XrHandPoseTypeMSFT    handPoseType;
    XrPosef               poseInHandMeshSpace;
} XrHandMeshSpaceCreateInfoMSFT;
### Member Descriptions

- **type** is the *XrStructureType* of this structure.
- **next** is **NULL** or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **handPoseType** is an *XrHandPoseTypeMSFT* used to specify the type of hand this mesh is tracking. Indices and vertices returned from *xrUpdateHandMeshMSFT* for a hand type will be relative to the corresponding space create with the same hand type.
- **poseInHandMeshSpace** is an *XrPosef* defining the position and orientation of the new space’s origin within the natural reference frame of the hand mesh space.

### Valid Usage (Implicit)

- The *XR_MSFT_hand_tracking_mesh* extension must be enabled prior to using *XrHandMeshSpaceCreateInfoMSFT*
- **type** must be **XR_TYPE_HAND_MESH_SPACE_CREATE_INFO_MSFT**
- **next** must be **NULL** or a valid pointer to the next structure in a structure chain
- **handPoseType** must be a valid *XrHandPoseTypeMSFT* value

### 12.81.4. Locate the hand mesh

The application can use the *xrUpdateHandMeshMSFT* function to retrieve the hand mesh at a given timestamp. The hand mesh’s vertices position and normal are represented in the hand mesh space created by *xrCreateHandMeshSpaceMSFT* with a same *XrHandTrackerEXT*.

```c
XrResult xrUpdateHandMeshMSFT(
    XrHandTrackerEXT handTracker,
    const XrHandMeshUpdateInfoMSFT* updateInfo,
    XrHandMeshMSFT* handMesh);
```
Parameter Descriptions

- **handTracker** is an XrHandTrackerEXT handle previously created with xrCreateHandTrackerEXT.
- **updateInfo** is an XrHandMeshUpdateInfoMSFT which contains information to query the hand mesh.
- **handMesh** is an XrHandMeshMSFT structure to receive the updates of hand mesh data.

The application **should** preallocate the index buffer and vertex buffer in XrHandMeshMSFT using the maxHandMeshIndexCount and maxHandMeshVertexCount from the XrSystemHandTrackingMeshPropertiesMSFT returned from the xrGetSystemProperties function.

The application **should** preallocate the XrHandMeshMSFT structure and reuse it for each frame so as to reduce the copies of data when underlying tracking data is not changed. The application should use indexBufferChanged and vertexBufferChanged in XrHandMeshMSFT to detect changes and avoid unnecessary data processing when there is no changes.

Valid Usage (Implicit)

- The XR_MSFT_hand_tracking_mesh extension **must** be enabled prior to calling xrUpdateHandMeshMSFT
- **handTracker** **must** be a valid XrHandTrackerEXT handle
- **updateInfo** **must** be a pointer to a valid XrHandMeshUpdateInfoMSFT structure
- **handMesh** **must** be a pointer to an XrHandMeshMSFT structure
Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_SIZE_INSUFFICIENT
• XR_ERROR_TIME_INVALID
• XR_ERROR_FEATURE_UNSUPPORTED

A XrHandMeshUpdateInfoMSFT describes the information to update a hand mesh.

typedef struct XrHandMeshUpdateInfoMSFT {
    XrStructureType       type;
    const void*           next;
    XrTime                time;
    XrHandPoseTypeMSFT    handPoseType;
} XrHandMeshUpdateInfoMSFT;

Member Descriptions

• type is the XrStructureType of this structure.

• next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

• time is the XrTime that describes the time for which the application wishes to query the hand mesh state.

• handPoseType is an XrHandPoseTypeMSFT which describes the type of hand pose of the hand mesh to update.
A runtime may not maintain a full history of hand mesh data, therefore the returned \texttt{XrHandMeshMSFT} might return data that's not exactly corresponding to the \texttt{time} input. If the runtime cannot return any tracking data for the given \texttt{time} at all, it must set \texttt{isActive} to \texttt{XR_FALSE} for the call to \texttt{xrUpdateHandMeshMSFT}. Otherwise, if the runtime returns \texttt{isActive} as \texttt{XR_TRUE}, the data in \texttt{XrHandMeshMSFT} must be valid to use.

An application can choose different \texttt{handPoseType} values to query the hand mesh data. The returned hand mesh must be consistent to the hand joint space location on the same \texttt{XrHandTrackerEXT} when using the same \texttt{XrHandPoseTypeMSFT}.

### Valid Usage (Implicit)

- The \texttt{XR_MSFT_hand_tracking_mesh} extension must be enabled prior to using \texttt{XrHandMeshUpdateInfoMSFT}
- \texttt{type} must be \texttt{XR_TYPE_HAND_MESH_UPDATE_INFO_MSFT}
- \texttt{next} must be \texttt{NULL} or a valid pointer to the next structure in a structure chain
- \texttt{handPoseType} must be a valid \texttt{XrHandPoseTypeMSFT} value

A \texttt{XrHandMeshMSFT} structure contains data and buffers to receive updates of hand mesh tracking data from \texttt{xrUpdateHandMeshMSFT} function.

```c
typedef struct XrHandMeshMSFT {
    XrStructureType               type;
    void*                         next;
    XrBool32                      isActive;
    XrBool32                      indexBufferChanged;
    XrBool32                      vertexBufferChanged;
    XrHandMeshIndexBufferMSFT     indexBuffer;
    XrHandMeshVertexBufferMSFT    vertexBuffer;
} XrHandMeshMSFT;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **isActive** is an `XrBool32` indicating if the current hand tracker is active.
- **indexBufferChanged** is an `XrBool32` indicating if the `indexBuffer` content was changed during the update.
- **vertexBufferChanged** is an `XrBool32` indicating if the `vertexBuffer` content was changed during the update.
- **indexBuffer** is an `XrHandMeshIndexBufferMSFT` returns the index buffer of the tracked hand mesh.
- **vertexBuffer** is an `XrHandMeshVertexBufferMSFT` returns the vertex buffer of the tracked hand mesh.

When the returned **isActive** value is `XR_FALSE`, the runtime indicates the hand is not actively tracked, for example, the hand is outside of sensor's range, or the input focus is taken away from the application. When the runtime returns `XR_FALSE` to **isActive**, it **must** set **indexBufferChanged** and **vertexBufferChanged** to `XR_FALSE`, and **must** not change the content in **indexBuffer** or **vertexBuffer**,

When the returned **isActive** value is `XR_TRUE`, the hand tracking mesh represented in **indexBuffer** and **vertexBuffer** are updated to the latest data of the time given to the `xrUpdateHandMeshMSFT` function. The runtime **must** set **indexBufferChanged** and **vertexBufferChanged** to reflect whether the index or vertex buffer's content are changed during the update. In this way, the application can easily avoid unnecessary processing of buffers when there's no new data.

The hand mesh is represented in triangle lists and each triangle's vertices are in clockwise order when looking from outside of the hand. When hand tracking is active, i.e. when **isActive** is returned as `XR_TRUE`, the returned **indexBuffer.indexCountOutput** value **must** be positive and multiple of 3, and **vertexBuffer.vertexCountOutput** value **must** be equal to or larger than 3.

Valid Usage (Implicit)

- The `XR_MSFT_hand_tracking_mesh` extension **must** be enabled prior to using `XrHandMeshMSFT`
- **type** **must** be `XR_TYPE_HAND_MESH_MSFT`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **indexBuffer** **must** be a valid `XrHandMeshIndexBufferMSFT` structure
- **vertexBuffer** **must** be a valid `XrHandMeshVertexBufferMSFT` structure
A `XrHandMeshIndexBufferMSFT` structure includes an array of indices describing the triangle list of a hand mesh.

```c
typedef struct XrHandMeshIndexBufferMSFT {
    uint32_t     indexBufferKey;
    uint32_t     indexCapacityInput;
    uint32_t     indexCountOutput;
    uint32_t*    indices;
} XrHandMeshIndexBufferMSFT;
```

**Member Descriptions**

- `indexBufferKey` is a `uint32_t` serving as the key of the returned index buffer content or 0 to indicate a request to retrieve the latest indices regardless of existing content in `indices`.
- `indexCapacityInput` is a positive `uint32_t` describes the capacity of the `indices` array.
- `indexCountOutput` is a `uint32_t` returned by the runtime with the count of indices written in `indices`.
- `indices` is an array of indices filled in by the runtime, specifying the indices of the triangles list in the vertex buffer.

An application **should** preallocate the indices array using the `maxHandMeshIndexCount` in `XrSystemHandTrackingMeshPropertiesMSFT` returned from `xrGetSystemProperties`. In this way, the application can avoid possible insufficient buffer sizes for each query, and therefore avoid reallocating memory each frame.

The input `indexCapacityInput` **must** not be 0, and `indices` **must** not be `NULL`, or else the runtime **must** return `XR_ERROR_VALIDATION_FAILURE` on calls to the `xrUpdateHandMeshMSFT` function.

If the input `indexCapacityInput` is not sufficient to contain all output indices, the runtime **must** return `XR_ERROR_SIZE_INSUFFICIENT` on calls to `xrUpdateHandMeshMSFT`, not change the content in `indexBufferKey` and `indices`, and return 0 for `indexCountOutput`.

If the input `indexCapacityInput` is equal to or larger than the `maxHandMeshIndexCount` in `XrSystemHandTrackingMeshPropertiesMSFT` returned from `xrGetSystemProperties`, the runtime **must** not return `XR_ERROR_SIZE_INSUFFICIENT` error on `xrUpdateHandMeshMSFT` because of insufficient index buffer size.

If the input `indexBufferKey` is 0, the capacity of indices array is sufficient, and hand mesh tracking is active, the runtime **must** return the latest non-zero `indexBufferKey`, and fill in `indexCountOutput` and `indices`.

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If the input `indexBufferKey` is not 0, the runtime can either return without changing `indexCountOutput` or content in `indices`, and return `XR_FALSE` for `indexBufferChanged` indicating the indices are not changed; or return a new non-zero `indexBufferKey` and fill in latest data in `indexCountOutput` and `indices`, and return `XR_TRUE` for `indexBufferChanged` indicating the indices are updated to a newer version.

An application can keep the `XrHandMeshIndexBufferMSFT` structure for each frame in a frame loop and use the returned `indexBufferKey` to identify different triangle list topology described in `indices`. The application can therefore avoid unnecessary processing of indices, such as coping them to GPU memory.

The runtime must return the same `indexBufferKey` for the same `XrHandTrackerEXT` at a given time, regardless of the input `XrHandPoseTypeMSFT` in `XrHandMeshUpdateInfoMSFT`. This ensures the index buffer has the same mesh topology and allows the application to reason about vertices across different hand pose types. For example, the application can build a procedure to perform UV mapping on vertices of a hand mesh using `XR_HAND_POSE_TYPE_REFERENCE_OPEN_PALM_MSFT`, and apply the resultant UV data on vertices to the mesh returned from the same hand tracker using `XR_HAND_POSE_TYPE_TRACKED_MSFT`.

### Valid Usage (Implicit)

- The `XR_MSFT_hand_tracking_mesh` extension must be enabled prior to using `XrHandMeshIndexBufferMSFT`
- `indices` must be a pointer to an array of `indexCapacityInput uint32_t` values
- The `indexCapacityInput` parameter must be greater than 0

A `XrHandMeshVertexBufferMSFT` structure includes an array of vertices of the hand mesh represented in the hand mesh space.

```c
typedef struct XrHandMeshVertexBufferMSFT {
    XrTime                   vertexUpdateTime;
    uint32_t                 vertexCapacityInput;
    uint32_t                 vertexCountOutput;
    XrHandMeshVertexMSFT*    vertices;
} XrHandMeshVertexBufferMSFT;
```
Member Descriptions

- **vertexUpdateTime** is an `XrTime` representing the time when the runtime receives the vertex buffer content or 0 to indicate a request to retrieve latest vertices regardless of existing content in `vertices`.

- **vertexCapacityInput** is a positive `uint32_t` describes the capacity of the `vertices` array.

- **vertexCountOutput** is a `uint32_t` filled in by the runtime with the count of vertices written in `vertices`.

- **vertices** is an array of `XrHandMeshVertexMSFT` filled in by the runtime, specifying the vertices of the hand mesh including the position and normal vector in the hand mesh space.

An application **should** preallocate the vertices array using the `maxHandMeshVertexCount` in `XrSystemHandTrackingMeshPropertiesMSFT` returned from `xrGetSystemProperties`. In this way, the application can avoid possible insufficient buffer sizes for each query, and therefore avoid reallocating memory each frame.

The input **vertexCapacityInput** **must** not be 0, and **vertices** **must** not be `NULL`, or else the runtime **must** return `XR_ERROR_VALIDATION_FAILURE` on calls to the `xrUpdateHandMeshMSFT` function.

If the input **vertexCapacityInput** is not sufficient to contain all output vertices, the runtime **must** return `XR_ERROR_SIZE_INSUFFICIENT` on calls to the `xrUpdateHandMeshMSFT`, do not change content in `vertexUpdateTime` and `vertices`, and return 0 for `vertexCountOutput`.

If the input **vertexCapacityInput** is equal to or larger than the `maxHandMeshVertexCount` in `XrSystemHandTrackingMeshPropertiesMSFT` returned from `xrGetSystemProperties`, the runtime **must** not return `XR_ERROR_SIZE_INSUFFICIENT` on calls to the `xrUpdateHandMeshMSFT` because of insufficient vertex buffer size.

If the input **vertexUpdateTime** is 0, and the capacity of the vertices array is sufficient, and hand mesh tracking is active, the runtime **must** return the latest non-zero **vertexUpdateTime**, and fill in the **vertexCountOutput** and **vertices** fields.

If the input **vertexUpdateTime** is not 0, the runtime **can** either return without changing **vertexCountOutput** or the content in **vertices**, and return `XR_FALSE` for `vertexBufferChanged` indicating the vertices are not changed; or return a new non-zero **vertexUpdateTime** and fill in latest data in **vertexCountOutput** and **vertices** and return `XR_TRUE` for `vertexBufferChanged` indicating the vertices are updated to a newer version.

An application **can** keep the `XrHandMeshVertexBufferMSFT` structure for each frame in frame loop and use the returned **vertexUpdateTime** to detect the changes of the content in **vertices**. The application can therefore avoid unnecessary processing of vertices, such as coping them to GPU memory.
Valid Usage (Implicit)

- The `XR_MSFT_hand_tracking_mesh` extension must be enabled prior to using `XrHandMeshVertexBufferMSFT`

- `vertices` must be a pointer to an array of `vertexCapacityInput XrHandMeshVertexMSFT` structures

- The `vertexCapacityInput` parameter must be greater than 0

Each `XrHandMeshVertexMSFT` includes the position and normal of a vertex of a hand mesh.

```c
typedef struct XrHandMeshVertexMSFT {
    XrVector3f position;
    XrVector3f normal;
} XrHandMeshVertexMSFT;
```

Member Descriptions

- `position` is an `XrVector3f` structure representing the position of the vertex in the hand mesh space, measured in meters.

- `normal` is an `XrVector3f` structure representing the unweighted normal of the triangle surface at the vertex as a unit vector in hand mesh space.

Valid Usage (Implicit)

- The `XR_MSFT_hand_tracking_mesh` extension must be enabled prior to using `XrHandMeshVertexBufferMSFT`

12.81.5. Example code for hand mesh tracking

Following example code demos preallocating hand mesh buffers and updating the hand mesh in rendering loop

```c
XrInstance instance; // previously initialized
XrSystemId systemId; // previously initialized
XrSession session; // previously initialized

// Inspect hand tracking mesh system properties
```
XrSystemHandTrackingMeshPropertiesMSFT
handMeshSystemProperties{XR_TYPE_SYSTEM_HAND_TRACKING_MESH_PROPERTIES_MSFT};
XrSystemProperties systemProperties{XR_TYPE_SYSTEM_PROPERTIES,
&handMeshSystemProperties};
CHK_XR(xrGetSystemProperties(instance, systemId, &systemProperties));
if (!handMeshSystemProperties.supportsHandTrackingMesh) {
    // the system does not support hand mesh tracking
    return;
}

// Get function pointer for xrCreateHandTrackerEXT
PFN_xrCreateHandTrackerEXT pfnCreateHandTrackerEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrCreateHandTrackerEXT",
    reinterpret_cast<PFN_xrVoidFunction*>(
        &pfnCreateHandTrackerEXT)));

// Create a tracker for left hand.
XrHandTrackerEXT leftHandTracker{};
{
    XrHandTrackerCreateInfoEXT createInfo{XR_TYPE_HAND_TRACKER_CREATE_INFO_EXT};
    createInfo.hand = XR_HAND_LEFT_EXT;
    createInfo.handJointSet = XR_HAND_JOINT_SET_DEFAULT_EXT;
    CHK_XR(pfnCreateHandTrackerEXT(session, &createInfo, &leftHandTracker));
}

// Get function pointer for xrCreateHandMeshSpaceMSFT
PFN_xrCreateHandMeshSpaceMSFT pfnCreateHandMeshSpaceMSFT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrCreateHandMeshSpaceMSFT",
    reinterpret_cast<PFN_xrVoidFunction*>(
        &pfnCreateHandMeshSpaceMSFT)));

// Create the hand mesh spaces
XrSpace leftHandMeshSpace{};
{
    XrHandMeshSpaceCreateInfoMSFT createInfo{XR_TYPE_HAND_MESH_SPACE_CREATE_INFO_MSFT};
    createInfo.poseInHandMeshSpace = {{0, 0, 0, 1}, {0, 0, 0}};
    CHK_XR(pfnCreateHandMeshSpaceMSFT(leftHandTracker, &createInfo, &leftHandMeshSpace));
}

// Preallocate buffers for hand mesh indices and vertices
std::vector<uint32_t> handMeshIndices(handMeshSystemProperties.maxHandMeshIndexCount);
std::vector<XrHandMeshVertexMSFT> handMeshVertices(handMeshSystemProperties.maxHandMeshVertexCount);

XrHandMeshMSFT leftHandMesh{XR_TYPE_HAND_MESH_MSFT};
leftHandMesh.indexBuffer.indexCapacityInput = (uint32_t)handMeshIndices.size();
leftHandMesh.indexBuffer.indices = handMeshIndices.data();
leftHandMesh.vertexBuffer.vertexCapacityInput = (uint32_t)handMeshVertices.size();
12.81.6. Get hand reference poses

By default, an XrHandTrackerEXT tracks a default hand pose type, that is to provide best fidelity to the user's actual hand motion. This is the same with XR_HAND_POSE_TYPE_TRACKED_MSFT (i.e. value 0) in a chained XrHandPoseTypeInfoMSFT structure to the next pointer of XrHandTrackerCreateInfoEXT when calling xrCreateHandTrackerEXT.

Some hand mesh visualizations may require an initial analysis or processing of the hand mesh relative to the joints of the hand. For example, a hand visualization may generate a UV mapping for the hand mesh vertices by raycasting outward from key joints against the mesh to find key vertices.

To avoid biasing such static analysis with the arbitrary tracked hand pose, an application can instead create a different XrHandTrackerEXT handle with a reference hand pose type when calling xrCreateHandTrackerEXT. This will instruct the runtime to provide a reference hand pose that is better suited for such static analysis.
An application can chain an `XrHandPoseTypeInfoMSFT` structure to the `XrHandTrackerCreateInfoEXT::next` pointer when calling `xrCreateHandTrackerEXT` to indicate the hand tracker to return the hand pose of specific `XrHandPoseTypeMSFT`.

```c
typedef struct XrHandPoseTypeInfoMSFT {
    XrStructureType type;
    const void* next;
    XrHandPoseTypeMSFT handPoseType;
} XrHandPoseTypeInfoMSFT;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **handPoseType** is an `XrHandPoseTypeMSFT` that describes the type of hand pose of the hand tracking.

**Valid Usage (Implicit)**

- The `XR_MSFT_hand_tracking_mesh` extension **must** be enabled prior to using `XrHandPoseTypeInfoMSFT`
- **type** must be `XR_TYPE_HAND_POSE_TYPE_INFO_MSFT`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- **handPoseType** must be a valid `XrHandPoseTypeMSFT` value

The `XrHandPoseTypeMSFT` describes the type of input hand pose from `XrHandTrackerEXT`.

```c
typedef enum XrHandPoseTypeMSFT {
    XR_HAND_POSE_TYPE_TRACKED_MSFT = 0,
    XR_HAND_POSE_TYPE_REFERENCE_OPEN_PALM_MSFT = 1,
    XR_HAND_POSE_TYPE_MAX_ENUM_MSFT = 0x7FFFFFFF
} XrHandPoseTypeMSFT;
```
Enumerant Descriptions

- **XR_HAND_POSE_TYPE_TRACKED_MSFT** represents a hand pose provided by actual tracking of the user's hand.
- **XR_HAND_POSE_TYPE_REFERENCE_OPEN_PALM_MSFT** represents a stable reference hand pose in a relaxed open hand shape.

The **XR_HAND_POSE_TYPE_TRACKED_MSFT** input provides best fidelity to the user's actual hand motion. When the hand tracking input requires the user to be holding a controller in their hand, the hand tracking input will appear as the user virtually holding the controller. This input can be used to render the hand shape together with the controller in hand.

The **XR_HAND_POSE_TYPE_REFERENCE_OPEN_PALM_MSFT** input does not move with the user's actual hand. Through this reference hand pose, an application can get a stable hand joint and mesh that has the same mesh topology as the tracked hand mesh using the same XrHandTrackerEXT, so that the application can apply the data computed from a reference hand pose to the corresponding tracked hand.

Although a reference hand pose does not move with user's hand motion, the bone length and hand thickness may be updated, for example when tracking result refines, or a different user's hand is detected. The application should update reference hand joints and meshes when the tracked mesh's indexBufferKey is changed or when the isActive value returned from xrUpdateHandMeshMSFT changes from XR_FALSE to XR_TRUE. It can use the returned indexBufferKey and vertexUpdateTime from xrUpdateHandMeshMSFT to avoid unnecessary CPU or GPU work to process the neutral hand inputs.

### 12.81.7. Example code for reference hand mesh update

The following example code demonstrates detecting reference hand mesh changes and retrieving data for processing.

```c
XrInstance instance;       // previously initialized
XrSession session;        // previously initialized
XrHandTrackerEXT handTracker;  // previously initialized with handJointSet set to XR_HAND_JOINT_SET_DEFAULT_MSFT
XrSpace handMeshReferenceSpace;  // previously initialized with handPoseType set to XR_HAND_POSE_TYPE_REFERENCE_OPEN_PALM_MSFT
XrHandMeshMSFT referenceHandMesh;  // previously initialized with preallocated buffers

// Get function pointer for xrUpdateHandMeshMSFT
PFN_xrUpdateHandMeshMSFT pfnUpdateHandMeshMSFT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrUpdateHandMeshMSFT",
    reinterpret_cast<PFN_xrVoidFunction*>(
        &pfnUpdateHandMeshMSFT)));
```
// Get function pointer for xrCreateHandTrackerEXT
PFN_xrCreateHandTrackerEXT pfnCreateHandTrackerEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrCreateHandTrackerEXT",
        reinterpret_cast<PFN_xrVoidFunction*>(
            &pfnCreateHandTrackerEXT)));

// Get function pointer for xrLocateHandJointsEXT
PFN_xrLocateHandJointsEXT pfnLocateHandJointsEXT;
CHK_XR(xrGetInstanceProcAddr(instance, "xrLocateHandJointsEXT",
        reinterpret_cast<PFN_xrVoidFunction*>(
            &pfnLocateHandJointsEXT)));

while(1){
    // For every frame in frame loop
    const XrTime time = frameState.predictedDisplayTime;

    XrHandMeshUpdateInfoMSFT updateInfo{XR_TYPE_HAND_MESH_UPDATE_INFO_MSFT};
    updateInfo.time = time;
    updateInfo.handPoseType = XR_HAND_POSE_TYPE_REFERENCE_OPEN_PALM_MSFT;
    CHK_XR(pfnUpdateHandMeshMSFT(handTracker, &updateInfo, &referenceHandMesh));

    // Detect if reference hand mesh is changed.
    if (referenceHandMesh.indexBufferChanged || referenceHandMesh.vertexBufferChanged) {
        // Query the joint location using "open palm" reference hand pose.
        XrHandPoseTypeInfoMSFT handPoseTypeInfo{XR_TYPE_HAND_POSE_TYPE_INFO_MSFT};
        handPoseTypeInfo.handPoseType = XR_HAND_POSE_TYPE_REFERENCE_OPEN_PALM_MSFT;

        XrHandTrackerCreateInfoEXT createInfo{XR_TYPE_HAND_TRACKER_CREATE_INFO_EXT};
        createInfo.hand = XR_HAND_LEFT_EXT;
        createInfo.handJointSet = XR_HAND_JOINT_SET_DEFAULT_EXT;
        createInfo.next = &handPoseTypeInfo;

        XrHandTrackerEXT referenceHandTracker;
        CHK_XR(pfnCreateHandTrackerEXT(session, &createInfo, &referenceHandTracker));

        XrHandJointsLocateInfoEXT locateInfo{XR_TYPE_HAND_JOINTS_LOCATE_INFO_EXT};
        locateInfo.next = &handPoseTypeInfo;
        locateInfo.baseSpace = handMeshReferenceSpace;  // Query joint location relative to hand mesh reference space
        locateInfo.time = time;

        std::array<XrHandJointLocationEXT, XR_HAND_JOINT_COUNT_EXT> jointLocations;
        XrHandJointLocationsEXT locations{XR_TYPE_HAND_JOINT_LOCATIONS_EXT};
        locations.jointCount = jointLocations.size();
        locations.jointLocations = jointLocations.data();
CHK_XR(pfnLocateHandJointsEXT(referenceHandTracker, &locateInfo, &locations));

// Generate UV map using tip/wrist location and referenceHandMesh.vertexBuffer
// For example, gradually changes color from the tip of the hand to wrist.
}

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_HAND_MESH_SPACE_CREATE_INFO_MSFT
- XR_TYPE_HAND_MESH_UPDATE_INFO_MSFT
- XR_TYPE_HAND_MESH_MSFT
- XR_TYPE_SYSTEM_HAND_TRACKING_MESH_PROPERTIES_MSFT
- XR_TYPE_HAND_POSE_TYPE_INFO_MSFT

New Enums

- XrHandPoseTypeMSFT

New Structures

- XrHandMeshSpaceCreateInfoMSFT
- XrHandMeshUpdateInfoMSFT
- XrHandMeshMSFT
- XrHandMeshIndexBufferMSFT
- XrHandMeshVertexBufferMSFT
- XrHandMeshVertexMSFT
- XrSystemHandTrackingMeshPropertiesMSFT
- XrHandPoseTypeInfoMSFT

New Functions

- xrCreateHandMeshSpaceMSFT
- xrUpdateHandMeshMSFT

Issues
Version History

- Revision 1, 2019-09-20 (Yin Li)
  - Initial extension description
- Revision 2, 2020-04-20 (Yin Li)
  - Change joint spaces to locate joints function.
- Revision 3, 2021-04-13 (Ryan Pavlik, Collabora)
  - Correctly show function pointer retrieval in sample code
- Revision 4, 2021-10-20 (Darryl Gough)
  - Winding order for hand mesh is corrected to clockwise to match runtime behavior.

12.82. XR_MSFT_holographic_window_attachment

Name String

XR_MSFT_holographic_window_attachment

Extension Type

Instance extension

Registered Extension Number

64

Revision

1

Extension and Version Dependencies

- Requires OpenXR 1.0

Contributors

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Overview

This extension enables the runtime to attach to app-provided HolographicSpace and CoreWindow WinRT objects when an XrSession is created. Applications may use this extension to create and control the CoreWindow/App View objects, allowing the app to subscribe to keyboard input events and react to activation event arguments. These events and data would otherwise be inaccessible if the application simply managed the app state and lifetime exclusively through the OpenXR API. This extension is only valid to use where an application can create a CoreWindow, such as UWP applications on the HoloLens.
The `XrHolographicWindowAttachmentMSFT` structure is defined as:

```c
typedef struct XrHolographicWindowAttachmentMSFT {
    XrStructureType    type;
    const void*        next;
    IUnknown*          holographicSpace;
    IUnknown*          coreWindow;
} XrHolographicWindowAttachmentMSFT;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **holographicSpace** is a pointer to a valid `Windows.Graphics.Holographic.HolographicSpace`.
- **coreWindow** is a pointer to a valid `Windows.UI.Core.CoreWindow`.

When creating a holographic window-backed `XrSession`, the application provides a pointer to an `XrHolographicWindowAttachmentMSFT` in the `next` chain of the `XrSessionCreateInfo`.

The session state of a holographic window-backed `XrSession` will only reach `XR_SESSION_STATE_VISIBLE` when the provided CoreWindow is made visible. If the CoreWindow is for a secondary app view, the application must programmatically request to make the CoreWindow visible (e.g. with `ApplicationViewSwitcher.TryShowAsStandaloneAsync` or `ApplicationViewSwitcher.SwitchAsync`).

The app **must** not call `xrCreateSession` while the specified CoreWindow thread is blocked, otherwise the call **may** deadlock.

**Valid Usage (Implicit)**

- The `XR_MSFT_holographic_window_attachment` extension **must** be enabled prior to using `XrHolographicWindowAttachmentMSFT`
- **type** **must** be `XR_TYPE_HOLOGRAPHIC_WINDOW_ATTACHMENT_MSFT`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **holographicSpace** **must** be a pointer to an `IUnknown` value
- **coreWindow** **must** be a pointer to an `IUnknown` value
12.82.1. Sample code

Following example demos the usage of holographic window attachment and use the attached CoreWindow to receive keyboard input, use CoreTextEditContext to handle text typing experience, and use IActivatedEventArgs to handle protocol launching arguments.

```cpp
struct AppView : implements<AppView, IFrameworkView> {
    void Initialize(CoreApplicationView const& applicationView) {
        applicationView.Activated({this, &AppView::OnActivated});
    }

    void Load(winrt::hstring const& entryPoint) {
    }

    void Uninitialize() {
    }

    void Run() {
        // Creating a HolographicSpace before activating the CoreWindow to make it a holographic window
        CoreWindow window = CoreWindow::GetForCurrentThread();
        HolographicSpace holographicSpace = Windows::Graphics::Holographic::HolographicSpace::CreateForCoreWindow(window);
        window.Activate();

        // [xrCreateInstance, xrGetSystem, and create a graphics binding]

        XrHolographicWindowAttachmentMSFT holographicWindowAttachment{XR_TYPE_ATTACHED_CORE_WINDOW_MSFT};
        holographicWindowAttachment.next = &graphicsBinding;
        holographicWindowAttachment.coreWindow = window.as<IUnknown>().get();
        holographicWindowAttachment.holographicSpace = holographicSpace.as<IUnknown>().get();

        XrSessionCreateInfo sessionCreateInfo{XR_TYPE_SESSION_CREATE_INFO};
        sessionCreateInfo.next = &holographicWindowAttachment;
        sessionCreateInfo.systemId = systemId;

        XrSession session;
        CHECK_XRCMD(xrCreateSession(instance, &sessionCreateInfo, &session));

        while (!m_windowClosed) {
            window.Dispatcher().ProcessEvents(CoreProcessEventsOption::ProcessAllIfPresent);

            // [OpenXR calls: Poll events, sync actions, render, and submit frames].
        }
    }
};
```
```cpp
void SetWindow(CoreWindow const& window) {
    window.Closed({this, &AppView::OnWindowClosed});
    window.KeyDown({this, &AppView::OnKeyDown});

    // This sample customizes the text input pane with manual display policy and email address scope.
    windows::CoreTextServicesManager manager = windows::CoreTextServicesManager::GetForCurrentView();
    windows::CoreTextEditContext editingContext = manager.CreateEditContext();
    editingContext.InputPaneDisplayPolicy(windows::CoreTextInputPaneDisplayPolicy::Manual);
    editingContext.InputScope(windows::CoreTextInputScope::EmailAddress);
}

void OnWindowClosed(CoreWindow const& sender, CoreWindowEventArgs const& args) {
    m_windowClosed = true;
}

void OnKeyDown(CoreWindow const& sender, KeyEventArgs const& args) {
    // [Process key down]
}

void OnActivated(CoreApplicationView const&, IActivatedEventArgs const& args) {
    if (args.Kind() == windows::ActivationKind::Protocol) {
        auto eventArgs{args.as<windows::ProtocolActivatedEventArgs>()};
        // Use the protocol activation parameters in eventArgs.Uri();
    }

    // Inspecting whether the application is launched from within holographic shell or from desktop.
    if (windows::HolographicApplicationPreview::IsHolographicActivation(args)) {
        // App activation is targeted at the holographic shell.
    } else {
        // App activation is targeted at the desktop.
    }

    // NOTE: CoreWindow is activated later after the HolographicSpace has been created.
}

bool m_windowClosed{false};
};

struct AppViewSource : winrt::implements<AppViewSource, IFrameworkViewSource> {
    windows::IFrameworkView CreateView() {
        return winrt::make<AppView>();
    }
};
```
Version History

• Revision 1, 2020-05-18 (Bryce Hutchings)
  ◦ Initial extension description

12.83. XR_MSFT_perception_anchor_interop

Name String
XR_MSFT_perception_anchor_interop

Extension Type
Instance extension

Registered Extension Number
57

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0
• Requires XR_MSFT_spatial_anchor

Last Modified Date
2020-06-16

IP Status
No known IP claims.

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Overview
This extension supports conversion between XrSpatialAnchorMSFT and
Windows.Perception.Spatial.SpatialAnchor. An application can use this extension to persist spatial anchors on the Windows device through SpatialAnchorStore or transfer spatial anchors between devices through SpatialAnchorTransferManager.

The xrCreateSpatialAnchorFromPerceptionAnchorMSFT function creates a XrSpatialAnchorMSFT handle from an IUnknown pointer to Windows.Perception.Spatial.SpatialAnchor.

```c
XrResult xrCreateSpatialAnchorFromPerceptionAnchorMSFT(
    XrSession session,
    IUnknown* perceptionAnchor,
    XrSpatialAnchorMSFT* anchor);
```

**Parameter Descriptions**

- **session** is the specified XrSession.
- **perceptionAnchor** is an IUnknown pointer to a Windows.Perception.Spatial.SpatialAnchor object.
- **anchor** is a pointer to XrSpatialAnchorMSFT to receive the returned anchor handle.

The input perceptionAnchor must support successful QueryInterface to Windows.Perception.Spatial.SpatialAnchor, otherwise the runtime must return XR_ERROR_VALIDATION_FAILURE.

If the function successfully returned, the output anchor must be a valid handle. This also increments the refcount of the perceptionAnchor object.

When application is done with the anchor handle, it can be destroyed using xrDestroySpatialAnchorMSFT function. This also decrements the refcount of underlying windows perception anchor object.

**Valid Usage (Implicit)**

- The XR_MSFT_perception_anchor_interop extension must be enabled prior to calling xrCreateSpatialAnchorFromPerceptionAnchorMSFT
- **session** must be a valid XrSession handle
- **perceptionAnchor** must be a pointer to an IUnknown value
- **anchor** must be a pointer to an XrSpatialAnchorMSFT handle
Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED

The `xrTryGetPerceptionAnchorFromSpatialAnchorMSFT` function converts a `XrSpatialAnchorMSFT` handle into an `IUnknown` pointer to `Windows.Perception.Spatial.SpatialAnchor`.

```c
XrResult xrTryGetPerceptionAnchorFromSpatialAnchorMSFT(
    XrSession session,
    XrSpatialAnchorMSFT anchor,
    IUnknown** perceptionAnchor);
```

Parameter Descriptions

- `session` is the specified `XrSession`.
- `anchor` is a valid `XrSpatialAnchorMSFT` handle.
- `perceptionAnchor` is a valid pointer to `IUnknown` pointer to receive the output `Windows.Perception.Spatial.SpatialAnchor` object.

If the runtime can convert the `anchor` to a `Windows.Perception.Spatial.SpatialAnchor` object, this function **must** return `XR_SUCCESS`, and the output `IUnknown` in the pointer of `perceptionAnchor` **must** be not `NULL`. This also increments the refcount of the object. The application **can** then use `QueryInterface` to get the pointer for `Windows.Perception.Spatial.SpatialAnchor` object. The application **should** release the COM pointer after done with the object, or attach it to a smart COM pointer such as `winrt::com_ptr`.
If the runtime cannot convert the anchor to a Windows.Perception.Spatial.SpatialAnchor object, the function must return XR_SUCCESS, and the output IUnknown in the pointer of perceptionAnchor must be NULL.

Valid Usage (Implicit)

- The XR_MSFT_perception_anchor_interop extension must be enabled prior to calling xrTryGetPerceptionAnchorFromSpatialAnchorMSFT
- session must be a valid XrSession handle
- anchor must be a valid XrSpatialAnchorMSFT handle
- perceptionAnchor must be a pointer to a pointer to an IUnknown value
- anchor must have been created, allocated, or retrieved from session

Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY

New Object Types

New Flag Types

New Enum Constants

New Enums

New Structures

New Functions

xrCreateSpatialAnchorFromPerceptionAnchorMSFT
Scene understanding provides applications with a structured, high-level representation of the planes, meshes, and objects in the user's environment, enabling the development of spatially-aware applications.
The application requests computation of a scene, receiving the list of scene components observed in the environment around the user. These scene components contain information such as:

- The type of the discovered objects (wall, floor, ceiling, or other surface type).
- The planes and their bounds that represent the object.
- The visual and collider triangle meshes that represent the object.

The application can use this information to reason about the structure and location of the environment, to place holograms on surfaces, or render clues for grounding objects.

An application typically uses this extension in the following steps:

1. Create an `XrSceneObserverMSFT` handle to manage the system resource of the scene understanding compute.
2. Start the scene compute by calling `xrComputeNewSceneMSFT` with `XrSceneBoundsMSFT` to specify the scan range and a list of `XrSceneComputeFeatureMSFT` features.
3. Inspect the completion of computation by polling `xrGetSceneComputeStateMSFT`.
4. Once compute is completed, create an `XrSceneMSFT` handle to the result by calling `xrCreateSceneMSFT`.
5. Get properties of scene components using `xrGetSceneComponentsMSFT`.

**Create a scene observer handle**

The `XrSceneObserverMSFT` handle represents the resources for computing scenes. It maintains a correlation of scene component identifiers across multiple scene computes.

> **Note**
> The application should destroy the `XrSceneObserverMSFT` handle when it is done with scene compute and scene component data to save system power consumption.

An `XrSceneObserverMSFT` handle is created using `xrCreateSceneObserverMSFT`.
XrResult xrCreateSceneObserverMSFT(
    XrSession                                   session,
    const XrSceneObserverCreateInfoMSFT*        createInfo,
    XrSceneObserverMSFT*                        sceneObserver);

Parameter Descriptions

- **session** is an XrSession in which the scene observer will be active.
- **createInfo** exists for extensibility purposes, it is NULL or a pointer to a valid XrSceneObserverCreateInfoMSFT structure.
- **sceneObserver** is the returned XrSceneObserverMSFT handle.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to calling xrCreateSceneObserverMSFT
- **session** must be a valid XrSession handle
- If **createInfo** is not NULL, **createInfo** must be a pointer to a valid XrSceneObserverCreateInfoMSFT structure
- **sceneObserver** must be a pointer to an XrSceneObserverMSFT handle
Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED

The XrSceneObserverCreateInfoMSFT structure is defined as:

typedef struct XrSceneObserverCreateInfoMSFT {
    XrStructureType    type;
    const void*        next;
} XrSceneObserverCreateInfoMSFT;

Member Descriptions

- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneObserverCreateInfoMSFT`
- `type` **must** be `XR_TYPE_SCENE_OBSERVER_CREATE_INFO_MSFT`
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain

The `xrDestroySceneObserverMSFT` function releases the `sceneObserver` and the underlying resources.

```c
XrResult xrDestroySceneObserverMSFT(
    XrSceneObserverMSFT sceneObserver);
```

Parameter Descriptions

- `sceneObserver` is an `XrSceneObserverMSFT` previously created by `xrCreateSceneObserverMSFT`.

Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to calling `xrDestroySceneObserverMSFT`
- `sceneObserver` **must** be a valid `XrSceneObserverMSFT` handle

Thread Safety

- Access to `sceneObserver`, and any child handles, **must** be externally synchronized
Return Codes

Success
- XR_SUCCESS

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_HANDLE_INVALID

Compute a new scene and wait for completion

The `xrComputeNewSceneMSFT` function begins the compute of a new scene and the runtime **must** return quickly without waiting for the compute to complete. The application **should** use `xrGetSceneComputeStateMSFT` to inspect the compute status.

The application **can** control the compute features by passing a list of `XrSceneComputeFeatureMSFT` via `XrNewSceneComputeInfoMSFT::requestedFeatures`.

- If `XR_SCENE_COMPUTE_FEATURE_PLANE_MSFT` is passed, but `XR_SCENE_COMPUTE_FEATURE_PLANE_MESH_MSFT` is not passed, then:
  - The application **may** be able to read `XR_SCENE_COMPONENT_TYPE_PLANE_MSFT` and `XR_SCENE_COMPONENT_TYPE_OBJECT_MSFT` scene components from the resulting `XrSceneMSFT` handle.
  - `XrScenePlaneMSFT::meshBufferId` **must** be zero to indicate that the plane scene component does not have a mesh buffer available to read.

- If `XR_SCENE_COMPUTE_FEATURE_PLANE_MSFT` and `XR_SCENE_COMPUTE_FEATURE_PLANE_MESH_MSFT` are passed, then:
  - the application **may** be able to read `XR_SCENE_COMPONENT_TYPE_PLANE_MSFT` and `XR_SCENE_COMPONENT_TYPE_OBJECT_MSFT` scene components from the resulting `XrSceneMSFT` handle
  - `XrScenePlaneMSFT::meshBufferId` **may** contain a non-zero mesh buffer identifier to indicate that the plane scene component has a mesh buffer available to read.

- If `XR_SCENE_COMPUTE_FEATURE_VISUAL_MESH_MSFT` is passed then:
  - the application **may** be able to read `XR_SCENE_COMPONENT_TYPE_VISUAL_MESH_MSFT` and `XR_SCENE_COMPONENT_TYPE_OBJECT_MSFT` scene components from the resulting `XrSceneMSFT` handle.

- If `XR_SCENE_COMPUTE_FEATURE_COLLIDER_MESH_MSFT` is passed then:
  - the application **may** be able to read `XR_SCENE_COMPONENT_TYPE_COLLIDER_MESH_MSFT` and `XR_SCENE_COMPONENT_TYPE_OBJECT_MSFT` scene components from the resulting `XrSceneMSFT` handle.
XrResult xrComputeNewSceneMSFT(
    XrSceneObserverMSFT sceneObserver,
    const XrNewSceneComputeInfoMSFT* computeInfo);

Parameter Descriptions

- `sceneObserver` is a handle to an `XrSceneObserverMSFT`.
- `computeInfo` is a pointer to an `XrNewSceneComputeInfoMSFT` structure.

The runtime must return `XR_ERROR_SCENE_COMPUTE_FEATURE_INCOMPATIBLE_MSFT` if incompatible features were passed or no compatible features were passed.

The runtime must return `XR_ERROR_SCENE_COMPUTE_FEATURE_INCOMPATIBLE_MSFT` if `XR_SCENE_COMPUTE_FEATURE_PLANE_MESH_MSFT` was passed but `XR_SCENE_COMPUTE_FEATURE_PLANE_MSFT` was not passed.

The runtime must return `XR_ERROR_SCENE_COMPUTE_FEATURE_INCOMPATIBLE_MSFT` if `xrComputeNewSceneMSFT` is called while the scene computation is in progress.

An application that wishes to use `XR_SCENE_COMPUTE_CONSISTENCY_OCCLUSION_OPTIMIZED_MSFT` must create an `XrSceneObserverMSFT` handle that passes neither `XR_SCENE_COMPUTE_CONSISTENCY_SNAPSHOT_COMPLETE_MSFT` nor `XR_SCENE_COMPUTE_CONSISTENCY_SNAPSHOT_INCOMPLETE_FAST_MSFT` to `xrComputeNewSceneMSFT` for the lifetime of that `XrSceneObserverMSFT` handle. This allows the runtime to return occlusion mesh at a different cadence than non-occlusion mesh or planes.

- The runtime must return `XR_ERROR_SCENE_COMPUTE_CONSISTENCY_MISMATCH_MSFT` if:
  - `XR_SCENE_COMPUTE_CONSISTENCY_OCCLUSION_OPTIMIZED_MSFT` is passed to `xrComputeNewSceneMSFT` and a previous call to `xrComputeNewSceneMSFT` did not pass `XR_SCENE_COMPUTE_CONSISTENCY_OCCLUSION_OPTIMIZED_MSFT` for the same `XrSceneObserverMSFT` handle.

- The runtime must return `XR_ERROR_SCENE_COMPUTE_CONSISTENCY_MISMATCH_MSFT` if:
  - `XR_SCENE_COMPUTE_CONSISTENCY_OCCLUSION_OPTIMIZED_MSFT` is not passed to `xrComputeNewSceneMSFT` and a previous call to `xrComputeNewSceneMSFT` did pass `XR_SCENE_COMPUTE_CONSISTENCY_OCCLUSION_OPTIMIZED_MSFT` for the same `XrSceneObserverMSFT` handle.

- The runtime must return `XR_ERROR_SCENE_COMPUTE_FEATURE_INCOMPATIBLE_MSFT` if:
• XR_SCENE_COMPUTE_CONSISTENCY_OCCLUSION_OPTIMIZED_MSFT is passed to xrComputeNewSceneMSFT and
  • neither XR_SCENE_COMPUTE_FEATURE_VISUAL_MESH_MSFT nor XR_SCENE_COMPUTE_FEATURE_COLLIDER_MESH_MSFT are also passed.

• The runtime must return XR_ERROR_SCENE_COMPUTE_FEATURE_INCOMPATIBLE_MSFT if:
  • XR_SCENE_COMPUTE_CONSISTENCY_OCCLUSION_OPTIMIZED_MSFT is passed to xrComputeNewSceneMSFT and
  • at least one of XR_SCENE_COMPUTE_FEATURE_SERIALIZE_SCENE_MSFT, XR_SCENE_COMPUTE_FEATURE_PLANE_MSFT, XR_SCENE_COMPUTE_FEATURE_PLANE_MESH_MSFT, or XR_SCENE_COMPUTE_FEATURE_SERIALIZE_SCENE_MSFT are also passed.

Valid Usage (Implicit)

• The XR_MSFT_scene_understanding extension must be enabled prior to calling xrComputeNewSceneMSFT
• sceneObserver must be a valid XrSceneObserverMSFT handle
• computeInfo must be a pointer to a valid XrNewSceneComputeInfoMSFT structure

Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_TIME_INVALID
• XR_ERROR_POSE_INVALID

An XrSceneMSFT handle represents the collection of scene components that were detected during the scene computation.
The `XrNewSceneComputeInfoMSFT` structure is defined as:

```c
typedef struct XrNewSceneComputeInfoMSFT {
    XrStructureType                     type;
    const void*                         next;
    uint32_t                            requestedFeatureCount;
    const XrSceneComputeFeatureMSFT*    requestedFeatures;
    XrSceneComputeConsistencyMSFT       consistency;
    XrSceneBoundsMSFT                   bounds;
} XrNewSceneComputeInfoMSFT;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain.
- **requestedFeatureCount** is the number of features.
- **requestedFeatures** is an array of `XrSceneComputeFeatureMSFT`.
- **consistency** indicates the requested `XrSceneComputeConsistencyMSFT`, trading off speed against the quality of the resulting scene.
- **bounds** is an `XrSceneBoundsMSFT` representing the culling volume. Scene components entirely outside this volume **should** culled.
Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrNewSceneComputeInfoMSFT`
- **type** **must** be `XR_TYPE_NEW_SCENE_COMPUTE_INFO_MSFT`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrVisualMeshComputeLodInfoMSFT`
- **requestedFeatures** **must** be a pointer to an array of `requestedFeatureCount` valid `XrSceneComputeFeatureMSFT` values
- **consistency** **must** be a valid `XrSceneComputeConsistencyMSFT` value
- **bounds** **must** be a valid `XrSceneBoundsMSFT` structure
- The `requestedFeatureCount` parameter **must** be greater than 0

The `XrSceneComputeFeatureMSFT` enumeration identifies the different scene compute features that may be passed to `xrComputeNewSceneMSFT`.

```c
typedef enum XrSceneComputeFeatureMSFT {
    XR_SCENE_COMPUTE_FEATURE_PLANE_MSFT = 1,
    XR_SCENE_COMPUTE_FEATURE_PLANE_MESH_MSFT = 2,
    XR_SCENE_COMPUTE_FEATURE_VISUAL_MESH_MSFT = 3,
    XR_SCENE_COMPUTE_FEATURE_COLLIDER_MESH_MSFT = 4,
    XR_SCENE_COMPUTE_FEATURE_SERIALIZE_SCENE_MSFT = 1000098000,
    XR_SCENE_COMPUTE_FEATURE_MAX_ENUM_MSFT = 0x7FFFFFFF
} XrSceneComputeFeatureMSFT;
```

Enumerant Descriptions

- `XR_SCENE_COMPUTE_FEATURE_PLANE_MSFT` specifies that plane data for objects should be included in the resulting scene.
- `XR_SCENE_COMPUTE_FEATURE_PLANE_MESH_MSFT` specifies that planar meshes for objects should be included in the resulting scene.
- `XR_SCENE_COMPUTE_FEATURE_VISUAL_MESH_MSFT` specifies that 3D visualization meshes for objects should be included in the resulting scene.
- `XR_SCENE_COMPUTE_FEATURE_COLLIDER_MESH_MSFT` specifies that 3D collider meshes for objects should be included in the resulting scene.
Note

Applications wanting to use the scene for analysis, or in a physics simulation should set `consistency` to `XR_SCENE_COMPUTE_CONSISTENCY_SNAPSHOT_COMPLETE_MSFT` in order to avoid physics objects falling through the gaps and escaping the scene.

Setting `consistency` to `XR_SCENE_COMPUTE_CONSISTENCY_SNAPSHOT_INCOMPLETE_FAST_MSFT` might speed up the compute but it will result in gaps in the scene.

Setting `consistency` to `XR_SCENE_COMPUTE_CONSISTENCY_OCCLUSION_OPTIMIZED_MSFT` should be done when the resulting mesh will only be used to occlude virtual objects that are behind real-world surfaces. This mode will be most efficient and have the lowest-latency, but will return meshes less suitable for analysis or visualization.

The `XrSceneComputeConsistencyMSFT` enumeration identifies the different scene compute consistencies that may be passed to `xrComputeNewSceneMSFT`.

```c
typedef enum XrSceneComputeConsistencyMSFT {
    XR_SCENE_COMPUTE_CONSISTENCY_SNAPSHOT_COMPLETE_MSFT = 1,
    XR_SCENE_COMPUTE_CONSISTENCY_SNAPSHOT_INCOMPLETE_FAST_MSFT = 2,
    XR_SCENE_COMPUTE_CONSISTENCY_OCCLUSION_OPTIMIZED_MSFT = 3,
    XR_SCENE_COMPUTE_CONSISTENCY_MAX_ENUM_MSFT = 0x7FFFFFFF
} XrSceneComputeConsistencyMSFT;
```

### Enumerant Descriptions

- **XR_SCENE_COMPUTE_CONSISTENCY_SNAPSHOT_COMPLETE_MSFT**. The runtime **must** return a scene that is a consistent and complete snapshot of the environment, inferring the size and shape of objects as needed where the objects were not directly observed, in order to generate a watertight representation of the scene.

- **XR_SCENE_COMPUTE_CONSISTENCY_SNAPSHOT_INCOMPLETE_FAST_MSFT**. The runtime **must** return a consistent snapshot of the scene with meshes that do not overlap adjacent meshes at their edges, but **may** skip returning objects with `XrSceneObjectTypeMSFT` of `XR_SCENE_OBJECT_TYPE_INFERRED_MSFT` in order to return the scene faster.

- **XR_SCENE_COMPUTE_CONSISTENCY_OCCLUSION_OPTIMIZED_MSFT**. The runtime **may** react to this value by computing scenes more quickly and reusing existing mesh buffer IDs more often to minimize app overhead, with potential tradeoffs such as returning meshes that are not watertight, meshes that overlap adjacent meshes at their edges to allow partial updates in the future, or other reductions in mesh quality that are less observable when mesh is used for occlusion only.
An application can pass one or more bounding volumes when calling `xrComputeNewSceneMSFT`. These bounding volumes are used to determine which scene components to include in the resulting scene. Scene components that intersect one or more of the bounding volumes should be included, and all other scene components should be excluded. If an application inputs no bounding volumes, then the runtime must not associate any scene components with the resulting `XrSceneMSFT` handle.

```c
typedef struct XrSceneBoundsMSFT {
    XrSpace space;
    XrTime time;
    uint32_t sphereCount;
    const XrSceneSphereBoundMSFT* spheres;
    uint32_t boxCount;
    const XrSceneOrientedBoxBoundMSFT* boxes;
    uint32_t frustumCount;
    const XrSceneFrustumBoundMSFT* frustums;
} XrSceneBoundsMSFT;
```

**Member Descriptions**

- `space` is a handle to the `XrSpace` in which the bounds are specified.
- `time` is the `XrTime` at which the bounds will be evaluated within `space`.
- `sphereCount` is the number of sphere bounds.
- `spheres` is an array of `XrSceneSphereBoundMSFT`.
- `boxCount` is the number of oriented box bounds.
- `boxes` is an array of `XrSceneOrientedBoxBoundMSFT`.
- `frustumCount` is the number of frustum bounds.
- `frustums` is an array of `XrSceneFrustumBoundMSFT`.
Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to using XrSceneBoundsMSFT
- space must be a valid XrSpace handle
- If sphereCount is not 0, spheres must be a pointer to an array of sphereCount XrSceneSphereBoundMSFT structures
- If boxCount is not 0, boxes must be a pointer to an array of boxCount XrSceneOrientedBoxBoundMSFT structures
- If frustumCount is not 0, frustums must be a pointer to an array of frustumCount XrSceneFrustumBoundMSFT structures

An XrSceneSphereBoundMSFT structure describes the center and radius of a sphere bounds.

```c
typedef struct XrSceneSphereBoundMSFT {
    XrVector3f    center;
    float         radius;
} XrSceneSphereBoundMSFT;
```

Member Descriptions

- center is an XrVector3f representing the center of the sphere bound within the reference frame of the corresponding XrSceneBoundsMSFT::space.
- radius is the finite positive radius of the sphere bound.

The runtime must return XR_ERROR_VALIDATION_FAILURE if radius is not a finite positive value.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to using XrSceneSphereBoundMSFT

An XrSceneOrientedBoxBoundMSFT structure describes the pose and extents of an oriented box bounds.
typedef struct XrSceneOrientedBoxBoundMSFT {
    XrPosef      pose;
    XrVector3f   extents;
} XrSceneOrientedBoxBoundMSFT;

Member Descriptions

- **pose** is an `XrPosef` defining the center position and orientation of the oriented bounding box bound within the reference frame of the corresponding `XrSceneBoundsMSFT::space`.
- **extents** is an `XrVector3f` defining the edge-to-edge length of the box along each dimension with `pose` as the center.

The runtime **must** return `XR_ERROR_VALIDATION_FAILURE` if any component of `extents` is not finite or less than or equal to zero.

Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneOrientedBoxBoundMSFT`.

An `XrSceneFrustumBoundMSFT` structure describes the pose, field of view, and far distance of a frustum bounds.

typedef struct XrSceneFrustumBoundMSFT {
    XrPosef    pose;
    XrFovf     fov;
    float      farDistance;
} XrSceneFrustumBoundMSFT;

Member Descriptions

- **pose** is an `XrPosef` defining the position and orientation of the tip of the frustum bound within the reference frame of the corresponding `XrSceneBoundsMSFT::space`.
- **fov** is an `XrFovf` for the four sides of the frustum bound where `angleLeft` and `angleRight` are along the X axis and `angleUp` and `angleDown` are along the Y axis of the frustum bound space.
- **farDistance** is the positive distance of the far plane of the frustum bound along the -Z direction of the frustum bound space.
The runtime must return XR_ERROR_VALIDATION_FAILURE if farDistance is less than or equal to zero. The runtime must return XR_ERROR_VALIDATION_FAILURE if the fov angles are not between between -π/2 and π/2 exclusively.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to using XrSceneFrustumBoundMSFT

Applications can request a desired visual mesh level of detail by including XrVisualMeshComputeLodInfoMSFT in the XrNewSceneComputeInfoMSFT::next chain. If XrVisualMeshComputeLodInfoMSFT is not included in the XrNewSceneComputeInfoMSFT::next chain, then XR_MESH_COMPUTE_LOD_COARSE_MSFT must be used for the visual mesh level of detail.

The XrVisualMeshComputeLodInfoMSFT structure is defined as:

```
typedef struct XrVisualMeshComputeLodInfoMSFT {
    XrStructureType         type;
    const void*             next;
    XrMeshComputeLodMSFT    lod;
} XrVisualMeshComputeLodInfoMSFT;
```

Member Descriptions

- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain.
- lod is the requested mesh level of detail specified by XrMeshComputeLodMSFT.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to using XrVisualMeshComputeLodInfoMSFT
- type must be XR_TYPE_VISUAL_MESH_COMPUTE_LOD_INFO_MSFT
- next must be NULL or a valid pointer to the next structure in a structure chain
- lod must be a valid XrMeshComputeLodMSFT value

The XrMeshComputeLodMSFT enumeration identifies the level of detail of visual mesh compute.
typedef enum XrMeshComputeLodMSFT {
    XR_MESH_COMPUTE_LOD_COARSE_MSFT = 1,
    XR_MESH_COMPUTE_LOD_MEDIUM_MSFT = 2,
    XR_MESH_COMPUTE_LOD_FINE_MSFT = 3,
    XR_MESH_COMPUTE_LOD_UNLIMITED_MSFT = 4,
    XR_MESH_COMPUTE_LOD_MAX_ENUM_MSFT = 0x7FFFFFFF
} XrMeshComputeLodMSFT;

Enumerant Descriptions

- **XR_MESH_COMPUTE_LOD_COARSE_MSFT**. Coarse mesh compute level of detail will generate roughly 100 triangles per cubic meter.

- **XR_MESH_COMPUTE_LOD_MEDIUM_MSFT**. Medium mesh compute level of detail will generate roughly 400 triangles per cubic meter.

- **XR_MESH_COMPUTE_LOD_FINE_MSFT**. Fine mesh compute level of detail will generate roughly 2000 triangles per cubic meter.

- **XR_MESH_COMPUTE_LOD_UNLIMITED_MSFT**. Unlimited mesh compute level of detail. There is no guarantee as to the number of triangles returned.

The `xrEnumerateSceneComputeFeaturesMSFT` function enumerates the supported scene compute features of the given system.

This function follows the **two-call idiom** for filling the `features` array.

```c
XrResult xrEnumerateSceneComputeFeaturesMSFT(
    XrInstance instance,
    XrSystemId systemId,
    uint32_t featureCapacityInput,
    uint32_t* featureCountOutput,
    XrSceneComputeFeatureMSFT* features);
```
Parameter Descriptions

- **instance** is a handle to an XrInstance.
- **systemId** is the XrSystemId whose scene compute features will be enumerated.
- **featureCapacityInput** is the capacity of the array, or 0 to indicate a request to retrieve the required capacity.
- **featureCountOutput** is a pointer to the count of scene compute features, or a pointer to the required capacity in the case that **featureCapacityInput** is insufficient.
- **features** is an array of XrSceneComputeFeatureMSFT.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to calling xrEnumerateSceneComputeFeaturesMSFT.
- **instance** must be a valid XrInstance handle.
- **featureCountOutput** must be a pointer to a uint32_t value.
- If **featureCapacityInput** is not 0, **features** must be a pointer to an array of **featureCapacityInput** XrSceneComputeFeatureMSFT values.

Return Codes

**Success**

- XR_SUCCESS

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_SYSTEM_INVALID

An application can inspect the completion of the compute by polling xrGetSceneComputeStateMSFT. This function should typically be called once per frame per XrSceneObserverMSFT.
XrResult xrGetSceneComputeStateMSFT(
    XrSceneObserverMSFT sceneObserver,
    XrSceneComputeStateMSFT* state);

**Parameter Descriptions**

- **sceneObserver** is a handle to an `XrSceneObserverMSFT`.
- **state** is the returned `XrSceneComputeStateMSFT` value.

**Valid Usage (Implicit)**

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to calling `xrGetSceneComputeStateMSFT`.
- **sceneObserver** must be a valid `XrSceneObserverMSFT` handle.
- **state** must be a pointer to an `XrSceneComputeStateMSFT` value.

**Return Codes**

**Success**
- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`

`XrSceneComputeStateMSFT` identifies the different states of computing a new scene.
typedef enum XrSceneComputeStateMSFT {
    XR_SCENE_COMPUTE_STATE_NONE_MSFT = 0,
    XR_SCENE_COMPUTE_STATE_UPDATING_MSFT = 1,
    XR_SCENE_COMPUTE_STATE_COMPLETED_MSFT = 2,
    XR_SCENE_COMPUTE_STATE_COMPLETED_WITH_ERROR_MSFT = 3,
    XR_SCENE_COMPUTE_STATE_MAX_ENUM_MSFT = 0x7FFFFFFF
} XrSceneComputeStateMSFT;

**Enumerant Descriptions**

- **XR_SCENE_COMPUTE_STATE_NONE_MSFT** indicates that no scene is available, and that a scene is not being computed. The application **may** call `xrComputeNewSceneMSFT` to start computing a scene.

- **XR_SCENE_COMPUTE_STATE_UPDATING_MSFT** indicates that a new scene is being computed. Calling `xrCreateSceneMSFT` or `xrComputeNewSceneMSFT` **must** return the error `XR_ERROR_COMPUTE_NEW_SCENE_NOT_COMPLETED_MSFT`.

- **XR_SCENE_COMPUTE_STATE_COMPLETED_MSFT** indicates that a new scene has completed computing. The application **may** call `xrCreateSceneMSFT` to get the results of the query or the application **may** call `xrComputeNewSceneMSFT` to start computing a new scene.

- **XR_SCENE_COMPUTE_STATE_COMPLETED_WITH_ERROR_MSFT** indicates that the new scene computation completed with an error. Calling `xrCreateSceneMSFT` **must** return a valid XrSceneMSFT handle but calling `xrGetSceneComponentsMSFT` with that handle **must** return zero scene components. The runtime **must** allow the application to call `xrComputeNewSceneMSFT` to try computing a scene again, even if the last call to `xrComputeNewSceneMSFT` resulted in `XR_SCENE_COMPUTE_STATE_COMPLETED_WITH_ERROR_MSFT`.

- The `xrGetSceneComputeStateMSFT` function **must** return `XR_SCENE_COMPUTE_STATE_NONE_MSFT` if it is called before `xrComputeNewSceneMSFT` is called for the first time for the given XrSceneObserverMSFT handle.

- After calling `xrComputeNewSceneMSFT` but before the asynchronous operation has completed, any calls to `xrGetSceneComputeStateMSFT` **should** return `XR_SCENE_COMPUTE_STATE_UPDATING_MSFT`.

- Once the asynchronous operation has completed successfully, `xrGetSceneComputeStateMSFT` **must** return `XR_SCENE_COMPUTE_STATE_COMPLETED_MSFT` until `xrComputeNewSceneMSFT` is called again.

**Create a scene handle after a new scene compute has completed**

The `xrCreateSceneMSFT` functions creates an XrSceneMSFT handle. It can only be called after `xrGetSceneComputeStateMSFT` returns `XR_SCENE_COMPUTE_STATE_COMPLETED_MSFT` to indicate that the asynchronous operation has completed. The XrSceneMSFT handle manages the collection of scene components that represents the detected objects found during the query.
After an `XrSceneMSFT` handle is created, the handle and associated data **must** remain valid until destroyed, even after `xrCreateSceneMSFT` is called again to create the next scene. The runtime **must** keep alive any component data and mesh buffers relating to this historical scene until its handle is destroyed.

```c
XrResult xrCreateSceneMSFT(
    XrSceneObserverMSFT     sceneObserver,
    const XrSceneCreateInfoMSFT* createInfo,
    XrSceneMSFT*            scene);
```

**Parameter Descriptions**

- `sceneObserver` is a handle to an `XrSceneObserverMSFT`.
- `createInfo` exists for extensibility purposes, it is `NULL` or a pointer to a valid `XrSceneCreateInfoMSFT` structure.
- `scene` is the returned `XrSceneMSFT` handle.

**Valid Usage (Implicit)**

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to calling `xrCreateSceneMSFT`
- `sceneObserver` **must** be a valid `XrSceneObserverMSFT` handle
- If `createInfo` is not `NULL`, `createInfo` **must** be a pointer to a valid `XrSceneCreateInfoMSFT` structure
- `scene` **must** be a pointer to an `XrSceneMSFT` handle
Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_LIMIT_REACHED

Calling `xrCreateSceneMSFT` when `xrGetSceneComputeStateMSFT` returns `XR_SCENE_COMPUTE_STATE_NONE_MSFT` or `XR_SCENE_COMPUTE_STATE_UPDATING_MSFT` must return the error `XR_ERROR_COMPUTE_NEW_SCENE_NOT_COMPLETED_MSFT`.

The `XrSceneCreateInfoMSFT` structure is defined as:

```c
typedef struct XrSceneCreateInfoMSFT {
    XrStructureType type;
    const void*    next;
} XrSceneCreateInfoMSFT;
```

Member Descriptions

• `type` is the `XrStructureType` of this structure.
• `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to using XrSceneCreateInfoMSFT
- type must be XR_TYPE_SCENE_CREATE_INFO_MSFT
- next must be NULL or a valid pointer to the next structure in a structure chain

The xrDestroySceneMSFT function releases the scene and the underlying resources.

```c
XrResult xrDestroySceneMSFT(
    XrSceneMSFT                     scene);
```

Parameter Descriptions

- scene is an XrSceneMSFT previously created by xrCreateSceneMSFT.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to calling xrDestroySceneMSFT
- scene must be a valid XrSceneMSFT handle

Thread Safety

- Access to scene, and any child handles, must be externally synchronized

Return Codes

**Success**
- XR_SUCCESS

**Failure**
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_HANDLE_INVALID
Scene component types and Universally Unique Identifiers

Each XrSceneMSFT may contain one or more scene components. Scene components are uniquely identified by a Universally Unique Identifier, represented by XrUuidMSFT. Each scene component belongs to one XrSceneComponentTypeMSFT. The XrSceneComponentTypeMSFT denotes which additional properties can be read for that scene component.

- Get a list of scene objects and their properties in the scene by calling xrGetSceneComponentsMSFT with XR_SCENE_COMPONENT_TYPE_OBJECT_MSFT and including XrSceneObjectsMSFT in the XrSceneComponentsMSFT::next chain.

- Get the list of scene planes and their properties in the scene if XR_SCENE_COMPUTE_FEATURE_PLANE_MSFT was passed to xrComputeNewSceneMSFT by calling xrGetSceneComponentsMSFT with XR_SCENE_COMPONENT_TYPE_PLANE_MSFT and including XrScenePlanesMSFT in the XrSceneComponentsMSFT::next chain.

- Get the list of scene visual meshes and their properties in the scene if XR_SCENE_COMPUTE_FEATURE_VISUAL_MESH_MSFT was passed to xrComputeNewSceneMSFT by calling xrGetSceneComponentsMSFT with XR_SCENE_COMPONENT_TYPE_VISUAL_MESH_MSFT and including XrSceneMeshesMSFT in the XrSceneComponentsMSFT::next chain.

- Get the list of scene collider meshes and their properties in the scene if XR_SCENE_COMPUTE_FEATURE_COLLIDER_MESH_MSFT was passed to xrComputeNewSceneMSFT by calling xrGetSceneComponentsMSFT with XR_SCENE_COMPONENT_TYPE_COLLIDER_MESH_MSFT and including XrSceneMeshesMSFT in the XrSceneComponentsMSFT::next chain.

The XrUuidMSFT structure is a 128-bit UUID (Universally Unique IDentifier) that follows RFC 4122 Variant 1. The structure is composed of 16 octets, typically with the sizes and order of the fields defined in RFC 4122 section 4.1.2. The XrUuidMSFT structure is defined as:

```c
typedef struct XrUuidMSFT {
    uint8_t    bytes[16];
} XrUuidMSFT;
```

**Member Descriptions**

- bytes is a 128-bit Variant-1 Universally Unique Identifier.

**Valid Usage (Implicit)**

- The XR_MSFT_scene_understanding extension must be enabled prior to using XrUuidMSFT
The `XrSceneComponentTypeMSFT` enumeration identifies the scene component type.

```c
typedef enum XrSceneComponentTypeMSFT {
   XR_SCENE_COMPONENT_TYPE_INVALID_MSFT = -1,
   XR_SCENE_COMPONENT_TYPE_OBJECT_MSFT = 1,
   XR_SCENE_COMPONENT_TYPE_PLANE_MSFT = 2,
   XR_SCENE_COMPONENT_TYPE_VISUAL_MESH_MSFT = 3,
   XR_SCENE_COMPONENT_TYPE_COLLIDER_MESH_MSFT = 4,
   XR_SCENE_COMPONENT_TYPE_SERIALIZED_SCENE_FRAGMENT_MSFT = 1000098000,
   XR_SCENE_COMPONENT_TYPE_MAX_ENUM_MSFT = 0x7FFFFFFF
} XrSceneComponentTypeMSFT;
```

**Enumerant Descriptions**

- **XR_SCENE_COMPONENT_TYPE_INVALID_MSFT** indicates an invalid scene component type.
- **XR_SCENE_COMPONENT_TYPE_OBJECT_MSFT** indicates a discrete object detected in the world, such as a wall, floor, ceiling or table. Scene objects then provide their geometric representations such as planes and meshes as child scene components with the types below.
- **XR_SCENE_COMPONENT_TYPE_PLANE_MSFT** indicates a flat 2D representation of a surface in the world, such as a wall, floor, ceiling or table.
- **XR_SCENE_COMPONENT_TYPE_VISUAL_MESH_MSFT** indicates a visual mesh representation of an object in the world, optimized for visual quality when directly rendering a wireframe or other mesh visualization to the user. Visual mesh can also be used for rendering the silhouettes of objects. Applications can request varying levels of detail for visual meshes when calling `xrComputeNewSceneMSFT` using `XrVisualMeshComputeLodInfoMSFT`.
- **XR_SCENE_COMPONENT_TYPE_COLLIDER_MESH_MSFT** indicates a collider mesh representation of an object in the world, optimized to maintain the silhouette of an object while reducing detail on mostly-flat surfaces. Collider mesh is useful when calculating physics collisions or when rendering silhouettes of objects for occlusion.

**Get scene components**

Scene components are read from an `XrSceneMSFT` using `xrGetSceneComponentsMSFT` and passing one `XrSceneComponentTypeMSFT`. This function follows the **two-call idiom** for filling multiple buffers in a struct. Different scene component types may have additional properties that can be read by chaining additional structures to `XrSceneComponentsMSFT`. Those additional structures must have an array size that is at least as large as `XrSceneComponentsMSFT::componentCapacityInput`, otherwise the runtime must return `XR_ERROR_SIZE_INSUFFICIENT`.

- If **XR_SCENE_COMPONENT_TYPE_OBJECT_MSFT** is passed to `xrGetSceneComponentsMSFT`, then
**XrSceneObjectsMSFT** may be included in the **XrSceneComponentsMSFT**:next chain.

- If **XR_SCENE_COMPONENT_TYPE_PLANE_MSFT** is passed to **xrGetSceneComponentsMSFT**, then **XrScenePlanesMSFT** may be included in the **XrSceneComponentsMSFT**:next chain.

- If **XR_SCENE_COMPONENT_TYPE_VISUAL_MESH_MSFT** or **XR_SCENE_COMPONENT_TYPE_COLLIDER_MESH_MSFT** are passed to **xrGetSceneComponentsMSFT**, then **XrSceneMeshesMSFT** may be included in the **XrSceneComponentsMSFT**:next chain.

```c
XrResult xrGetSceneComponentsMSFT(
    XrSceneMSFT scene,
    const XrSceneComponentsGetInfoMSFT* getInfo,
    XrSceneComponentsMSFT* components);
```

### Parameter Descriptions

- **scene** is an **XrSceneMSFT** previously created by **xrCreateSceneMSFT**.
- **getInfo** is a pointer to an **XrSceneComponentsGetInfoMSFT** structure.
- **components** is the **XrSceneComponentsMSFT** output structure.

### Valid Usage (Implicit)

- The **XR_MSFT_scene_understanding** extension must be enabled prior to calling **xrGetSceneComponentsMSFT**
- **scene** must be a valid **XrSceneMSFT** handle
- **getInfo** must be a pointer to a valid **XrSceneComponentsGetInfoMSFT** structure
- **components** must be a pointer to an **XrSceneComponentsMSFT** structure
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_SIZE_INSUFFICIENT

An application can use `XrSceneComponentsGetInfoMSFT` to read the state of a specific component type using the `xrGetSceneComponentsMSFT` function. Applications can chain one or more of following extension structures to the `XrSceneComponentsGetInfoMSFT::next` chain to further narrow the returned components. The returned components must satisfy all conditions in the extension structs.

• `XrSceneComponentParentFilterInfoMSFT` to return only scene components that match the given parent object identifier.

• `XrSceneObjectTypesFilterInfoMSFT` to return only scene components that match any of the given `XrSceneObjectTypeMSFT` values or if a scene component does not have an `XrSceneObjectTypeMSFT` property then the parent’s `XrSceneObjectTypeMSFT` property will be compared.

• `XrScenePlaneAlignmentFilterInfoMSFT` to return only scene components that match any of the given `XrScenePlaneAlignmentTypeMSFT` values.

The `XrSceneComponentsGetInfoMSFT` structure is defined as:

```c
typedef struct XrSceneComponentsGetInfoMSFT {
    XrStructureType             type;
    const void*                 next;
    XrSceneComponentTypeMSFT    componentType;
} XrSceneComponentsGetInfoMSFT;
```
**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain.
- **componentType** is the scene component type requested.

**Valid Usage (Implicit)**

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneComponentsGetInfoMSFT`
- **type** **must** be `XR_TYPE_SCENE_COMPONENTS_GET_INFO_MSFT`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain. See also: `XrSceneComponentParentFilterInfoMSFT`, `XrSceneObjectTypesFilterInfoMSFT`, `XrScenePlaneAlignmentFilterInfoMSFT`
- **componentType** **must** be a valid `XrSceneComponentTypeMSFT` value

The `XrSceneComponentsMSFT` structure contains an array of `XrSceneComponentMSFT` returning the components that satisfy the conditions in `xrGetSceneComponentsMSFT::getInfo`. The `XrSceneComponentsMSFT` structure is defined as:

```c
typedef struct XrSceneComponentsMSFT {
    XrStructureType          type;
    void*                    next;
    uint32_t                 componentCapacityInput;
    uint32_t                 componentCountOutput;
    XrSceneComponentMSFT*    components;
} XrSceneComponentsMSFT;
```
## Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is **NULL** or a pointer to the next structure in a structure chain.
- **componentCapacityInput** is the capacity of the array, or 0 to indicate a request to retrieve the required capacity.
- **componentCountOutput** is a pointer to the count of components, or a pointer to the required capacity in the case that `componentCapacityInput` is insufficient.
- **components** is an array of `XrSceneComponentMSFT`.
- See **Buffer Size Parameters** chapter for a detailed description of retrieving the required `components` size.

## Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneComponentsMSFT`.
- **type** **must** be `XR_TYPE_SCENE_COMPONENTS_MSFT`.
- **next** **must** be **NULL** or a valid pointer to the next structure in a structure chain. See also: `XrSceneMeshesMSFT`, `XrSceneObjectsMSFT`, `XrScenePlanesMSFT`.
- If `componentCapacityInput` is not 0, **components** **must** be a pointer to an array of `componentCapacityInput` `XrSceneComponentMSFT` structures.

The `XrSceneComponentMSFT` structure is defined as:

```c
typedef struct XrSceneComponentMSFT {
    XrSceneComponentTypeMSFT    componentType;
    XrUuidMSFT                  id;
    XrUuidMSFT                  parentId;
    XrTime                      updateTime;
} XrSceneComponentMSFT;
```
Member Descriptions

- `componentType` is the `XrSceneComponentTypeMSFT` of the scene component.
- `id` is the `XrUuidMSFT` of the scene component.
- `parentId` is the `XrUuidMSFT` of the parent scene object. If the scene component does not have a parent, then `parentId` will be equal to zero.
- `updateTime` is the `XrTime` that this scene component was last updated.

The runtime **must** set `parentId` to either zero or a valid `XrUuidMSFT` that corresponds to a scene component of type `XR_SCENE_COMPONENT_TYPE_OBJECT_MSFT` that exists in the `XrSceneMSFT`.

**Note**

The parent scene object is intended to allow scene components to be grouped. For example, the scene object for a wall might have multiple scene component children like `XR_SCENE_COMPONENT_TYPE_PLANE_MSFT`, `XR_SCENE_COMPONENT_TYPE_VISUAL_MESH_MSFT`, and `XR_SCENE_COMPONENT_TYPE_COLLIDER_MESH_MSFT`. Those child scene components would be alternative representations of the same wall.

Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneComponentMSFT`
- `componentType` **must** be a valid `XrSceneComponentTypeMSFT` value

Get scene components using filters

The scene components that are returned by `xrGetSceneComponentsMSFT` **can** be filtered by chaining optional structures to `XrSceneComponentsGetInfoMSFT`. The runtime **must** combine multiple filters with a logical AND.

The `XrSceneComponentParentFilterInfoMSFT` structure is defined as:

```c
typedef struct XrSceneComponentParentFilterInfoMSFT {
    XrStructureType type;
    const void*    next;
    XrUuidMSFT     parentId;
} XrSceneComponentParentFilterInfoMSFT;
```
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain.
- **parentId** is the XrUuidMSFT of the parent scene component to filter by.

The runtime **must** return only scene components with matching **parentId**. If **parentId** is zero then the runtime **must** return only scene components that do not have a parent.

Valid Usage (Implicit)

- The **XR_MSFT_scene_understanding** extension **must** be enabled prior to using XrSceneComponentParentFilterInfoMSFT
- **type** **must** be XR_TYPE_SCENE_COMPONENT_PARENT_FILTER_INFO_MSFT
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain

The XrSceneObjectTypesFilterInfoMSFT structure is defined as:

```c
typedef struct XrSceneObjectTypesFilterInfoMSFT {
    XrStructureType                  type;
    const void*                      next;
    uint32_t                         objectTypeCount;
    const XrSceneObjectTypeMSFT*     objectTypes;
} XrSceneObjectTypesFilterInfoMSFT;
```

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain.
- **objectTypeCount** is a uint32_t describing the count of elements in the **objectTypes** array.
- **objectTypes** is an array of XrSceneObjectTypeMSFT to filter by.

The runtime **must** return only scene components that match any of the XrSceneObjectTypeMSFT in **objectTypes**. If a scene component does not have an XrSceneObjectTypeMSFT then the parent's XrSceneObjectTypeMSFT value will be used for the comparison if it exists.
Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension must be enabled prior to using `XrSceneObjectTypesFilterInfoMSFT`
- `type` must be `XR_TYPE_SCENE_OBJECT_TYPES_FILTER_INFO_MSFT`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- If `objectTypeCount` is not `0`, `objectTypes` must be a pointer to an array of `objectTypeCount` valid `XrSceneObjectTypeMSFT` values

The `XrScenePlaneAlignmentFilterInfoMSFT` structure is defined as:

```c
typedef struct XrScenePlaneAlignmentFilterInfoMSFT {
    XrStructureType                         type;
    const void*                             next;
    uint32_t                                alignmentCount;
    const XrScenePlaneAlignmentTypeMSFT*    alignments;
} XrScenePlaneAlignmentFilterInfoMSFT;
```

Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain.
- `alignmentCount` is a `uint32_t` describing the count of elements in the `alignments` array.
- `alignments` is an array of `XrScenePlaneAlignmentTypeMSFT` to filter by.

The runtime must return only scene components that match one of the `XrScenePlaneAlignmentTypeMSFT` values passed in `alignments`.

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Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrScenePlaneAlignmentFilterInfoMSFT`
- `type` **must** be `XR_TYPE_SCENE_PLANE_ALIGNMENT_FILTER_INFO_MSFT`
- `next` **must** be `NULL` or a valid pointer to the next structure in a structure chain
- If `alignmentCount` is not 0, `alignments` **must** be a pointer to an array of `alignmentCount` valid `XrScenePlaneAlignmentTypeMSFT` values

Get scene objects

The runtime **must** fill out the `XrSceneObjectsMSFT` structure when included in the `XrSceneComponentsMSFT::next` chain. The `XrSceneComponentsGetInfoMSFT::componentType` **must** be `XR_SCENE_COMPONENT_TYPE_OBJECT_MSFT` when `XrSceneObjectsMSFT` is included in the next chain. If it is not, the `XR_ERROR_SCENE_COMPONENT_TYPE_MISMATCH_MSFT` error **must** be returned.

The `XrSceneObjectsMSFT` structure is defined as:

```c
typedef struct XrSceneObjectsMSFT {
    XrStructureType       type;
    void*                 next;
    uint32_t              sceneObjectCount;
    XrSceneObjectMSFT*    sceneObjects;
} XrSceneObjectsMSFT;
```

Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain.
- `sceneObjectCount` is a `uint32_t` describing the count of elements in the `sceneObjects` array.
- `sceneObjects` is an array of `XrSceneObjectMSFT`.

The runtime **must** only set `XrSceneObjectMSFT::objectType` to any of the following `XrSceneObjectTypeMSFT` values:

- `XR_SCENE_OBJECT_TYPE_UNCATEGORIZED_MSFT`
- `XR_SCENE_OBJECT_TYPE_BACKGROUND_MSFT`
- `XR_SCENE_OBJECT_TYPE_WALL_MSFT`
The `XrSceneObjectMSFT` structure represents the state of a scene object.

It is defined as:

```c
typedef struct XrSceneObjectMSFT {
    XrSceneObjectTypeMSFT objectType;
} XrSceneObjectMSFT;
```

### Member Descriptions

- `objectType` is the type of the object specified by `XrSceneObjectTypeMSFT`.

### Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension must be enabled prior to using `XrSceneObjectsMSFT`
- `objectType` must be a valid `XrSceneObjectTypeMSFT` value

The `XrSceneObjectTypeMSFT` enumeration identifies the different types of scene objects.
typedef enum XrSceneObjectTypeMSFT {
    XR_SCENE_OBJECT_TYPE_UNCATEGORIZED_MSFT = -1,
    XR_SCENE_OBJECT_TYPE_BACKGROUND_MSFT = 1,
    XR_SCENE_OBJECT_TYPE_WALL_MSFT = 2,
    XR_SCENE_OBJECT_TYPE_FLOOR_MSFT = 3,
    XR_SCENE_OBJECT_TYPE_CEILING_MSFT = 4,
    XR_SCENE_OBJECT_TYPE_PLATFORM_MSFT = 5,
    XR_SCENE_OBJECT_TYPE_INFERRED_MSFT = 6,
    XR_SCENE_OBJECT_TYPE_MAX_ENUM_MSFT = 0x7FFFFFFF
} XrSceneObjectTypeMSFT;

### Enumerant Descriptions

- **XR_SCENE_OBJECT_TYPE_UNCATEGORIZED_MSFT.** This scene object has yet to be classified and assigned a type. This should not be confused with background, as this object could be anything; the system has just not come up with a strong enough classification for it yet.

- **XR_SCENE_OBJECT_TYPE_BACKGROUND_MSFT.** The scene object is known to be not one of the other recognized types of scene object. This class should not be confused with uncategorized where background is known not to be wall/floor/ceiling etc. while uncategorized is not yet categorized.

- **XR_SCENE_OBJECT_TYPE_WALL_MSFT.** A physical wall. Walls are assumed to be immovable environmental structures.

- **XR_SCENE_OBJECT_TYPE_FLOOR_MSFT.** Floors are any surfaces on which one can walk. Note: stairs are not floors. Also note, that floors assume any walkable surface and therefore there is no explicit assumption of a singular floor. Multi-level structures, ramps, etc. should all classify as floor.

- **XR_SCENE_OBJECT_TYPE_CEILING_MSFT.** The upper surface of a room.

- **XR_SCENE_OBJECT_TYPE_PLATFORM_MSFT.** A large flat surface on which you could place holograms. These tend to represent tables, countertops, and other large horizontal surfaces.

- **XR_SCENE_OBJECT_TYPE_INFERRED_MSFT.** An imaginary object that was added to the scene in order to make the scene watertight and avoid gaps.

### Get scene planes

The runtime **must** fill out the `XrScenePlanesMSFT` structure when included in the `XrSceneComponentsMSFT::next` chain. The `XrSceneComponentsGetInfoMSFT::componentType` **must** be `XR_SCENE_COMPONENT_TYPE_PLANE_MSFT` when `XrScenePlanesMSFT` is included in the next chain. If it is not, the `XR_ERROR_SCENE_COMPONENT_TYPE_MISMATCH_MSFT` error **must** be returned.

The `XrScenePlanesMSFT` structure is defined as:
typedef struct XrScenePlanesMSFT {
    XrStructureType      type;
    void*                next;
    uint32_t             scenePlaneCount;
    XrScenePlaneMSFT*    scenePlanes;
} XrScenePlanesMSFT;

**Member Descriptions**

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain.
- `scenePlaneCount` is a `uint32_t` describing the count of elements in the `XrScenePlaneMSFT` array.
- `scenePlanes` is an array of `XrScenePlaneMSFT`.

**Valid Usage (Implicit)**

- The `XR_MSFT_scene_understanding` extension must be enabled prior to using `XrScenePlanesMSFT`.
- `type` must be `XR_TYPE_SCENE_PLANES_MSFT`.
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain.
- If `scenePlaneCount` is not 0, `scenePlanes` must be a pointer to an array of `scenePlaneCount` `XrScenePlaneMSFT` structures.

The `XrScenePlaneMSFT` structure represents the state of a scene plane.

It is defined as:

typedef struct XrScenePlaneMSFT {
    XrScenePlaneAlignmentTypeMSFT    alignment;
    XrExtent2Df                     size;
    uint64_t                        meshBufferId;
    XrBool32                        supportsIndicesUint16;
} XrScenePlaneMSFT;
Member Descriptions

- **alignment** is the alignment type of the plane specified by `XrScenePlaneAlignmentTypeMSFT`.
- **size** is the 2D size of the plane's extent, where `size::width` is the width of the plane along the X axis, and `size::height` is the height of the plane along the Y axis.
- **meshBufferId** is the `uint64_t` identifier that specifies the scene mesh buffer of this plane's triangle mesh. If `meshBufferId` is zero then this plane does not have a mesh. The triangles in a planar mesh are coplanar.
- **supportsIndicesUint16** is `XR_TRUE` if the mesh supports reading 16-bit unsigned indices.

The **size** of a plane refers to the plane's size in the x-y plane of the plane's coordinate system. A plane with a position of {0,0,0}, rotation of {0,0,0,1} (no rotation), and an extent of {1,1} refers to a 1 meter x 1 meter plane centered at {0,0,0} with its front face normal vector pointing towards the +Z direction in the plane component's space. For planes with an alignment of `XR_SCENE_PLANE_ALIGNMENT_TYPE_VERTICAL_MSFT`, the +Y direction must point up away from the direction of gravity.

![Figure 9. Scene Understanding Plane Coordinate System](image)

**Note**

OpenXR uses an X-Y plane with +Z as the plane normal but other APIs may use an X-Z plane with +Y as the plane normal. The X-Y plane can be converted to an X-Z plane by rotating $-\pi/2$ radians around the +X axis.
Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension must be enabled prior to using `XrScenePlaneMSFT`.
- `alignment` must be a valid `XrScenePlaneAlignmentTypeMSFT` value.

`XrScenePlaneAlignmentTypeMSFT` identifies the different plane alignment types.

typedef enum XrScenePlaneAlignmentTypeMSFT {
    XR_SCENE_PLANE_ALIGNMENT_TYPE_NON_ORTHOGONAL_MSFT = 0,
    XR_SCENE_PLANE_ALIGNMENT_TYPE_HORIZONTAL_MSFT = 1,
    XR_SCENE_PLANE_ALIGNMENT_TYPE_VERTICAL_MSFT = 2,
    XR_SCENE_PLANE_ALIGNMENT_TYPE_MAX_ENUM_MSFT = 0x7FFFFFFF
} XrScenePlaneAlignmentTypeMSFT;

Enumerant Descriptions

- `XR_SCENE_PLANE_ALIGNMENT_TYPE_NON_ORTHOGONAL_MSFT` means the plane's normal is not orthogonal or parallel to the gravity direction.
- `XR_SCENE_PLANE_ALIGNMENT_TYPE_HORIZONTAL_MSFT` means the plane's normal is roughly parallel to the gravity direction.
- `XR_SCENE_PLANE_ALIGNMENT_TYPE_VERTICAL_MSFT` means the plane's normal is roughly orthogonal to the gravity direction.

Get scene mesh

The runtime must fill out the `XrSceneMeshesMSFT` structure when included in the `XrSceneComponentsMSFT::next` chain. The `XrSceneComponentsGetInfoMSFT::componentType` must be `XR_SCENE_COMPONENT_TYPE_VISUAL_MESH_MSFT` or `XR_SCENE_COMPONENT_TYPE_COLLIDER_MESH_MSFT` when `XrSceneMeshesMSFT` is included in the next chain. If it is not, the `XR_ERROR_SCENE_COMPONENT_TYPE_MISMATCH_MSFT` error must be returned.

The `XrSceneMeshesMSFT` structure is defined as:
typedef struct XrSceneMeshesMSFT {
    XrStructureType     type;
    void*               next;
    uint32_t            sceneMeshCount;
    XrSceneMeshMSFT*    sceneMeshes;
} XrSceneMeshesMSFT;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain.
- **sceneMeshCount** is a uint32_t describing the count of elements in the sceneMeshes array.
- **sceneMeshes** is an array of XrSceneMeshMSFT.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension **must** be enabled prior to using XrSceneMeshesMSFT
- **type** must be XR_TYPE_SCENE_MESHES_MSFT
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- If **sceneMeshCount** is not 0, **sceneMeshes** must be a pointer to an array of sceneMeshCount XrSceneMeshMSFT structures

The XrSceneMeshMSFT structure represents the state of a scene component's mesh.

It is defined as:

typedef struct XrSceneMeshMSFT {
    uint64_t    meshBufferId;
    XrBool32    supportsIndicesUint16;
} XrSceneMeshMSFT;
Member Descriptions

- **meshBufferId** is the `uint64_t` identifier that specifies the scene mesh buffer. If `meshBufferId` is zero then this scene component does not have mesh data of corresponding `XrSceneComponentTypeMSFT` in `xrGetSceneComponentsMSFT::getInfo`.
- **supportIndicesUint16** is `XR_TRUE` if the mesh supports reading 16-bit unsigned indices.

Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneMeshMSFT`.

Read scene mesh buffer

The `xrGetSceneMeshBuffersMSFT` function retrieves the scene mesh vertex buffer and index buffer for the given scene mesh buffer identifier.

**Note**
Applications may use the scene mesh buffer identifier as a key to cache the vertices and indices of a mesh for reuse within an `XrSceneMSFT` or across multiple `XrSceneMSFT` for the same `XrSession`.

Applications can avoid unnecessarily calling `xrGetSceneMeshBuffersMSFT` for a scene component if `XrSceneComponentMSFT::updateTime` is equal to the `XrSceneComponentMSFT::updateTime` value in the previous `XrSceneMSFT`. A scene component is uniquely identified by `XrUuidMSFT`.

This function follows the two-call idiom for filling multiple buffers in a struct.

The `xrGetSceneMeshBuffersMSFT` function is defined as:

```c
XrResult xrGetSceneMeshBuffersMSFT(
    XrSceneMSFT scene,
    const XrSceneMeshBuffersGetInfoMSFT* getInfo,
    XrSceneMeshBuffersMSFT* buffers);
```
Parameter Descriptions

- **scene** is an XrSceneMSFT previously created by xrCreateSceneMSFT.
- **getInfo** is a pointer to an XrSceneMeshBuffersGetInfoMSFT structure.
- **buffers** is a pointer to an XrSceneMeshBuffersMSFT structure for reading a scene mesh buffer.

Applications can request the vertex buffer of the mesh by including XrSceneMeshVertexBufferMSFT in the XrSceneMeshBuffersMSFT::next chain. Runtimes must support requesting a 32-bit index buffer and may support requesting a 16-bit index buffer. Applications can request a 32-bit index buffer by including XrSceneMeshIndicesUint32MSFT in the XrSceneMeshBuffersMSFT::next chain. Applications can request a 16-bit index buffer by including XrSceneMeshIndicesUint16MSFT in the XrSceneMeshBuffersMSFT::next chain. If the runtime for the given scene mesh buffer does not support requesting a 16-bit index buffer then XR_ERROR_VALIDATION_FAILURE must be returned. The runtime must support reading a 16-bit index buffer for the given scene mesh buffer if XrScenePlaneMSFT:supportsIndicesUint16 or XrSceneMeshMSFT:supportsIndicesUint16 are XR_TRUE for the scene component that contained that scene mesh buffer identifier.

The runtime must return XR_ERROR_SCENE_MESH_BUFFER_ID_INVALID_MSFT if none of the scene components in the given XrSceneMSFT contain XrSceneMeshBuffersGetInfoMSFT::meshBufferId. The runtime must return XR_ERROR_SCENE_MESH_BUFFER_ID_INVALID_MSFT if XrSceneMeshBuffersGetInfoMSFT::meshBufferId is zero. The runtime must return XR_ERROR_VALIDATION_FAILURE if both XrSceneMeshIndicesUint32MSFT and XrSceneMeshIndicesUint16MSFT are included in the XrSceneMeshBuffersMSFT::next chain. The runtime must return XR_ERROR_VALIDATION_FAILURE if the XrSceneMeshBuffersMSFT::next does not contain at least one of XrSceneMeshVertexBufferMSFT, XrSceneMeshIndicesUint32MSFT or XrSceneMeshIndicesUint16MSFT.

The runtime must return the same vertices and indices for a given scene mesh buffer identifier and XrSession. A runtime may return zero vertices and indices if the underlying mesh data is no longer available.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to calling xrGetSceneMeshBuffersMSFT
- **scene** must be a valid XrSceneMSFT handle
- **getInfo** must be a pointer to a valid XrSceneMeshBuffersGetInfoMSFT structure
- **buffers** must be a pointer to an XrSceneMeshBuffersMSFT structure
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_SCENE_COMPONENT_ID_INVALID_MSFT

XrSceneMeshBuffersGetInfoMSFT is an input structure for the xrGetSceneMeshBuffersMSFT function.

typedef struct XrSceneMeshBuffersGetInfoMSFT {
    XrStructureType    type;
    const void*        next;
    uint64_t           meshBufferId;
} XrSceneMeshBuffersGetInfoMSFT;

Member Descriptions

• type is the XrStructureType of this structure.
• next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
• meshBufferId is the uint64_t identifier that specifies the scene mesh buffer to read.


**Valid Usage (Implicit)**

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneMeshBuffersGetInfoMSFT`
- **type** **must** be `XR_TYPE_SCENE_MESH_BUFFERS_GET_INFO_MSFT`
- **next** **must** be `NULL` or a valid pointer to the **next structure in a structure chain**

`XrSceneMeshBuffersMSFT` is an input/output structure for reading scene mesh buffers.

```c
typedef struct XrSceneMeshBuffersMSFT {
    XrStructureType type;
    void* next;
} XrSceneMeshBuffersMSFT;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the **next structure in a structure chain**.

**Valid Usage (Implicit)**

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneMeshBuffersMSFT`
- **type** **must** be `XR_TYPE_SCENE_MESH_BUFFERS_MSFT`
- **next** **must** be `NULL` or a valid pointer to the **next structure in a structure chain**

`XrSceneMeshVertexBufferMSFT` is an input/output structure for reading scene mesh buffer vertices.

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typedef struct XrSceneMeshVertexBufferMSFT {
    XrStructureType    type;
    void*              next;
    uint32_t           vertexCapacityInput;
    uint32_t           vertexCountOutput;
    XrVector3f*        vertices;
} XrSceneMeshVertexBufferMSFT;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain.
- **vertexCapacityInput** is the capacity of the array, or 0 to indicate a request to retrieve the required capacity.
- **vertexCountOutput** is a pointer to the count of vertices, or a pointer to the required capacity in the case that vertexCapacityInput is insufficient.
- **vertices** is an array of XrVector3f filled in by the runtime returns the position of vertices in the mesh component's space.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required vertices size.

**Valid Usage (Implicit)**

- The XR_MSFT_scene_understanding extension must be enabled prior to using XrSceneMeshVertexBufferMSFT
- **type** must be XR_TYPE_SCENE_MESH_VERTEX_BUFFER_MSFT
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- If vertexCapacityInput is not 0, **vertices** must be a pointer to an array of vertexCapacityInput XrVector3f structures

XrSceneMeshIndicesUint32MSFT is an input/output structure for reading 32-bit indices from a scene mesh buffer.
typedef struct XrSceneMeshIndicesUint32MSFT {
    XrStructureType    type;
    void*              next;
    uint32_t           indexCapacityInput;
    uint32_t           indexCountOutput;
    uint32_t*          indices;
} XrSceneMeshIndicesUint32MSFT;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain.
- **indexCapacityInput** is the capacity of the array, or 0 to indicate a request to retrieve the required capacity.
- **indexCountOutput** is a pointer to the count of indices, or a pointer to the required capacity in the case that indexCapacityInput is insufficient.
- **indices** is an array of triangle indices filled in by the runtime, specifying the indices of the scene mesh buffer in the vertices array. The triangle indices must be returned in counter-clockwise order and three indices denote one triangle.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required indices size.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to using XrSceneMeshIndicesUint32MSFT
- type must be XR_TYPE_SCENE_MESH_INDICES_UINT32_MSFT
- next must be NULL or a valid pointer to the next structure in a structure chain
- If indexCapacityInput is not 0, indices must be a pointer to an array of indexCapacityInput uint32_t values

XrSceneMeshIndicesUint16MSFT is an input/output structure for reading 16-bit indices from a scene mesh buffer.
typedef struct XrSceneMeshIndicesUint16MSFT {
    XrStructureType    type;
    void*              next;
    uint32_t           indexCapacityInput;
    uint32_t           indexCountOutput;
    uint16_t*          indices;
} XrSceneMeshIndicesUint16MSFT;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain.
- **indexCapacityInput** is the capacity of the array, or 0 to indicate a request to retrieve the required capacity.
- **indexCountOutput** is a pointer to the count of indices, or a pointer to the required capacity in the case that **indexCapacityInput** is insufficient.
- **indices** is an array of triangle indices filled in by the runtime, specifying the indices of the scene mesh buffer in the vertices array. The triangle indices must be returned in counter-clockwise order and three indices denote one triangle.
- See Buffer Size Parameters chapter for a detailed description of retrieving the required **indices** size.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to using XrSceneMeshIndicesUint16MSFT
- **type** must be XR_TYPE_SCENE_MESH_INDICES_UINT16_MSFT
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- If **indexCapacityInput** is not 0, **indices** must be a pointer to an array of **indexCapacityInput** uint16_t values

Locate scene objects

The xrLocateSceneComponentsMSFT function locates an array of scene components to a base space at a given time.
XrResult xrLocateSceneComponentsMSFT(
    XrSceneMSFT scene,
    const XrSceneComponentsLocateInfoMSFT* locateInfo,
    XrSceneComponentLocationsMSFT* locations);

Parameter Descriptions

- **scene** is a handle to an XrSceneMSFT.
- **locateInfo** is a pointer to XrSceneComponentsLocateInfoMSFT describing information to locate scene components.
- **locations** is a pointer to XrSceneComponentLocationsMSFT receiving the returned scene component locations.

The runtime must return XR_ERROR_SIZE_INSUFFICIENT if XrSceneComponentLocationsMSFT::locationCount is less than XrSceneComponentsLocateInfoMSFT::componentIdCount.

**Note**

Similar to xrLocateSpace, apps should call xrLocateSceneComponentsMSFT each frame because the location returned by xrLocateSceneComponentsMSFT in later frames may change over time as the target space or the scene components may refine their locations.

Valid Usage (Implicit)

- The XR_MSFT_scene_understanding extension must be enabled prior to calling xrLocateSceneComponentsMSFT
- **scene** must be a valid XrSceneMSFT handle
- **locateInfo** must be a pointer to a valid XrSceneComponentsLocateInfoMSFT structure
- **locations** must be a pointer to an XrSceneComponentLocationsMSFT structure
The `XrSceneComponentsLocateInfoMSFT` structure describes the information to locate scene components.

```c
typedef struct XrSceneComponentsLocateInfoMSFT {
    XrStructureType      type;
    const void*          next;
    XrSpace              baseSpace;
    XrTime               time;
    uint32_t             componentIdCount;
    const XrUuidMSFT*    componentIds;
} XrSceneComponentsLocateInfoMSFT;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **baseSpace** is an `XrSpace` within which the scene components will be located.
- **time** is an `XrTime` at which to locate the scene components.
- **componentIdCount** is a `uint32_t` describing the count of elements in the `componentIds` array.
- **componentIds** is an array of `XrUuidMSFT` identifiers for the scene components to location.

Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneComponentsLocateInfoMSFT`.
- **type** **must** be `XR_TYPE_SCENE_COMPONENTS_LOCATE_INFO_MSFT`.
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain.
- **baseSpace** **must** be a valid `XrSpace` handle.
- If **componentIdCount** is not **0**, **componentIds** **must** be a pointer to an array of **componentIdCount** `XrUuidMSFT` structures.

The `XrSceneComponentLocationsMSFT` structure returns scene component locations.

```c
typedef struct XrSceneComponentLocationsMSFT {
    XrStructureType           type;
    void*                     next;
    uint32_t                  locationCount;
    XrSceneComponentLocationMSFT* locations;
} XrSceneComponentLocationsMSFT;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **locationCount** is a `uint32_t` describing the count of elements in the **locations** array.
- **locations** is an array of `XrSceneComponentLocationMSFT` scene component locations.

Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneComponentLocationsMSFT`.
- **type** **must** be `XR_TYPE_SCENE_COMPONENT_LOCATIONS_MSFT`.
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain.
- If **locationCount** is not 0, **locations** **must** be a pointer to an array of **locationCount** `XrSceneComponentLocationMSFT` structures.

The `XrSceneComponentLocationMSFT` structure describes the position and orientation of a scene component to space `XrSceneComponentsLocateInfoMSFT::baseSpace` at time `XrSceneComponentsLocateInfoMSFT::time`. If the scene component identified by `XrUuidMSFT` is not found, **flags** should be empty.

```c
typedef struct XrSceneComponentLocationMSFT {
    XrSpaceLocationFlags    flags;
    XrPosef                 pose;
} XrSceneComponentLocationMSFT;
```

Member Descriptions

- **flags** is a bitfield, with bit masks defined in `XrSpaceLocationFlagBits`, to indicate which members contain valid data.
- **pose** is an `XrPosef` defining the position and orientation of the scene component within the reference frame of the corresponding `XrSceneComponentsLocateInfoMSFT::baseSpace`. 
Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding` extension **must** be enabled prior to using `XrSceneComponentLocationMSFT`
- `flags` **must** be `0` or a valid combination of `XrSpaceLocationFlagBits` values

New Object Types

- `XrSceneObserverMSFT`
- `XrSceneMSFT`

New Flag Types

New Enum Constants

`XrObjectType` enumeration is extended with:

- `XR_OBJECT_TYPE_SCENE_OBSERVER_MSFT`
- `XR_OBJECT_TYPE_SCENE_MSFT`

`XrStructureType` enumeration is extended with:

- `XR_TYPE_SCENE_OBSERVER_CREATE_INFO_MSFT`
- `XR_TYPE_SCENE_CREATE_INFO_MSFT`
- `XR_TYPE_NEW_SCENE_COMPUTE_INFO_MSFT`
- `XR_TYPE_VISUAL_MESH_COMPUTE_LOD_INFO_MSFT`
- `XR_TYPE_SCENE_COMPONENTS_MSFT`
- `XR_TYPE_SCENE_COMPONENTS_GET_INFO_MSFT`
- `XR_TYPE_SCENE_COMPONENTS_LOCATE_INFO_MSFT`
- `XR_TYPE_SCENE_OBJECTS_MSFT`
- `XR_TYPE_SCENE_COMPONENT_PARENT_FILTER_INFO_MSFT`
- `XR_TYPE_SCENE_OBJECT_TYPES_FILTER_INFO_MSFT`
- `XR_TYPE_SCENE_PLANES_MSFT`
- `XR_TYPE_SCENE_PLANE_ALIGNMENT_FILTER_INFO_MSFT`
- `XR_TYPE_SCENE_MESHES_MSFT`
- `XR_TYPE_SCENE_MESH_BUFFERS_GET_INFO_MSFT`
- `XR_TYPE_SCENE_MESH_BUFFERS_MSFT`
**XrResult** enumeration is extended with:

- XR_ERROR_COMPUTE_NEW_SCENE_NOT_COMPLETED_MSFT
- XR_ERROR_SCENE_COMPONENT_ID_INVALID_MSFT
- XR_ERROR_SCENE_COMPONENT_TYPE_MISMATCH_MSFT
- XR_ERROR_SCENE_MESH_BUFFER_ID_INVALID_MSFT
- XR_ERROR_SCENE_COMPUTE_FEATURE_INCOMPATIBLE_MSFT
- XR_ERROR_SCENE_COMPUTE_CONSISTENCY_MISMATCH_MSFT

**New Enums**

- XrSceneComputeFeatureMSFT
- XrSceneComputeConsistencyMSFT
- XrSceneObjectTypeMSFT
- XrScenePlaneAlignmentTypeMSFT
- XrSceneComputeStateMSFT
- XrSceneComponentTypeMSFT
- XrMeshComputeLodMSFT

**New Structures**

- XrSceneObserverCreateInfoMSFT
- XrSceneCreateInfoMSFT
- XrNewSceneComputeInfoMSFT
- XrUuidMSFT
- XrSceneObserverCreateInfoMSFT
- XrSceneCreateInfoMSFT
- XrNewSceneComputeInfoMSFT
- XrVisualMeshComputeLodInfoMSFT
- XrSceneSphereBoundMSFT
- XrSceneOrientedBoxBoundMSFT
- XrSceneFrustumBoundMSFT
- XrSceneBoundsMSFT
- XrSceneComponentMSFT
- XrSceneComponentsMSFT
- XrSceneComponentsGetInfoMSFT
• XrSceneComponentLocationMSFT
• XrSceneComponentLocationsMSFT
• XrSceneComponentsLocateInfoMSFT
• XrSceneObjectMSFT
• XrSceneObjectsMSFT
• XrSceneComponentParentFilterInfoMSFT
• XrSceneObjectTypesFilterInfoMSFT
• XrScenePlaneMSFT
• XrScenePlanesMSFT
• XrScenePlaneAlignmentFilterInfoMSFT
• XrSceneMeshMSFT
• XrSceneMeshesMSFT
• XrSceneMeshBuffersGetInfoMSFT
• XrSceneMeshBuffersMSFT

New Functions

• xrCreateSceneObserverMSFT
• xrDestroySceneObserverMSFT
• xrCreateSceneMSFT
• xrDestroySceneMSFT
• xrComputeNewSceneMSFT
• xrGetSceneComponentsMSFT
• xrLocateSceneComponentsMSFT
• xrGetSceneMeshBuffersMSFT

Issues

Version History

• Revision 1, 2021-05-03 (Darryl Gough)
  ◦ Initial extension description

12.85. XR_MSFT_scene_understanding_serialization

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XR_MSFT_scene_understanding_serialization
Extension Type
Instance extension

Registered Extension Number
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Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0
• Requires XR_MSFT_scene_understanding

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IP Status
No known IP claims.

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Overview
This extension extends the scene understanding extension and enables scenes to be serialized or deserialized. It enables computing a new scene into a serialized binary stream and it enables deserializing a binary stream into an XrSceneMSFT handle.

Serialize a scene
This extension adds XR_SCENE_COMPUTE_FEATURE_SERIALIZE_SCENE_MSFT to XrSceneComputeFeatureMSFT, which can be passed to xrComputeNewSceneMSFT plus one or more of XR_SCENE_COMPUTE_FEATURE_PLANE_MSFT, XR_SCENE_COMPUTE_FEATURE_PLANE_MESH_MSFT, XR_SCENE_COMPUTE_FEATURE_VISUAL_MESH_MSFT or XR_SCENE_COMPUTE_FEATURE_COLLIDER_MESH_MSFT to inform the runtime that it should compute a serialized binary representation of the scene. If XR_SCENE_COMPUTE_FEATURE_SERIALIZE_SCENE_MSFT is the only XrSceneComputeFeatureMSFT passed to xrComputeNewSceneMSFT then XR_ERROR_SCENE_COMPUTE_FEATURE_INCOMPATIBLE_MSFT must be returned.

If an XrSceneMSFT was created using XR_SCENE_COMPUTE_FEATURE_SERIALIZE_SCENE_MSFT then XR_SCENE_COMPONENT_TYPE_SERIALIZED_SCENE_FRAGMENT_MSFT can be passed to the
xrGetSceneComponentsMSFT function to read the list of serialized scene fragment XrUuidMSFT values from XrSceneComponentMSFT::id. The XrUuidMSFT of a scene fragment can be passed to xrGetSerializedSceneFragmentDataMSFT to read the binary data of the given scene fragment.

The application can call the xrGetSerializedSceneFragmentDataMSFT function to read the binary data of a serialized scene fragment from the XrSceneMSFT handle. This function follows the two-call idiom for filling the buffer.

The xrGetSerializedSceneFragmentDataMSFT function is defined as:

```c
XrResult xrGetSerializedSceneFragmentDataMSFT(
    XrSceneMSFT                                 scene,
    const XrSerializedSceneFragmentDataGetInfoMSFT* getInfo,
    uint32_t                                    countInput,
    uint32_t*                                   readOutput,
    uint8_t*                                    buffer);
```

### Parameter Descriptions

- **scene** is the XrSceneMSFT handle to read from.
- **getInfo** is a pointer to an XrSerializedSceneFragmentDataGetInfoMSFT structure.
- **countInput** is the number of bytes that should be read.
- **readOutput** is the number of bytes read.
- **buffer** is a pointer to the buffer where the data should be copied.

The runtime must return XR_ERROR_SCENE_COMPONENT_ID_INVALID_MSFT if the given scene fragment XrUuidMSFT was not found.

### Valid Usage (Implicit)

- The XR_MSFT_scene_understanding_serialization extension must be enabled prior to calling xrGetSerializedSceneFragmentDataMSFT
- **scene** must be a valid XrSceneMSFT handle
- **getInfo** must be a pointer to a valid XrSerializedSceneFragmentDataGetInfoMSFT structure
- **readOutput** must be a pointer to a uint32_t value
- If **countInput** is not 0, **buffer** must be a pointer to an array of **countInput** uint8_t values
Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_SIZE_INSUFFICIENT

The `XrSerializedSceneFragmentDataGetInfoMSFT` structure is defined as:

```c
typedef struct XrSerializedSceneFragmentDataGetInfoMSFT {
    XrStructureType    type;
    const void*        next;
    XrUuidMSFT         sceneFragmentId;
} XrSerializedSceneFragmentDataGetInfoMSFT;
```

Member Descriptions

• `type` is the `XrStructureType` of this structure.

• `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.

• `sceneFragmentId` is the `XrUuidMSFT` of the serialized scene fragment that was previously read from `XrGetSceneComponentsMSFT` with `XR_SCENE_COMPONENT_TYPE_SERIALIZE_SCENE_FRAGMENT_MSFT`. 
Valid Usage (Implicit)

- The XR_MSFT_scene_understanding_serialization extension must be enabled prior to using XrSerializedSceneFragmentDataGetInfoMSFT
- type must be XR_TYPE_SERIALIZED_SCENE_FRAGMENT_DATA_GET_INFO_MSFT
- next must be NULL or a valid pointer to the next structure in a structure chain

Deserialize a scene

This extension enables an application to deserialize the binary representation of a scene that was previously serialized.

For a given XrSceneObserverMSFT handle, instead of calling xrComputeNewSceneMSFT, which computes the scene from the system's sensors, the application can use xrDeserializeSceneMSFT to produce a scene from the given binary scene fragment data.

The xrDeserializeSceneMSFT function is defined as:

```c
XrResult xrDeserializeSceneMSFT(
    XrSceneObserverMSFT                         sceneObserver,
    const XrSceneDeserializeInfoMSFT*           deserializeInfo);
```

Parameter Descriptions

- sceneObserver is a handle to an XrSceneObserverMSFT previously created with xrCreateSceneObserverMSFT.
- deserializeInfo is a pointer to an XrSceneDeserializeInfoMSFT structure.

The xrDeserializeSceneMSFT function begins deserializing a list of serialized scene fragments. The runtime must return quickly without waiting for the deserialization to complete. The application should use xrGetSceneComputeStateMSFT to inspect the completeness of the deserialization.

The xrGetSceneComputeStateMSFT function must return XR_SCENE_COMPUTE_STATE_UPDATING_MSFT while the deserialization is in progress, and XR_SCENE_COMPUTE_STATE_COMPLETED_MSFT when the deserialization has completed successfully. If the runtime fails to deserialize the binary stream, xrGetSceneComputeStateMSFT must return XR_SCENE_COMPUTE_STATE_COMPLETED_WITH_ERROR_MSFT to indicate that the deserialization has completed but an error occurred.

When xrGetSceneComputeStateMSFT returns XR_SCENE_COMPUTE_STATE_COMPLETED_MSFT, the application may call xrCreateSceneMSFT to create the XrSceneMSFT handle. If xrCreateSceneMSFT is called while
xrGetSceneComputeStateMSFT returns XR_SCENE_COMPUTE_STATE_COMPLETED_WITH_ERROR_MSFT, a valid XrSceneMSFT handle must be returned, but that handle must contain zero scene components.

**Valid Usage (Implicit)**

- The XR_MSFT_scene_understanding_serialization extension must be enabled prior to calling xrDeserializeSceneMSFT
- sceneObserver must be a valid XrSceneObserverMSFT handle
- deserializeInfo must be a pointer to a valid XrSceneDeserializeInfoMSFT structure

**Return Codes**

**Success**
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY

XrSceneDeserializeInfoMSFT is an input structure that describes the array of serialized scene fragments that will be deserialized by the xrDeserializeSceneMSFT function.

```c
typedef struct XrSceneDeserializeInfoMSFT {
    XrStructureType                          type;
    const void*                              next;
    uint32_t                                 fragmentCount;
    const XrDeserializeSceneFragmentMSFT*    fragments;
} XrSceneDeserializeInfoMSFT;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **fragmentCount** is the count of `XrDeserializeSceneFragmentMSFT` structures in the *fragments* array.
- **fragments** is an array of `XrDeserializeSceneFragmentMSFT`.

If the scene fragments are not in the same order as returned by `xrGetSceneComponentsMSFT` or the runtime failed to deserialized the binary data then `xrGetSceneComputeStateMSFT` must return `XR_SCENE_COMPUTE_STATE_COMPLETED_WITH_ERROR_MSFT`.

Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding_serialization` extension must be enabled prior to using `XrSceneDeserializeInfoMSFT`.
- **type** must be `XR_TYPE_SCENE_DESERIALIZE_INFO_MSFT`.
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain.
- If **fragmentCount** is not 0, **fragments** must be a pointer to an array of **fragmentCount** valid `XrDeserializeSceneFragmentMSFT` structures.

The `XrDeserializeSceneFragmentMSFT` structure represents a single fragment of a binary stream to be deserialized. It is defined as:

```c
typedef struct XrDeserializeSceneFragmentMSFT {
    uint32_t     bufferSize;
    const uint8_t* buffer;
} XrDeserializeSceneFragmentMSFT;
```

Member Descriptions

- **bufferSize** is the size of the **buffer** array.
- **buffer** is an array of uint_8 data for the scene fragment to be deserialized.
Valid Usage (Implicit)

- The `XR_MSFT_scene_understanding_serialization` extension must be enabled prior to using `XrDeserialzeSceneFragmentMSFT`.
- If `bufferSize` is not 0, `buffer` must be a pointer to an array of `bufferSize uint8_t` values.

New Object Types

New Flag Types

New Enum Constants

`XrSceneComponentTypeMSFT` enumeration is extended with:

- `XR_SCENE_COMPONENT_TYPE_SERIALIZED_SCENE_FRAGMENT_MSFT`

`XrSceneComputeFeatureMSFT` enumeration is extended with:

- `XR_SCENE_COMPUTE_FEATURE_SERIALIZE_SCENE_MSFT`

`XrStructureType` enumeration is extended with:

- `XR_TYPE_SERIALIZED_SCENE_FRAGMENT_DATA_GET_INFO_MSFT`
- `XR_TYPE_SCENE_DESERIALIZE_INFO_MSFT`

New Enums

New Structures

- `XrSerializedSceneFragmentDataGetInfoMSFT`
- `XrSceneDeserializeInfoMSFT`
- `XrDeserialzeSceneFragmentMSFT`

New Functions

- `xrGetSerializedSceneFragmentDataMSFT`
- `xrDeserialzeSceneMSFT`

Issues

Version History

- Revision 1, 2021-05-03 (Darryl Gough)
  - Initial extension description
12.86. XR_MSFT_secondary_view_configuration

Name String

XR_MSFT_secondary_view_configuration

Extension Type

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Registered Extension Number

54

Revision

1

Extension and Version Dependencies

• Requires OpenXR 1.0

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No known IP claims.

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12.86.1. Overview

This extension allows an application to enable support for one or more secondary view configurations. A secondary view configuration is a well-known set of views that the runtime can make active while a session is running. In a frame where a secondary view configuration is active, the application’s single frame loop should additionally render into those active secondary views, sharing the frame waiting logic and update loop with the primary view configuration for that running session.

A proper secondary view configuration support includes following steps:

1. When calling xrCreateInstance, enable the XR_MSFT_secondary_view_configuration extension and the extension defines a concrete secondary view configuration type, for example, XR_MSFT_first_person_observer.

2. Inspect supported secondary view configurations using the xrEnumerateViewConfigurations function.

3. Enable supported secondary view configurations using the xrBeginSession function with an
4. Inspect if an enabled secondary view configuration is activated by the system or the user using the `xrWaitFrame` function with an `XrSecondaryViewConfigurationFrameStateMSFT` chained extension structure.

5. When a secondary view configuration is changed to active, get the latest view configuration properties using the `xrGetViewConfigurationProperties` and `xrEnumerateViewConfigurationViews` functions.

6. Create the swapchain images for the active secondary view configuration using the `xrCreateSwapchain` function with an `XrSecondaryViewConfigurationSwapchainCreateInfoMSFT` chained extension structure using `recommendedImageRectWidth` and `recommendedImageRectHeight` in the corresponding `XrViewConfigurationView` structure returned from `xrEnumerateViewConfigurationViews`.

7. Locate the secondary view configuration views using the `xrLocateViews` function with the active secondary view configuration type.

8. Submit the composition layers using the swapchain images for an active secondary view configuration using the `xrEndFrame` function with the `XrSecondaryViewConfigurationFrameEndInfoMSFT` chained extension structure.

12.86.2. Enumerate supported secondary view configurations

The first step is for the application to inspect if a runtime supports certain secondary view configurations. The app uses the existing API `xrEnumerateViewConfigurations` for this.

For example, when the `XR_MSFT_first_person_observer` extension is enabled, the application will enumerate a view configuration of type `XR_VIEW_CONFIGURATION_TYPE_SECONDARY_MONO_FIRST_PERSON_OBSERVER_MSFT`, and can use this secondary view configuration type in later functions.

12.86.3. Secondary view configuration properties

The application can inspect the properties of a secondary view configuration through the existing `xrGetViewConfigurationProperties`, `xrEnumerateViewConfigurationViews` and `xrEnumerateEnvironmentBlendModes` functions using a supported secondary view configuration type.

The runtime may change the recommended properties, such as recommended image width or height, when the secondary view configuration becomes active. The application should use the latest recommended width and height when creating swapchain images and related resources for the active secondary view configuration.

When an application creates swapchain images for a secondary view configuration, it can chain a `XrSecondaryViewConfigurationSwapchainCreateInfoMSFT` structure to `XrSwapchainCreateInfo` when calling `xrCreateSwapchain`. This hints to the runtime that the created swapchain image will be submitted to the given secondary view configuration, allowing the runtime to make optimizations for such usage when there is opportunity.
typedef struct XrSecondaryViewConfigurationSwapchainCreateInfoMSFT {
    XrStructureType            type;
    const void*                next;
    XrViewConfigurationType    viewConfigurationType;
} XrSecondaryViewConfigurationSwapchainCreateInfoMSFT;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **viewConfigurationType** is the secondary view configuration type the application is intending to use this swapchain for.

If this structure is not present in the XrSwapchainCreateInfo next chain when calling xrCreateSwapchain, the runtime should optimize the created swapchain for the primary view configuration of the session.

If the application submits a swapchain image created with one view configuration type to a composition layer for another view configuration, the runtime may need to copy the resource across view configurations. However, the runtime must correctly compose the image regardless which view configuration type was hinted when swapchain image was created.

**Valid Usage (Implicit)**

- The XR_MSFT_secondary_view_configuration extension must be enabled prior to using XrSecondaryViewConfigurationSwapchainCreateInfoMSFT
- **type** must be XR_TYPE_SECONDARY_VIEW_CONFIGURATION_SWAPCHAIN_CREATE_INFO_MSFT
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **viewConfigurationType** must be a valid XrViewConfigurationType value

### 12.86.4. Enable secondary view configuration

The application indicates to the runtime which secondary view configurations it can support by chaining an XrSecondaryViewConfigurationSessionBeginInfoMSFT structure to the XrSessionBeginInfo::next pointer when calling xrBeginSession.

The XrSecondaryViewConfigurationSessionBeginInfoMSFT structure is used by the application to
indicate the list of secondary XrViewConfigurationType to enable for this session.

It is defined as:

```c
typedef struct XrSecondaryViewConfigurationSessionBeginInfoMSFT {
    XrStructureType                   type;
    const void*                       next;
    uint32_t                          viewConfigurationCount;
    const XrViewConfigurationType*    enabledViewConfigurationTypes;
} XrSecondaryViewConfigurationSessionBeginInfoMSFT;
```

**Member Descriptions**

- *type* is the XrStructureType of this structure.
- *next* is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- *viewConfigurationCount* is the number of elements in *enabledViewConfigurationTypes*
- *enabledViewConfigurationTypes* is an array of enabled secondary view configuration types that application supports.

If there are any duplicated view configuration types in the array of *enabledViewConfigurationTypes*, the runtime **must** return error XR_ERROR_VALIDATION_FAILURE.

If there are any primary view configuration types in the array of *enabledViewConfigurationTypes*, the runtime **must** return error XR_ERROR_VALIDATION_FAILURE.

If there are any secondary view configuration types not returned by xrEnumerateViewConfigurations in the array of *enabledViewConfigurationTypes*, the runtime **must** return error XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED.
Valid Usage (Implicit)

- The `XR_MSFT_secondary_view_configuration` extension must be enabled prior to using `XrSecondaryViewConfigurationSessionBeginInfoMSFT`
- `type` must be `XR_TYPE_SECONDARY_VIEW_CONFIGURATION_SESSION_BEGIN_INFO_MSFT`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `enabledViewConfigurationTypes` must be a pointer to an array of `viewConfigurationCount` valid `XrViewConfigurationType` values
- The `viewConfigurationCount` parameter must be greater than 0

12.86.5. Per-frame active view configurations

The runtime then tells the application at each `xrWaitFrame` function call which of the enabled secondary view configurations are active for that frame. When extension structure `XrSecondaryViewConfigurationFrameStateMSFT` is chained to the `XrFrameState::next` pointer, the runtime writes into this structure the state of each enabled secondary view configuration.

The `XrSecondaryViewConfigurationFrameStateMSFT` structure returns whether the enabled view configurations are active or inactive.

It is defined as as:

```c
typedef struct XrSecondaryViewConfigurationFrameStateMSFT {
    XrStructureType                           type;
    void*                                     next;
    uint32_t                                  viewConfigurationCount;
    XrSecondaryViewConfigurationStateMSFT*    viewConfigurationStates;
} XrSecondaryViewConfigurationFrameStateMSFT;
```

**Member Descriptions**

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `viewConfigurationCount` is the number of elements in `viewConfigurationStates`.
- `viewConfigurationStates` is an array of `XrSecondaryViewConfigurationStateMSFT` structures.

The array size `viewConfigurationCount` in the `XrSecondaryViewConfigurationFrameStateMSFT`
structure **must** be the same as the array size enabled through \( \text{XrSecondaryViewConfigurationSessionBeginInfoMSFT} \) when calling \( \text{xrBeginSession} \) earlier, otherwise the runtime **must** return error \( \text{XR_ERROR_VALIDATION_FAILURE} \).

### Valid Usage (Implicit)

- The \( \text{XR_MSFT_secondary_view_configuration} \) extension **must** be enabled prior to using \( \text{XrSecondaryViewConfigurationFrameStateMSFT} \)
- **type** **must** be \( \text{XR_TYPE_SECONDARY_VIEW_CONFIGURATION_FRAME_STATE_MSFT} \)
- **next** **must** be \( \text{NULL} \) or a valid pointer to the **next** structure in a structure chain
- **viewConfigurationStates** **must** be a pointer to an array of **viewConfigurationCount** \( \text{XrSecondaryViewConfigurationStateMSFT} \) structures
- The **viewConfigurationCount** parameter **must** be greater than \( 0 \)

The \( \text{XrSecondaryViewConfigurationStateMSFT} \) structure returns the state of an enabled secondary view configurations.

```c
typedef struct XrSecondaryViewConfigurationStateMSFT {
    XrStructureType              type;
    void*                        next;
    XrViewConfigurationType      viewConfigurationType;
    XrBool32                     active;
} XrSecondaryViewConfigurationStateMSFT;
```

### Member Descriptions

- **type** is the **XrStructureType** of this structure.
- **next** is **NULL** or a pointer to the **next** structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **viewConfigurationType** is an **XrViewConfigurationType** that represents the returned state.
- **active** is an **XrBool32** returns whether the secondary view configuration is active and displaying frames to users.

When a secondary view configuration becomes active, the application **should** render its secondary views as soon as possible, by getting their view transforms and FOV using \( \text{xrLocateViews} \) and then submitting composition layers to \( \text{xrEndFrame} \) through the \( \text{XrSecondaryViewConfigurationFrameEndInfoMSFT} \) extension structure. When a secondary view configuration changes from inactive to active, the runtime **may** change \( \text{XrViewConfigurationView} \) of
the given view configuration such as the recommended image width or height. An application should query for latest XrViewConfigurationView through xrEnumerateViewConfigurationViews function for the secondary view configuration and consider recreating swapchain images if necessary. The runtime must not change the XrViewConfigurationView, including recommended image width and height of a secondary view configuration when active remains true until the secondary view configuration deactivated or the session has ended.

If necessary, the application can take longer than a frame duration to prepare by calling xrEndFrame without submitting layers for that secondary view configuration until ready. The runtime should delay the underlying scenario managed by the secondary view configuration until the application begins submitting frames with layers for that configuration. The active secondary view configuration composed output is undefined if the application stops submitting frames with layers for a secondary view configuration while active remains true.

When the runtime intends to conclude a secondary view configuration, for example when user stops video capture, the runtime makes the view configuration inactive by setting the corresponding active in the XrSecondaryViewConfigurationStateMSFT structure to false.

Valid Usage (Implicit)

- The XR_MSFT_secondary_view_configuration extension must be enabled prior to using XrSecondaryViewConfigurationStateMSFT
- type must be XR_TYPE_SECONDARY_VIEW_CONFIGURATION_STATE_MSFT
- next must be NULL or a valid pointer to the next structure in a structure chain
- viewConfigurationType must be a valid XrViewConfigurationType value

12.86.6. Locate and inspect view states of secondary view configurations

When the application calls xrLocateViews, it can use XrViewLocateInfo::viewConfigurationType field to query the view locations and projections for any enabled XrViewConfigurationType for the running session.

The runtime must return XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED from xrLocateViews if the specified XrViewConfigurationType is not enabled for the running session using XrSecondaryViewConfigurationSessionBeginInfoMSFT when calling xrBeginSession.

If the view configuration is supported but not active, as indicated in XrSecondaryViewConfigurationFrameStateMSFT, xrLocateViews will successfully return, but the resulting XrViewState may have XR_VIEW_STATE_ORIENTATION_TRACKED_BIT and XR_VIEW_STATE_ORIENTATION_TRACKED_BIT unset.
12.86.7. Submit composition layers to secondary view configurations

The application should submit layers each frame for all active secondary view configurations using the `xrEndFrame` function, by chaining the `XrSecondaryViewConfigurationFrameEndInfoMSFT` structure to the next pointer of `XrFrameEndInfo` structure.

The `XrSecondaryViewConfigurationFrameEndInfoMSFT` structure is defined as:

```c
typedef struct XrSecondaryViewConfigurationFrameEndInfoMSFT {
    XrStructureType                                     type;  
    const void*                                         next;  
    uint32_t                                            viewConfigurationCount;  
    const XrSecondaryViewConfigurationLayerInfoMSFT*    viewConfigurationLayersInfo;
} XrSecondaryViewConfigurationFrameEndInfoMSFT;
```

### Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **viewConfigurationCount** is the number of elements in `viewConfigurationLayersInfo`.
- **viewConfigurationLayersInfo** is an array of `XrSecondaryViewConfigurationLayerInfoMSFT`, containing composition layers to be submitted for the specified active view configuration.

The view configuration type in each `XrSecondaryViewConfigurationLayerInfoMSFT` must be one of the view configurations enabled when calling `xrBeginSession` in `XrSecondaryViewConfigurationSessionBeginInfoMSFT`, or else the runtime must return error `XR_ERROR_SECONDARY_VIEW_CONFIGURATION_TYPE_NOT_ENABLED_MSFT`.

The view configuration type in each `XrSecondaryViewConfigurationLayerInfoMSFT` must not be the primary view configuration in this session, or else the runtime must return error `XR_ERROR_LAYER_INVALID`. The primary view configuration layers continue to be submitted through `XrFrameEndInfo` directly.

If the view configuration is not active, as indicated in `XrSecondaryViewConfigurationFrameStateMSFT`, the composition layers submitted to this view configuration may be ignored by the runtime. Applications should avoid rendering into secondary views when the view configuration is inactive.
Valid Usage (Implicit)

- The `XR_MSFT_secondary_view_configuration` extension **must** be enabled prior to using `XrSecondaryViewConfigurationFrameEndInfoMSFT`
- **type** **must** be `XR_TYPE_SECONDARY_VIEW_CONFIGURATION_FRAME_END_INFO_MSFT`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **viewConfigurationLayersInfo** **must** be a pointer to an array of `viewConfigurationCount` valid `XrSecondaryViewConfigurationLayerInfoMSFT` structures
- The `viewConfigurationCount` parameter **must** be greater than 0

The application should submit an `XrSecondaryViewConfigurationLayerInfoMSFT` in `XrSecondaryViewConfigurationFrameEndInfoMSFT` for each active secondary view configuration type when calling `xrEndFrame`.

The `XrSecondaryViewConfigurationLayerInfoMSFT` structure is defined as as:

```c
typedef struct XrSecondaryViewConfigurationLayerInfoMSFT {
    XrStructureType                               type;
    const void*                                   next;
    XrViewConfigurationType                       viewConfigurationType;
    XrEnvironmentBlendMode                        environmentBlendMode;
    uint32_t                                      layerCount;
    const XrCompositionLayerBaseHeader* const*    layers;
} XrSecondaryViewConfigurationLayerInfoMSFT;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **viewConfigurationType** is `XrViewConfigurationType` to which the composition layers will be displayed.
- **environmentBlendMode** is the `XrEnvironmentBlendMode` value representing the desired environment blend mode for this view configuration.
- **layerCount** is the number of composition layers in this frame for the secondary view configuration type. The maximum supported layer count is identified by `XrSystemGraphicsProperties::maxLayerCount`. If `layerCount` is greater than the maximum supported layer count then `XR_ERROR_LAYER_LIMIT_EXCEEDED` is returned.
- **layers** is a pointer to an array of `XrCompositionLayerBaseHeader` pointers.

This structure is similar to the `XrFrameEndInfo` structure, with an extra `XrViewConfigurationType` field to specify the view configuration for which the submitted layers will be rendered.

The application **should** render its content for both the primary and secondary view configurations using the same `predictedDisplayTime` reported by `xrWaitFrame`. The runtime **must** treat both the primary views and secondary views as being submitted for the same `displayTime` specified in the call to `xrEndFrame`.

For layers such as quad layers whose content is identical across view configurations, the application **can** submit the same `XrCompositionLayerBaseHeader` structures to multiple view configurations in the same `xrEndFrame` function call.

For each frame, the application **should** only render and submit layers for the secondary view configurations that were active that frame, as indicated in the `XrSecondaryViewConfigurationFrameStateMSFT` filled in for that frame’s `xrWaitFrame` call. The runtime **must** ignore composition layers submitted for an inactive view configuration.
Valid Usage (Implicit)

• The XR_MSFT_secondary_view_configuration extension must be enabled prior to using XrSecondaryViewConfigurationLayerInfoMSFT
• type must be XR_TYPE_SECONDARY_VIEW_CONFIGURATION_LAYER_INFO_MSFT
• next must be NULL or a valid pointer to the next structure in a structure chain
• viewConfigurationType must be a valid XrViewConfigurationType value
• environmentBlendMode must be a valid XrEnvironmentBlendMode value
• layers must be a pointer to an array of layerCount valid XrCompositionLayerBaseHeader-based structures. See also: XrCompositionLayerCubeKHR, XrCompositionLayerCylinderKHR, XrCompositionLayerEquirect2KHR, XrCompositionLayerEquirectKHR, XrCompositionLayerProjection, XrCompositionLayerQuad
• The layerCount parameter must be greater than 0

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

• XR_TYPE_SECONDARY_VIEW_CONFIGURATION_SESSION_BEGIN_INFO_MSFT
• XR_TYPE_SECONDARY_VIEW_CONFIGURATION_STATE_MSFT
• XR_TYPE_SECONDARY_VIEW_CONFIGURATION_FRAME_STATE_MSFT
• XR_TYPE_SECONDARY_VIEW_CONFIGURATION_FRAME_END_INFO_MSFT
• XR_TYPE_SECONDARY_VIEW_CONFIGURATION_LAYER_INFO_MSFT
• XR_ERROR_SECONDARY_VIEW_CONFIGURATION_TYPE_NOT_ENABLED_MSFT

New Enums

New Structures

• XrSecondaryViewConfigurationSessionBeginInfoMSFT
• XrSecondaryViewConfigurationStateMSFT
• XrSecondaryViewConfigurationFrameStateMSFT
• XrSecondaryViewConfigurationFrameEndInfoMSFT
• XrSecondaryViewConfigurationLayerInfoMSFT

New Functions
12.87. XR_MSFT_spatial_anchor

Name String
XR_MSFT_spatial_anchor

Extension Type
Instance extension

Registered Extension Number
40

Revision
2

Extension and Version Dependencies
• Requires OpenXR 1.0

Overview
This extension allows an application to create a spatial anchor, an arbitrary freespace point in the user’s physical environment that will then be tracked by the runtime. The runtime should then adjust the position and orientation of that anchor’s origin over time as needed, independently of all other spaces and anchors, to ensure that it maintains its original mapping to the real world.

Spatial anchors are often used in combination with an UNBOUNDED_MSFT reference space. UNBOUNDED_MSFT reference spaces adjust their origin as necessary to keep the viewer’s coordinates relative to the space’s origin stable. Such adjustments maintain the visual stability of content currently near the viewer, but may cause content placed far from the viewer to drift in its alignment to the real world by the time the user moves close again. By creating an XrSpatialAnchorMSFT where a piece of content is placed and then always rendering that content relative to its anchor’s space, an application can ensure that each piece of content stays at a fixed location in the environment.

The xrCreateSpatialAnchorMSFT function is defined as:
XrResult xrCreateSpatialAnchorMSFT(
    XrSession session,
    const XrSpatialAnchorCreateInfoMSFT* createInfo,
    XrSpatialAnchorMSFT* anchor);

Parameter Descriptions

- **session** is a handle to an XrSession.
- **createInfo** is a pointer to an XrSpatialAnchorCreateInfoMSFT structure containing information about how to create the anchor.
- **anchor** is a pointer to a handle in which the created XrSpatialAnchorMSFT is returned.

Creates an XrSpatialAnchorMSFT handle representing a spatial anchor that will track a fixed location in the physical world over time. That real-world location is specified by the position and orientation of the specified pose within space at time.

If space cannot be located relative to the environment at the moment of the call to xrCreateSpatialAnchorMSFT, the runtime must return XR_ERROR_CREATE_SPATIAL_ANCHOR_FAILED_MSFT.

After the anchor is created, the runtime should then adjust its position and orientation over time relative to other spaces so as to maintain maximum alignment to its original real-world location, even if that changes the anchor's relationship to the original space used to initialize it.

Valid Usage (Implicit)

- The XR_MSFT_spatial_anchor extension must be enabled prior to calling xrCreateSpatialAnchorMSFT
- **session** must be a valid XrSession handle
- **createInfo** must be a pointer to a valid XrSpatialAnchorCreateInfoMSFT structure
- **anchor** must be a pointer to an XrSpatialAnchorMSFT handle
Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_TIME_INVALID
- XR_ERROR_POSE_INVALID
- XR_ERROR_CREATE_SPATIAL_ANCHOR_FAILED_MSFT

The `XrSpatialAnchorCreateInfoMSFT` structure is defined as:

typedef struct XrSpatialAnchorCreateInfoMSFT {
    XrStructureType type;
    const void* next;
    XrSpace space;
    XrPosef pose;
    XrTime time;
} XrSpatialAnchorCreateInfoMSFT;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **space** is a handle to the `XrSpace` in which **pose** is specified.
- **pose** is the `XrPosef` within **space** at **time** that specifies the point in the real world used to initialize the new anchor.
- **time** is the `XrTime` at which **pose** will be evaluated within **space**.

Valid Usage (Implicit)

- The `XR_MSFT_spatial_anchor` extension must be enabled prior to using `XrSpatialAnchorCreateInfoMSFT`
- **type** must be `XR_TYPE_SPATIAL_ANCHOR_CREATE_INFO_MSFT`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- **space** must be a valid `XrSpace` handle

The `xrCreateSpatialAnchorSpaceMSFT` function is defined as:

```c
XrResult xrCreateSpatialAnchorSpaceMSFT(
    XrSession session,
    const XrSpatialAnchorSpaceCreateInfoMSFT* createInfo,
    XrSpace* space);
```

Parameter Descriptions

- **session** is a handle to an `XrSession`.
- **createInfo** is a pointer to an `XrSpatialAnchorSpaceCreateInfoMSFT` structure containing information about how to create the anchor.
- **space** is a pointer to a handle in which the created `XrSpace` is returned.

Creates an `XrSpace` handle based on a spatial anchor. Application can provide an `XrPosef` to define the position and orientation of the new space's origin relative to the anchor's natural origin.

Multiple `XrSpace` handles may exist for a given `XrSpatialAnchorMSFT` simultaneously, up to some limit.
imposed by the runtime. The \texttt{XrSpace} handle must be eventually freed via the \texttt{xrDestroySpace} function or by destroying the parent \texttt{XrSpatialAnchorMSFT} handle.

### Valid Usage (Implicit)

- The \texttt{XR_MSFT_spatial_anchor} extension must be enabled prior to calling \texttt{xrCreateSpatialAnchorSpaceMSFT}
- \texttt{session} must be a valid \texttt{XrSession} handle
- \texttt{createInfo} must be a pointer to a valid \texttt{XrSpatialAnchorSpaceCreateInfoMSFT} structure
- \texttt{space} must be a pointer to an \texttt{XrSpace} handle

### Return Codes

**Success**

- \texttt{XR_SUCCESS}
- \texttt{XR_SESSION_LOSS_PENDING}

**Failure**

- \texttt{XR_ERROR_FUNCTION_UNSUPPORTED}
- \texttt{XR_ERROR_VALIDATION_FAILURE}
- \texttt{XR_ERROR_HANDLE_INVALID}
- \texttt{XR_ERROR_INSTANCE_LOST}
- \texttt{XR_ERROR_SESSION_LOST}
- \texttt{XR_ERROR_OUT_OF_MEMORY}
- \texttt{XR_ERROR_LIMIT_REACHED}
- \texttt{XR_ERROR_POSE_INVALID}

The \texttt{XrSpatialAnchorSpaceCreateInfoMSFT} structure is defined as:

```c
typedef struct XrSpatialAnchorSpaceCreateInfoMSFT {
    XrStructureType        type;
    const void*            next;
    XrSpatialAnchorMSFT    anchor;
    XrPosef                poseInAnchorSpace;
} XrSpatialAnchorSpaceCreateInfoMSFT;
```
Member Descriptions

- `type` is the `XrStructureType` of this structure.
- `next` is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `anchor` is a handle to an `XrSpatialAnchorMSFT` previously created with `xrCreateSpatialAnchorMSFT`.
- `poseInAnchorSpace` is an `XrPosef` defining the position and orientation of the new space's origin relative to the anchor's natural origin.

Valid Usage (Implicit)

- The `XR_MSFT_spatial_anchor` extension must be enabled prior to using `XrSpatialAnchorSpaceCreateInfoMSFT`
- `type` must be `XR_TYPE_SPATIAL_ANCHOR_SPACE_CREATE_INFO_MSFT`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `anchor` must be a valid `XrSpatialAnchorMSFT` handle

The `xrDestroySpatialAnchorMSFT` function is defined as:

```c
XrResult xrDestroySpatialAnchorMSFT(
    XrSpatialAnchorMSFT anchor);
```

Parameter Descriptions

- `anchor` is a handle to an `XrSpatialAnchorMSFT` previously created by `xrCreateSpatialAnchorMSFT`.

`XrSpatialAnchorMSFT` handles are destroyed using `xrDestroySpatialAnchorMSFT`. By destroying an anchor, the runtime can stop spending resources used to maintain tracking for that anchor's origin.
Valid Usage (Implicit)

- The `XR_MSFT_spatial_anchor` extension must be enabled prior to calling `xrDestroySpatialAnchorMSFT`.
- `anchor` must be a valid `XrSpatialAnchorMSFT` handle.

Thread Safety

- Access to `anchor`, and any child handles, must be externally synchronized.

Return Codes

**Success**
- `XR_SUCCESS`

**Failure**
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_HANDLE_INVALID`

New Object Types

`XrSpatialAnchorMSFT`

New Flag Types

New Enum Constants

`XrObjectType` enumeration is extended with:
- `XR_OBJECT_TYPE_SPATIAL_ANCHOR_MSFT`

`XrStructureType` enumeration is extended with:
- `XR_TYPE_SPATIAL_ANCHOR_CREATE_INFO_MSFT`
- `XR_TYPE_SPATIAL_ANCHOR_SPACE_CREATE_INFO_MSFT`

`XrResult` enumeration is extended with:
- `XR_ERROR_CREATE_SPATIAL_ANCHOR_FAILED_MSFT`

New Enums
New Structures

XrSpatialAnchorCreateInfoMSFT
XrSpatialAnchorSpaceCreateInfoMSFT

New Functions

xrCreateSpatialAnchorMSFT
xrCreateSpatialAnchorSpaceMSFT
xrDestroySpatialAnchorMSFT

Issues

Version History

• Revision 1, 2019-07-30 (Alex Turner)
  ◦ Initial extension description
• Revision 2, 2021-06-02 (Ryan Pavlik, Collabora)
  ◦ Note that the parameter to xrDestroySpatialAnchorMSFT must be externally synchronized

12.88. XR_MSFT_spatial_anchor_persistence

Name String

XR_MSFT_spatial_anchor_persistence

Extension Type

Instance extension

Registered Extension Number

143

Revision

2

Extension and Version Dependencies

• Requires OpenXR 1.0
• Requires XR_MSFT_spatial_anchor

Last Modified Date

2021-07-15
12.88.1. Overview

This extension allows persistence and retrieval of spatial anchors sharing and localization across application sessions on a device. Spatial anchors persisted during an application session on a device will only be able to be retrieved during sessions of that same application on the same device. This extension requires XR_MSFT_spatial_anchor to also be enabled.

12.88.2. Spatial Anchor Store Connection

The XrSpatialAnchorStoreConnectionMSFT handle represents a connection to the spatial anchor store and is used by the application to perform operations on the spatial anchor store such as:

- Persisting and unpersisting of spatial anchors.
- Enumeration of currently persisted anchors.
- Clearing the spatial anchor store of all anchors.

The application can use the xrCreateSpatialAnchorStoreConnectionMSFT function to create an handle to the spatial anchor store. The application can use this handle to interact with the spatial anchor store in order to persist anchors across application sessions.

The xrCreateSpatialAnchorStoreConnectionMSFT function may be a slow operation and therefore should be invoked from a non-timing critical thread.
Parameter Descriptions

- **session** is the XrSession the anchor was created with.
- **spatialAnchorStore** is a pointer to the XrSpatialAnchorStoreConnectionMSFT handle.

Valid Usage (Implicit)

- The **XR_MSFT_spatial_anchor_persistence** extension must be enabled prior to calling **xrCreateSpatialAnchorStoreConnectionMSFT**
- **session** must be a valid XrSession handle
- **spatialAnchorStore** must be a pointer to an XrSpatialAnchorStoreConnectionMSFT handle

Return Codes

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED

The application can use the **xrDestroySpatialAnchorStoreConnectionMSFT** function to destroy an anchor store connection.

```c
XrResult xrDestroySpatialAnchorStoreConnectionMSFT(
    XrSpatialAnchorStoreConnectionMSFT spatialAnchorStore);
```
Parameter Descriptions

- `spatialAnchorStore` is the `XrSpatialAnchorStoreConnectionMSFT` to be destroyed.

Valid Usage (Implicit)

- The `XR_MSFT_spatial_anchor_persistence` extension must be enabled prior to calling `xrDestroySpatialAnchorStoreConnectionMSFT`
- `spatialAnchorStore` must be a valid `XrSpatialAnchorStoreConnectionMSFT` handle

Thread Safety

- Access to `spatialAnchorStore`, and any child handles, must be externally synchronized

Return Codes

**Success**

- `XR_SUCCESS`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_OUT_OF_MEMORY`

12.88.3. Persist Spatial Anchor

The application can use the `xrPersistSpatialAnchorMSFT` function to persist a spatial anchor in the spatial anchor store for this application. The given `spatialAnchorName` will be the string to retrieve the spatial anchor from the Spatial Anchor store or subsequently remove the record of this spatial anchor from the store. This name will uniquely identify the spatial anchor for the current application. If there is already a spatial anchor of the same name persisted in the spatial anchor store, the existing spatial anchor will be replaced and `xrPersistSpatialAnchorMSFT` must return `XR_SUCCESS`.

```c
XrResult xrPersistSpatialAnchorMSFT(
    XrSpatialAnchorStoreConnectionMSFT          spatialAnchorStore,
    const XrSpatialAnchorPersistenceInfoMSFT*   spatialAnchorPersistenceInfo);
```
**Parameter Descriptions**

- `spatialAnchorStore` is the `XrSpatialAnchorStoreConnectionMSFT` with which to persist the `spatialAnchor`.

- `spatialAnchorPersistenceInfo` is a pointer to `XrSpatialAnchorPersistenceInfoMSFT` structure to specify the anchor and its name to persist.

**Valid Usage (Implicit)**

- The `XR_MSFT_spatial_anchor_persistence` extension **must** be enabled prior to calling `xrPersistSpatialAnchorMSFT`

- `spatialAnchorStore` **must** be a valid `XrSpatialAnchorStoreConnectionMSFT` handle

- `spatialAnchorPersistenceInfo` **must** be a pointer to a valid `XrSpatialAnchorPersistenceInfoMSFT` structure

**Return Codes**

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_SPATIAL_ANCHOR_NAME_INVALID_MSFT`

The `XrSpatialAnchorPersistenceNameMSFT` structure is the name associated with the `XrSpatialAnchorMSFT` in the spatial anchor store. It is used to perform persist and unpersist on an `spatialAnchor` in the spatial anchor store.

The `XrSpatialAnchorPersistenceNameMSFT` structure is defined as:
typedef struct XrSpatialAnchorPersistenceNameMSFT {
    char name[XR_MAX_SPATIAL_ANCHOR_NAME_SIZE_MSFT];
} XrSpatialAnchorPersistenceNameMSFT;

**Member Descriptions**

- *name* is a null terminated character array of size `XR_MAX_SPATIAL_ANCHOR_NAME_SIZE_MSFT`.

If an `XrSpatialAnchorPersistenceNameMSFT` with an empty *name* value is passed to any function as a parameter, that function **must** return `XR_ERROR_SPATIAL_ANCHOR_NAME_INVALID_MSFT`.

**Valid Usage (Implicit)**

- The `XR_MSFT_spatial_anchor_persistence` extension **must** be enabled prior to using `XrSpatialAnchorPersistenceNameMSFT`
- *name** **must** be a null-terminated UTF-8 string whose length is less than or equal to `XR_MAX_SPATIAL_ANCHOR_NAME_SIZE_MSFT`

The `XrSpatialAnchorPersistenceInfoMSFT` structure is defined as:

typedef struct XrSpatialAnchorPersistenceInfoMSFT {
    XrStructureType type;
    const void* next;
    XrSpatialAnchorPersistenceNameMSFT spatialAnchorPersistenceName;
    XrSpatialAnchorMSFT spatialAnchor;
} XrSpatialAnchorPersistenceInfoMSFT;

**Member Descriptions**

- *type* is the `XrStructureType` of this structure.
- *next* is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- *spatialAnchorPersistenceName* is an `XrSpatialAnchorPersistenceNameMSFT` containing the name associated with the `XrSpatialAnchorMSFT` in the spatial anchor store.
- *spatialAnchor* is the `XrSpatialAnchorMSFT` that the application wishes to perform persistence operations on.
Valid Usage (Implicit)

- The `XR_MSFT_spatial_anchor_persistence` extension must be enabled prior to using `XrSpatialAnchorPersistenceInfoMSFT`
- `type` must be `XR_TYPE_SPATIAL_ANCHOR_PERSISTENCE_INFO_MSFT`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `spatialAnchorPersistenceName` must be a valid `XrSpatialAnchorPersistenceNameMSFT` structure
- `spatialAnchor` must be a valid `XrSpatialAnchorMSFT` handle

The application can use the `xrEnumeratePersistedSpatialAnchorNamesMSFT` function to enumerate the names of all spatial anchors currently persisted in the spatial anchor store for this application. This function follows the two-call idiom for filling the `spatialAnchorNames`.

```c
XrResult xrEnumeratePersistedSpatialAnchorNamesMSFT(
    XrSpatialAnchorStoreConnectionMSFT          spatialAnchorStore,
    uint32_t                                    spatialAnchorNamesCapacityInput,
    uint32_t*                                   spatialAnchorNamesCountOutput,
    XrSpatialAnchorPersistenceNameMSFT*         persistedAnchorNames);
```

Parameter Descriptions

- `spatialAnchorStore` is the `XrSpatialAnchorStoreConnectionMSFT` anchor store to perform the enumeration operation on.
- `spatialAnchorNamesCapacityInput` is the capacity of the `spatialAnchorNames` array, or 0 to indicate a request to retrieve the required capacity.
- `spatialAnchorNamesCountOutput` is filled in by the runtime with the count of anchor names written or the required capacity in the case that `spatialAnchorNamesCapacityInput` is insufficient.
- `persistedAnchorNames` is a pointer to an array of `XrSpatialAnchorPersistenceNameMSFT` structures, but can be `NULL` if `propertyCapacityInput` is 0.
- See the Buffer Size Parameters section for a detailed description of retrieving the required `persistedAnchorNames` size.
Valid Usage (Implicit)

- The `XR_MSFT_spatial_anchor_persistence` extension must be enabled prior to calling `xrEnumeratePersistedSpatialAnchorNamesMSFT`
- `spatialAnchorStore` must be a valid `XrSpatialAnchorStoreConnectionMSFT` handle
- If `spatialAnchorNamesCountOutput` is not NULL, `spatialAnchorNamesCountOutput` must be a pointer to a `uint32_t` value
- If `spatialAnchorNamesCapacityInput` is not 0, `persistedAnchorNames` must be a pointer to an array of `spatialAnchorNamesCapacityInput` `XrSpatialAnchorPersistenceNameMSFT` structures

Return Codes

Success

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_SIZE_INSUFFICIENT`

The application can use the `xrCreateSpatialAnchorFromPersistedNameMSFT` function to create a `XrSpatialAnchorMSFT` from the spatial anchor store. If the `spatialAnchorName` provided does not correspond to a currently stored anchor (i.e. the list of spatial anchor names returned from `xrEnumeratePersistedSpatialAnchorNamesMSFT`), the function must return `XR_ERROR_SPATIAL_ANCHOR_NAME_NOT_FOUND_MSFT`.

```c
XrResult xrCreateSpatialAnchorFromPersistedNameMSFT(
    XrSession                                   session,
    const XrSpatialAnchorFromPersistedAnchorCreateInfoMSFT* spatialAnchorCreateInfo,
    XrSpatialAnchorMSFT*                        spatialAnchor);
```
Parameter Descriptions

- session is a handle to an XrSession previously created with xrCreateSession.
- spatialAnchorCreateInfo is a pointer to the XrSpatialAnchorFromPersistedAnchorCreateInfoMSFT.
- spatialAnchor is a pointer to an XrSpatialAnchorMSFT handle that will be set by the runtime on successful load.

Valid Usage (Implicit)

- The XR_MSFT_spatial_anchor_persistence extension must be enabled prior to calling xrCreateSpatialAnchorFromPersistedNameMSFT
- session must be a valid XrSession handle
- spatialAnchorCreateInfo must be a pointer to a valid XrSpatialAnchorFromPersistedAnchorCreateInfoMSFT structure
- spatialAnchor must be a pointer to an XrSpatialAnchorMSFT handle

Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_SPATIAL_ANCHOR_NAME_NOT_FOUND_MSFT
- XR_ERROR_SPATIAL_ANCHOR_NAME_INVALID_MSFT

The XrSpatialAnchorFromPersistedAnchorCreateInfoMSFT structure is defined as:
```c
typedef struct XrSpatialAnchorFromPersistedAnchorCreateInfoMSFT {
    XrStructureType       type;
    const void*           next;
    XrSpatialAnchorStoreConnectionMSFT spatialAnchorStore;
    XrSpatialAnchorPersistenceNameMSFT spatialAnchorPersistenceName;
} XrSpatialAnchorFromPersistedAnchorCreateInfoMSFT;
```

### Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR.
- **spatialAnchorStore** is the `XrSpatialAnchorStoreConnectionMSFT` from which the spatial anchor will be loaded from.
- **spatialAnchorPersistenceName** is the `XrSpatialAnchorPersistenceNameMSFT` associated with the `XrSpatialAnchorMSFT` in the spatial anchor store. This name is used to create an `XrSpatialAnchorMSFT` handle from a spatial anchor persisted in the spatial anchor store.

The **name** is a character array of maximum size `XR_MAX_SPATIAL_ANCHOR_NAME_SIZE_MSFT`, which must include a null terminator and must not be empty (i.e. the first element is the null terminator). If an empty **name** value is passed to any function as a parameter, that function must return `XR_ERROR_SPATIAL_ANCHOR_NAME_INVALID_MSFT`.

### Valid Usage (Implicit)

- The `XR_MSFT_spatial_anchor_persistence` extension must be enabled prior to using `XrSpatialAnchorFromPersistedAnchorCreateInfoMSFT`
- **type** must be `XR_TYPE_SPATIAL_ANCHOR_FROM_PERSISTED_ANCHOR_CREATE_INFO_MSFT`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- **spatialAnchorStore** must be a valid `XrSpatialAnchorStoreConnectionMSFT` handle
- **spatialAnchorPersistenceName** must be a valid `XrSpatialAnchorPersistenceNameMSFT` structure

The application can use the `xrUnpersistSpatialAnchorMSFT` function to remove the record of the anchor in the spatial anchor store. This operation will not affect any `XrSpatialAnchorMSFT` handles previously created. If the **spatialAnchorName** provided does not correspond to a currently stored anchor, the function must return `XR_ERROR_SPATIAL_ANCHOR_NAME_NOT_FOUND_MSFT`. 
XrResult xrUnpersistSpatialAnchorMSFT(
    XrSpatialAnchorStoreConnectionMSFT spatialAnchorStore,
    const XrSpatialAnchorPersistenceNameMSFT* spatialAnchorPersistenceName);

**Parameter Descriptions**

- *spatialAnchorStore* is an `XrSpatialAnchorStoreConnectionMSFT` anchor store to perform the unpersist operation on.
- *spatialAnchorPersistenceName* is a pointer to the `XrSpatialAnchorPersistenceNameMSFT`.

**Valid Usage (Implicit)**

- The `XR_MSFT_spatial_anchor_persistence` extension **must** be enabled prior to calling `xrUnpersistSpatialAnchorMSFT`
- *spatialAnchorStore** must** be a valid `XrSpatialAnchorStoreConnectionMSFT` handle
- *spatialAnchorPersistenceName** must** be a pointer to a valid `XrSpatialAnchorPersistenceNameMSFT` structure

**Return Codes**

**Success**
- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_SPATIAL_ANCHOR_NAME_NOT_FOUND_MSFT`
- `XR_ERROR_SPATIAL_ANCHOR_NAME_INVALID_MSFT`
The application can use the `xrClearSpatialAnchorStoreMSFT` function to remove all spatial anchors from the spatial anchor store for this application. The function only removes the record of the spatial anchors in the store but does not affect any `XrSpatialAnchorMSFT` handles previously loaded in the current session.

```c
XrResult xrClearSpatialAnchorStoreMSFT(
    XrSpatialAnchorStoreConnectionMSFT spatialAnchorStore);
```

### Parameter Descriptions

- `spatialAnchorStore` is `XrSpatialAnchorStoreConnectionMSFT` to perform the clear operation on.

### Valid Usage (Implicit)

- The `XR_MSFT_spatial_anchor_persistence` extension must be enabled prior to calling `xrClearSpatialAnchorStoreMSFT`
- `spatialAnchorStore` must be a valid `XrSpatialAnchorStoreConnectionMSFT` handle

### Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`

### New Object Types

- `XrSpatialAnchorStoreConnectionMSFT`
New Flag Types

New Enum Constants

- XR_TYPE_SPATIAL_ANCHOR_PERSISTENCE_INFO_MSFT
- XR_TYPE_SPATIAL_ANCHOR_FROM_PERSISTED_ANCHOR_CREATE_INFO_MSFT
- XR_ERROR_SPATIAL_ANCHOR_NAME_NOT_FOUND_MSFT
- XR_ERROR_SPATIAL_ANCHOR_NAME_INVALID_MSFT
- XR_MAX_SPATIAL_ANCHOR_NAME_SIZE_MSFT

New Enums

New Structures

- XrSpatialAnchorPersistenceNameMSFT
- XrSpatialAnchorPersistenceInfoMSFT
- XrSpatialAnchorFromPersistedAnchorCreateInfoMSFT

New Functions

- xrCreateSpatialAnchorStoreConnectionMSFT
- xrDestroySpatialAnchorStoreConnectionMSFT
- xrPersistSpatialAnchorMSFT
- xrEnumeratePersistedSpatialAnchorNamesMSFT
- xrCreateSpatialAnchorFromPersistedNameMSFT
- xrUnpersistSpatialAnchorMSFT
- xrClearSpatialAnchorStoreMSFT

Version History

- Revision 1, 2021-02-19 (Lachlan Ford)
  - Initial extension proposal
- Revision 2, 2021-07-15 (Yin Li)
  - Extension proposal to OpenXR working group

12.89. XR_MSFT_spatial_graph_bridge

Name String

XR_MSFT_spatial_graph_bridge
Extension Type

Instance extension

Registered Extension Number

50

Revision

2

Extension and Version Dependencies

• Requires OpenXR 1.0

Contributors

Darryl Gough, Microsoft
Yin Li, Microsoft
Alex Turner, Microsoft
David Fields, Microsoft

Overview

This extension enables applications to interop between XrSpace handles and other Windows Mixed Reality device platform libraries or APIs. These libraries represent a spatially tracked point, also known as a "spatial graph node", with a GUID value. This extension enables applications to create XrSpace handles from spatial graph nodes. Applications can also try to get a spatial graph node from an XrSpace handle.

12.89.1. Create XrSpace from Spatial Graph Node

The xrCreateSpatialGraphNodeSpaceMSFT function creates an XrSpace handle for a given spatial graph node type and ID.

```
XrResult xrCreateSpatialGraphNodeSpaceMSFT(
    XrSession                                   session,
    const XrSpatialGraphNodeSpaceCreateInfoMSFT* createInfo,
    XrSpace*                                    space);
```
Parameter Descriptions

- session is the XrSession which will use the created space.
- createInfo is an XrSpatialGraphNodeSpaceCreateInfoMSFT specifying the space to be created.
- space is the returned XrSpace handle for the given spatial node ID.

Valid Usage (Implicit)

- The XR_MSFT_spatial_graph_bridge extension must be enabled prior to calling xrCreateSpatialGraphNodeSpaceMSFT
- session must be a valid XrSession handle
- createInfo must be a pointer to a valid XrSpatialGraphNodeSpaceCreateInfoMSFT structure
- space must be a pointer to an XrSpace handle

Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_POSE_INVALID

The XrSpatialGraphNodeSpaceCreateInfoMSFT structure is used with xrCreateSpatialGraphNodeSpaceMSFT to create an XrSpace handle for a given spatial node type and node ID.
typedef struct XrSpatialGraphNodeSpaceCreateInfoMSFT {
    XrStructureType               type;
    const void*                   next;
    XrSpatialGraphNodeTypeMSFT    nodeType;
    uint8_t                       nodeId[XR_GUID_SIZE_MSFT];
    XrPosef                       pose;
} XrSpatialGraphNodeSpaceCreateInfoMSFT;

Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **nodeType** is an `XrSpatialGraphNodeTypeMSFT` specifying the spatial node type.
- **nodeId** is a global unique identifier (a.k.a. GUID or 16 byte array), representing the spatial node that is being tracked.
- **pose** is an `XrPosef` defining the position and orientation of the new space’s origin within the natural reference frame of the spatial graph node.

Valid Usage (Implicit)

- The `XR_MSFT_spatial_graph_bridge` extension must be enabled prior to using `XrSpatialGraphNodeSpaceCreateInfoMSFT`
- **type** must be `XR_TYPE_SPATIAL_GRAPH_NODE_SPACE_CREATE_INFO_MSFT`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain
- **nodeType** must be a valid `XrSpatialGraphNodeTypeMSFT` value

The enum `XrSpatialGraphNodeTypeMSFT` describes the types of spatial graph nodes.

typedef enum XrSpatialGraphNodeTypeMSFT {
    XR_SPATIAL_GRAPH_NODE_TYPE_STATIC_MSFT = 1,
    XR_SPATIAL_GRAPH_NODE_TYPE_DYNAMIC_MSFT = 2,
    XR_SPATIAL_GRAPH_NODE_TYPE_MAX_ENUM_MSFT = 0x7FFFFFFF
} XrSpatialGraphNodeTypeMSFT;

There are two types of spatial graph nodes: static and dynamic.
Static spatial nodes track the pose of a fixed location in the world relative to reference spaces. The tracking of static nodes may slowly adjust the pose over time for better accuracy but the pose is relatively stable in the short term, such as between rendering frames. For example, a QR code tracking library can use a static node to represent the location of the tracked QR code. Static spatial nodes are represented by \texttt{XR\_SPATIAL\_GRAPH\_NODE\_TYPE\_STATIC\_MSFT}.

Dynamic spatial nodes track the pose of a physical object that moves continuously relative to reference spaces. The pose of dynamic spatial nodes can be very different within the duration of a rendering frame. It is important for the application to use the correct timestamp to query the space location using \texttt{xrLocateSpace}. For example, a color camera mounted in front of a HMD is also tracked by the HMD so a web camera library can use a dynamic node to represent the camera location. Dynamic spatial nodes are represented by \texttt{XR\_SPATIAL\_GRAPH\_NODE\_TYPE\_DYNAMIC\_MSFT}.

### 12.89.2. Create Spatial Graph Node Binding from XrSpace

The \texttt{XrSpatialGraphNodeBindingMSFT} handle represents a binding to a spatial graph node. This handle allows an application to get a spatial graph node GUID from an \texttt{XrSpace} to use in other Windows Mixed Reality device platform libraries or APIs.

The runtime must remember the spatial graph node and track it for the lifetime of the \texttt{XrSpatialGraphNodeBindingMSFT} handle. When the \texttt{XrSpatialGraphNodeBindingMSFT} handle is destroyed then the runtime's tracking system may forget about the spatial graphic node and stop tracking it.

```c
XR_DEFINE_HANDLE(XrSpatialGraphNodeBindingMSFT)
```

The \texttt{xrTryCreateSpatialGraphStaticNodeBindingMSFT} function tries to create a spatial graph static node binding nearest to the given location and returns an \texttt{XrSpatialGraphNodeBindingMSFT} handle.

```c
XrResult xrTryCreateSpatialGraphStaticNodeBindingMSFT(
    XrSession                                   session,
    const XrSpatialGraphStaticNodeBindingCreateInfoMSFT* createInfo,
    XrSpatialGraphNodeBindingMSFT*              nodeBinding);
```
Parameter Descriptions

- **session** is the specified `XrSession`.
- **createInfo** is the `XrSpatialGraphStaticNodeBindingCreateInfoMSFT` input structure.
- **nodeBinding** is the `XrSpatialGraphNodeBindingMSFT` output structure.

The runtime **may** return `XR_SUCCESS` and set `nodeBinding` to `XR_NULL_HANDLE` if it is unable to create a spatial graph static node binding. This may happen when the given `XrSpace` cannot be properly tracked at the moment. The application can retry creating the `XrSpatialGraphNodeBindingMSFT` handle again after a reasonable period of time when tracking is regained.

Valid Usage (Implicit)

- The `XR_MSFT_spatial_graph_bridge` extension **must** be enabled prior to calling `xrTryCreateSpatialGraphStaticNodeBindingMSFT`
- **session** **must** be a valid `XrSession` handle
- **createInfo** **must** be a pointer to a valid `XrSpatialGraphStaticNodeBindingCreateInfoMSFT` structure
- **nodeBinding** **must** be a pointer to an `XrSpatialGraphNodeBindingMSFT` handle
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_TIME_INVALID
- XR_ERROR_POSE_INVALID

XrSpatialGraphStaticNodeBindingCreateInfoMSFT is an input structure for xrTryCreateSpatialGraphStaticNodeBindingMSFT.

typedef struct XrSpatialGraphStaticNodeBindingCreateInfoMSFT {
    XrStructureType    type;
    const void*        next;
    XrSpace            space;
    XrPosef            poseInSpace;
    XrTime             time;
} XrSpatialGraphStaticNodeBindingCreateInfoMSFT;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain.
- **space** is a handle to the XrSpace in which poseInSpace is specified.
- **poseInSpace** is the XrPosef within space at time.
- **time** is the XrTime at which poseInSpace will be evaluated within space.

Valid Usage (Implicit)

- The XR_MSFT_spatial_graph_bridge extension must be enabled prior to using XrSpatialGraphStaticNodeBindingCreateInfoMSFT
- **type** must be XR_TYPE_SPATIAL_GRAPH_STATIC_NODE_BINDING_CREATE_INFO_MSFT
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **space** must be a valid XrSpace handle

The xrDestroySpatialGraphNodeBindingMSFT function releases the nodeBinding and the underlying resources.

```c
XrResult xrDestroySpatialGraphNodeBindingMSFT(
    XrSpatialGraphNodeBindingMSFT nodeBinding);
```

Parameter Descriptions

- **nodeBinding** is an XrSpatialGraphNodeBindingMSFT previously created by xrTryCreateSpatialGraphStaticNodeBindingMSFT.

Valid Usage (Implicit)

- The XR_MSFT_spatial_graph_bridge extension must be enabled prior to calling xrDestroySpatialGraphNodeBindingMSFT
- **nodeBinding** must be a valid XrSpatialGraphNodeBindingMSFT handle
Thread Safety

- Access to `nodeBinding`, and any child handles, **must** be externally synchronized

Return Codes

**Success**
- XR_SUCCESS

**Failure**
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_HANDLE_INVALID

Get spatial graph node binding properties

The `xrGetSpatialGraphNodeBindingPropertiesMSFT` function retrieves the spatial graph node GUID and the pose in the node space from an `XrSpatialGraphNodeBindingMSFT` handle.

```
XrResult xrGetSpatialGraphNodeBindingPropertiesMSFT(
    XrSpatialGraphNodeBindingMSFT               nodeBinding,
    const XrSpatialGraphNodeBindingPropertiesGetInfoMSFT* getInfo,
    XrSpatialGraphNodeBindingPropertiesMSFT*    properties);
```

Parameter Descriptions

- `nodeBinding` is an `XrSpatialGraphNodeBindingMSFT` previously created by `xrTryCreateSpatialGraphStaticNodeBindingMSFT`.
- `getInfo` is a pointer to an `XrSpatialGraphNodeBindingPropertiesGetInfoMSFT` input structure.
- `properties` is a pointer to an `XrSpatialGraphNodeBindingPropertiesMSFT` output structure.
Valid Usage (Implicit)

- The `XR_MSFT_spatial_graph_bridge` extension **must** be enabled prior to calling `xrGetSpatialGraphNodeBindingPropertiesMSFT`.
- `nodeBinding` **must** be a valid `XrSpatialGraphNodeBindingMSFT` handle.
- If `getInfo` is not `NULL`, `getInfo` **must** be a pointer to a valid `XrSpatialGraphNodeBindingPropertiesGetInfoMSFT` structure.
- `properties` **must** be a pointer to an `XrSpatialGraphNodeBindingPropertiesMSFT` structure.

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_OUT_OF_MEMORY`

`XrSpatialGraphNodeBindingPropertiesGetInfoMSFT` is an input structure for `xrGetSpatialGraphNodeBindingPropertiesMSFT`.

typedef struct XrSpatialGraphNodeBindingPropertiesGetInfoMSFT {
    XrStructureType    type;
    const void*        next;
} XrSpatialGraphNodeBindingPropertiesGetInfoMSFT;
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain.

Valid Usage (Implicit)

- The `XR_MSFT_spatial_graph_bridge` extension **must** be enabled prior to using `XrSpatialGraphNodeBindingPropertiesGetInfoMSFT`
- **type** **must** be `XR_TYPE_SPATIAL_GRAPH_NODE_BINDING_PROPERTIES_GET_INFO_MSFT`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain

`XrSpatialGraphNodeBindingPropertiesMSFT` is an output structure for `xrGetSpatialGraphNodeBindingPropertiesMSFT`.

typedef struct XrSpatialGraphNodeBindingPropertiesMSFT {
    XrStructureType    type;
    void*              next;
    uint8_t            nodeId[XR_GUID_SIZE_MSFT];
    XrPosef            poseInNodeSpace;
} XrSpatialGraphNodeBindingPropertiesMSFT;

Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain.
- **nodeId** is a global unique identifier (a.k.a. GUID or 16 byte array), representing the spatial graph node.
- **poseInNodeSpace** is an `XrPosef` defining the pose in the underlying node's space.
Valid Usage (Implicit)

- The XR_MSFT_spatial_graph_bridge extension must be enabled prior to using XrSpatialGraphNodeBindingPropertiesMSFT
- type must be XR_TYPE_SPATIAL_GRAPH_NODE_BINDING_PROPERTIES_MSFT
- next must be NULL or a valid pointer to the next structure in a structure chain

New Object Types

- XrSpatialGraphNodeBindingMSFT

New Flag Types

New Enum Constants

XrObjectType enumeration is extended with:

- XR_OBJECT_TYPE_SPATIAL_GRAPH_NODE_BINDING_MSFT

XrStructureType enumeration is extended with:

- XR_TYPE_SPATIAL_GRAPH_NODE_SPACE_CREATE_INFO_MSFT
- XR_TYPE_SPATIAL_GRAPH_STATIC_NODE_BINDING_CREATE_INFO_MSFT
- XR_TYPE_SPATIAL_GRAPH_NODE_BINDING_PROPERTIES_GET_INFO_MSFT
- XR_TYPE_SPATIAL_GRAPH_NODE_BINDING_PROPERTIES_MSFT

New Enums

- XrSpatialGraphNodeTypeMSFT

New Structures

- XrSpatialGraphNodeSpaceCreateInfoMSFT
- XrSpatialGraphStaticNodeBindingCreateInfoMSFT
- XrSpatialGraphNodeBindingPropertiesGetInfoMSFT
- XrSpatialGraphNodeBindingPropertiesMSFT

New Functions

- xrTryCreateSpatialGraphStaticNodeBindingMSFT
- xrDestroySpatialGraphNodeBindingMSFT
- xrGetSpatialGraphNodeBindingPropertiesMSFT
Issues

Version History

- Revision 1, 2019-10-31 (Yin LI)
  - Initial extension description
- Revision 2, 2022-01-13 (Darryl Gough)
  - Added Spatial Graph Node Binding handle.

12.90. XR_MSFT_unbounded_reference_space

Name String

XR_MSFT_unbounded_reference_space

Extension Type

Instance extension

Registered Extension Number

39

Revision

1

Extension and Version Dependencies

- Requires OpenXR 1.0

Overview

This extension allows an application to create an UNBOUNDED_MSFT reference space. This reference space enables the viewer to move freely through a complex environment, often many meters from where they started, while always optimizing for coordinate system stability near the viewer. This is done by allowing the origin of the reference space to drift as necessary to keep the viewer's coordinates relative to the space's origin stable.

To create an UNBOUNDED_MSFT reference space, the application can pass XR_REFERENCE_SPACE_TYPE_UNBOUNDED_MSFT to xrCreateReferenceSpace.

The UNBOUNDED_MSFT reference space establishes a world-locked origin, gravity-aligned to exclude pitch and roll, with +Y up, +X to the right, and -Z forward. This space begins with an arbitrary initial position and orientation, which the runtime may define to be either the initial position at app launch or some other initial zero position. Unlike a STAGE reference space, the runtime may place the origin of an UNBOUNDED_MSFT reference space at any height, rather than fixing it at the floor. This is because the viewer may move through various rooms and levels of their environment, each of which has a different floor height. Runtimes should not automatically adjust the position of the origin when the
viewer moves to a room with a different floor height.

**UNBOUNDED_MSFT** space is useful when an app needs to render **world-scale** content that spans beyond the bounds of a single **STAGE**, for example, an entire floor or multiple floors of a building.

An **UNBOUNDED_MSFT** space maintains stability near the viewer by slightly adjusting its origin over time. The runtime **must** not queue the **XrEventDataReferenceSpaceChangePending** event in response to these minor adjustments.

When views, controllers or other spaces experience tracking loss relative to the **UNBOUNDED_MSFT** space, runtimes **should** continue to provide inferred or last-known **position** and **orientation** values. These inferred poses can, for example, be based on neck model updates, inertial dead reckoning, or a last-known position, so long as it is still reasonable for the application to use that pose. While a runtime is providing position data, it **must** continue to set **XR_SPACE_LOCATION_POSITION_VALID_BIT** and **XR_VIEW_STATE_POSITION_VALID_BIT** but it **can** clear **XR_SPACE_LOCATION_POSITION_TRACKED_BIT** and **XR_VIEW_STATE_POSITION_TRACKED_BIT** to indicate that the position is inferred or last-known in this way.

When tracking is recovered, runtimes **should** snap the pose of other spaces back into position relative to the **UNBOUNDED_MSFT** space’s original origin. However, if tracking recovers into a new tracking volume in which the original origin can no longer be located (e.g. the viewer moved through a dark hallway and regained tracking in a new room), the runtime **may** recenter the origin arbitrarily, for example moving the origin to coincide with the viewer. If such recentering occurs, the runtime **must** queue the **XrEventDataReferenceSpaceChangePending** event with **poseValid** set to false.

If the viewer moves far enough away from the origin of an **UNBOUNDED_MSFT** reference space that floating point error would introduce noticeable error when locating the viewer within that space, the runtime **may** recenter the space’s origin to a new location closer to the viewer. If such recentering occurs, the runtime **must** queue the **XrEventDataReferenceSpaceChangePending** event with **poseValid** set to true.

Runtimes **must** support the **UNBOUNDED_MSFT** reference space when this extension is enabled.

**New Object Types**

**New Flag Types**

**New Enum Constants**

**XrReferenceSpaceType** enumeration is extended with:

- **XR_REFERENCE_SPACE_TYPE_UNBOUNDED_MSFT**

**New Enums**

**New Structures**

**New Functions**

**Issues**
Version History

- Revision 1, 2019-07-30 (Alex Turner)
  - Initial extension description

12.91. XR_OCULUS_android_session_state_enable

Name String

XR_OCULUS_android_session_state_enable

Extension Type

Instance extension

Registered Extension Number

45

Revision

1

Extension and Version Dependencies

- Requires OpenXR 1.0

Overview

This extension enables the integration of the Android session lifecycle and an OpenXR runtime session state. Some OpenXR runtimes may require this extension to transition the application to the session READY or STOPPING state.

Applications that run on an Android system with this extension enabled have a different OpenXR Session state flow.

On Android, it is the Android Activity lifecycle that will dictate when the system is ready for the application to begin or end its session, not the runtime.

When XR_OCULUS_android_session_state is enabled, the following changes are made to Session State handling:

- The runtime does not determine when the application’s session should be moved to the ready state, XR_SESSION_STATE_READY. The application should not wait to receive the XR_SESSION_STATE_READY session state changed event before beginning a session. Instead, the application should begin their session once there is a surface and the activity is resumed.

- The application should not call xrRequestExitSession to request the session move to the stopping state, XR_SESSION_STATE_STOPPING. xrRequestExitSession will return XR_ERROR_VALIDATION_FAILURE if called.

- The application should not wait to receive the XR_SESSION_STATE_STOPPING session state changed
event before ending a session. Instead, the application should end its session once the surface is destroyed or the activity is paused.

- The runtime will not transition to `XR_SESSION_STATE_READY` or `XR_SESSION_STATE_STOPPING` as the state is implicit from the Android activity and surface lifecycles.

**Android Activity life cycle**

An Android Activity can only be in the session running state while the activity is in the resumed state. The following shows how beginning and ending an XR session fits into the Android Activity life cycle.

1. VrActivity::onCreate() <--------+
2. VrActivity::onStart() <-------+  |
3. VrActivity::onResume() <----+  |
4. xrBeginSession() | |
5. xrEndSession() | |
6. VrActivity::onPause() -----+  |
7. VrActivity::onStop() ---------+  |
8. VrActivity::onDestroy() ---------+

**Android Surface life cycle**

An Android Activity can only be in the session running state while there is a valid Android Surface. The following shows how beginning and ending an XR session fits into the Android Surface life cycle.

1. VrActivity::surfaceCreated() <----+
2. VrActivity::surfaceChanged()      |
3. xrBeginSession()                  |
4. xrEndSession()                    |
5. VrActivity::surfaceDestroyed() ---+

Note that the life cycle of a surface is not necessarily tightly coupled with the life cycle of an activity. These two life cycles may interleave in complex ways. Usually `surfaceCreated()` is called after `onResume()` and `surfaceDestroyed()` is called between `onPause()` and `onDestroy()`. However, this is not guaranteed and, for instance, `surfaceDestroyed()` may be called after `onDestroy()` or even before `onPause()`.

An Android Activity is only in the resumed state with a valid Android Surface between `surfaceChanged()` or `onResume()`, whichever comes last, and `surfaceDestroyed()` or `onPause()`, whichever comes first. In other words, a XR application will typically begin the session from `surfaceChanged()` or `onResume()`, whichever comes last, and end the session from `surfaceDestroyed()` or `onPause()`, whichever comes first.

**New Object Types**

**New Flag Types**
New Enum Constants
New Enums
New Structures
New Functions
Issues

Version History

• Revision 1, 2019-08-16 (Cass Everitt)
  ◦ Initial extension description

12.92. XR_OCULUS_audio_device_guid

Name String
  XR_OCULUS_audio_device_guid

Extension Type
  Instance extension

Registered Extension Number
  160

Revision
  1

Extension and Version Dependencies
  • Requires OpenXR 1.0

Overview

This extension enables the querying of audio device information associated with an OpenXR instance.

On Windows, there may be multiple audio devices available on the system. This extension allows applications to query the runtime for the appropriate audio devices for the active HMD.

New Object Types
New Flag Types
New Enum Types

New Enum Constants
  • XR_MAX_AUDIO_DEVICE_STR_SIZE_OCULUS
New Enums

New Structures

New Functions

```c
XrResult xrGetAudioOutputDeviceGuidOculus(
    XrInstance instance,
    wchar_t buffer[XR_MAX_AUDIO_DEVICE_STR_SIZE_OCULUS]);
```

Parameter Descriptions

- **instance** is the `XrInstance` to query the audio device state in.
- **buffer** is a fixed size buffer which will contain the audio device GUID. The format of this data matches the `IMMDevice::GetId` API.

Valid Usage (Implicit)

- The `XR_OCULUS_audio_device_guid` extension **must** be enabled prior to calling `xrGetAudioOutputDeviceGuidOculus`
- **instance** **must** be a valid `XrInstance` handle
- **buffer** **must** be a wide character array of length `XR_MAX_AUDIO_DEVICE_STR_SIZE_OCULUS`

Return Codes

Success

- `XR_SUCCESS`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_FEATURE_UNSUPPORTED`
XrResult xrGetAudioInputDeviceGuidOculus(
    XrInstance instance,
    wchar_t buffer[XR_MAX_AUDIO_DEVICE_STR_SIZE_OCULUS]);

Parameter Descriptions

- **instance** is the XrInstance to query the audio device state in.
- **buffer** is a fixed size buffer which will contain the audio device GUID. The format of this data matches the IMMDevice::GetId API.

Valid Usage (Implicit)

- The XR_OCULUS_audio_device_guid extension **must** be enabled prior to calling xrGetAudioInputDeviceGuidOculus
- **instance** **must** be a valid XrInstance handle
- **buffer** **must** be a wide character array of length XR_MAX_AUDIO_DEVICE_STR_SIZE_OCULUS

Return Codes

**Success**

- XR_SUCCESS

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_FEATURE_UNSUPPORTED

Issues

Version History

- Revision 1, 2021-05-13 (John Kearney)
12.93. XR_ULTRALEAP_hand_tracking_forearm

Name String

XR_ULTRALEAP_hand_tracking_forearm

Extension Type

Instance extension

Registered Extension Number

150

Revision

1

Extension and Version Dependencies

• Requires OpenXR 1.0
• Requires XR_EXT_hand_tracking

Last Modified Date

2022-04-19

IP Status

No known IP claims.

Contributors

Robert Blenkinsopp, Ultraleap
Adam Harwood, Ultraleap

Overview

This extension augments the XR_EXT_hand_tracking extension to enable applications to request the default set of 26 hand joints, with the addition a joint representing the user's elbow.

The application must also enable the XR_EXT_hand_tracking extension in order to use this extension.

New joint set

This extension extends the XrHandJointSetEXT enumeration with a new member XrHandJointSet EXT_HAND_WITH_FOREARM_ULTRALEAP. This joint set is the same as the XrHandJointSet_DEFAULT_EXT, plus a joint representing the user’s elbow, XrHandJointForearm_ELBOW_ULTRALEAP.
typedef enum XrHandForearmJointULTRALEAP {
    XR_HAND_FOREARM_JOINT_PALM_ULTRALEAP = 0,
    XR_HAND_FOREARM_JOINT_WRIST_ULTRALEAP = 1,
    XR_HAND_FOREARM_JOINT_THUMB_METACARPAL_ULTRALEAP = 2,
    XR_HAND_FOREARM_JOINT_THUMB_PROXIMAL_ULTRALEAP = 3,
    XR_HAND_FOREARM_JOINT_THUMB_DISTAL_ULTRALEAP = 4,
    XR_HAND_FOREARM_JOINT_THUMB_TIP_ULTRALEAP = 5,
    XR_HAND_FOREARM_JOINT_INDEX_METACARPAL_ULTRALEAP = 6,
    XR_HAND_FOREARM_JOINT_INDEX_PROXIMAL_ULTRALEAP = 7,
    XR_HAND_FOREARM_JOINT_INDEX_INTERMEDIATE_ULTRALEAP = 8,
    XR_HAND_FOREARM_JOINT_INDEX_DISTAL_ULTRALEAP = 9,
    XR_HAND_FOREARM_JOINT_INDEX_TIP_ULTRALEAP = 10,
    XR_HAND_FOREARM_JOINT_MIDDLE_METACARPAL_ULTRALEAP = 11,
    XR_HAND_FOREARM_JOINT_MIDDLE_PROXIMAL_ULTRALEAP = 12,
    XR_HAND_FOREARM_JOINT_MIDDLE_INTERMEDIATE_ULTRALEAP = 13,
    XR_HAND_FOREARM_JOINT_MIDDLE_DISTAL_ULTRALEAP = 14,
    XR_HAND_FOREARM_JOINT_MIDDLE_TIP_ULTRALEAP = 15,
    XR_HAND_FOREARM_JOINT_RING_METACARPAL_ULTRALEAP = 16,
    XR_HAND_FOREARM_JOINT_RING_PROXIMAL_ULTRALEAP = 17,
    XR_HAND_FOREARM_JOINT_RING_INTERMEDIATE_ULTRALEAP = 18,
    XR_HAND_FOREARM_JOINT_RING_DISTAL_ULTRALEAP = 19,
    XR_HAND_FOREARM_JOINT_RING_TIP_ULTRALEAP = 20,
    XR_HAND_FOREARM_JOINT_LITTLE_METACARPAL_ULTRALEAP = 21,
    XR_HAND_FOREARM_JOINT_LITTLE_PROXIMAL_ULTRALEAP = 22,
    XR_HAND_FOREARM_JOINT_LITTLE_INTERMEDIATE_ULTRALEAP = 23,
    XR_HAND_FOREARM_JOINT_LITTLE_DISTAL_ULTRALEAP = 24,
    XR_HAND_FOREARM_JOINT_LITTLE_TIP_ULTRALEAP = 25,
    XR_HAND_FOREARM_JOINT_ELBOW_ULTRALEAP = 26,
    XR_HAND_FOREARM_JOINT_MAX_ENUM_ULTRALEAP = 0x7FFFFFFF
} XrHandForearmJointULTRALEAP;

Note
The first XR_HAND_JOINT_COUNT_EXT members of XrHandForearmJointULTRALEAP are identical to the members of XrHandJointEXT and can be used interchangeably.

The XR_HAND_FOREARM_JOINT_ELBOW_ULTRALEAP joint represents the center of an elbow and is orientated with the backwards (+Z) direction parallel to the forearm and points away from the hand.

The up (+Y) direction is pointing out of the dorsal side of the forearm. The X direction is perpendicular to Y and Z and follows the right hand rule.

#define XR_HAND_FOREARM_JOINT_COUNT_ULTRALEAP 27
**XR_HAND_FOREARM_JOINT_COUNT_ULTRALEAP** defines the number of hand joint enumerants defined in **XrHandForearmJointULTRALEAP**.

**New Object Types**

**New Flag Types**

**New Enum Constants**

- **XR_HAND_FOREARM_JOINT_COUNT_ULTRALEAP**

**XrHandJointSetEXT** enumeration is extended with:

- **XR_HAND_JOINT_SET_HAND_WITH_FOREARM_ULTRALEAP**

**New Enums**

- **XrHandForearmJointULTRALEAP**

**New Structures**

**New Functions**

**Issues**

**Version History**

- Revision 1, 2022-04-19 (Robert Blenkinsopp)
  - Initial version

### 12.94. XR_VALVE_analog_threshold

**Name String**

**XR_VALVE_analog_threshold**

**Extension Type**

- Instance extension

**Registered Extension Number**

- 80

**Revision**

- 2

**Extension and Version Dependencies**

- Requires OpenXR 1.0
Overview

This extension allows the application to control the threshold and haptic feedback applied to an analog to digital conversion. See XrInteractionProfileAnalogThresholdVALVE for more information.

Applications should also enable the XR_KHR_binding_modification extension to be able to define multiple thresholds.

New Object Types

New Flag Types

New Enum Constants

New Enums

New Structures

The XrInteractionProfileAnalogThresholdVALVE structure is an input struct that defines thresholds and haptic feedback behavior for action bindings and should be added to the bindingModifications array of the XrBindingModificationsKHR structure (See XR_KHR_binding_modification extension).

typedef struct XrInteractionProfileAnalogThresholdVALVE {
    XrStructureType              type;
    const void*                  next;
    XrAction                     action;
    XrPath                       binding;
    float                        onThreshold;
    float                        offThreshold;
    const XrHapticBaseHeader*    onHaptic;
    const XrHapticBaseHeader*    offHaptic;
} XrInteractionProfileAnalogThresholdVALVE;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **action** is the handle of an action in the suggested binding list.
- **binding** is the input path used for the specified action in the suggested binding list.
- **onThreshold** is the value between 0.0 and 1.0 at which the runtime **must** consider the binding to be true. The binding must remain true until the input analog value falls below **offThreshold**.
- **offThreshold** is the value between 0.0 and 1.0 at which the runtime **must** consider the binding to be false if it was previous true.
- **onHaptic** is the haptic output that the runtime **must** trigger when the binding changes from false to true. If this field is NULL, the runtime **must** not trigger any haptic output on the threshold. This field **can** point to any supported sub-type of XrHapticBaseHeader.
- **offHaptic** is the haptic output that the runtime **must** trigger when the binding changes from true to false. If this field is NULL, the runtime **must** not trigger any haptic output on the threshold. This field **can** point to any supported sub-type of XrHapticBaseHeader.

Applications can also chain a single XrInteractionProfileAnalogThresholdVALVE structure on the next chain of any xrSuggestInteractionProfileBindings call. Runtimes **must** support this kind of chaining. This method of specifying analog thresholds is deprecated however, and should not be used by any new applications.

If a threshold struct is present for a given conversion, the runtime **must** use those thresholds instead of applying its own whenever it is using the binding suggested by the application.

**onThreshold** and **offThreshold** permit allow the application to specify that it wants hysteresis to be applied to the threshold operation. If **onThreshold** is smaller than **offThreshold**, the runtime **must** return XR_ERROR_VALIDATION_FAILURE.

**onHaptic** and **offHaptic** allow the application to specify that it wants automatic haptic feedback to be generated when the boolean output of the threshold operation changes from false to true or vice versa. If these fields are not NULL, the runtime **must** trigger a haptic output with the specified characteristics. If the device has multiple haptic outputs, the runtime **should** use the haptic output that is most appropriate for the specified input path.

If a suggested binding with **action** and **binding** is not in the binding list for this interaction profile, the runtime **must** return XR_ERROR_PATH_UNSUPPORTED.
Valid Usage (Implicit)

- The `XR_VALVE_analog_threshold` extension **must** be enabled prior to using `XrInteractionProfileAnalogThresholdVALVE`.
- **type** must be `XR_TYPE_INTERACTION_PROFILE_ANALOG_THRESHOLD_VALVE`.
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain.
- **action** must be a valid `XrAction` handle.
- If `onHaptic` is not `NULL`, **onHaptic** must be a pointer to a valid `XrHapticBaseHeader`-based structure. See also: `XrHapticVibration`.
- If `offHaptic` is not `NULL`, **offHaptic** must be a pointer to a valid `XrHapticBaseHeader`-based structure. See also: `XrHapticVibration`.

New Functions

Issues

Version History

- Revision 1, 2020-06-29 (Joe Ludwig)
  - Initial version.
- Revision 2, 2021-07-28 (Rune Berg)
  - Deprecate chaining of struct in `XrInteractionProfileSuggestedBinding`, applications should use `XrBindingModificationsKHR` defined in the `XR_KHR_binding_modification` extension instead.

12.95. XR_VARJO_composition_layer_depth_test

Name String

`XR_VARJO_composition_layer_depth_test`

Extension Type

Instance extension

Registered Extension Number

123

Revision

2

Extension and Version Dependencies

- Requires OpenXR 1.0
• Requires XR_KHR_composition_layer_depth

**Last Modified Date**
2021-07-15

**IP Status**
No known IP claims.

**Contributors**
Sergiy Dubovik, Varjo Technologies  
Antti Hirvonen, Varjo Technologies  
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**Overview**

This extension enables depth-based layer composition inside the compositor.

Core OpenXR specifies that layer compositing must happen in the layer submission order (as described in *Compositing*). However, an application may want to composite the final image against the other layers based on depth information for proper occlusion. Layers can now provide depth information that will be used to calculate occlusion between those layers, as well as with the environment depth estimator (*XR_VARJO_environment_depth_estimation*) when enabled.

This extension defines a new type, *XrCompositionLayerDepthTestVARJO*, which can be chained to *XrCompositionLayerProjection* in order to activate this functionality. An application must also specify a range where depth testing will happen, potentially covering only a subset of the full depth range.

**Composition**

Layer composition rules change when this extension is enabled.

If the application does not chain *XrCompositionLayerDepthTestVARJO*, "painter's algorithm" such as described in *Compositing* must be used for layer composition.

Overall, composition should be performed in the following way:

1. Layers must be composited in the submission order. The compositor must track the depth value nearest to the virtual camera. Initial value for the nearest depth should be infinity.

2. If the currently processed layer does not contain depth, compositor should composite the layer against the previous layers with "painter's algorithm" and move to the next layer.

3. If the layer depth or the active nearest depth fall inside the depth test range of the layer, the compositor must perform depth test against the layer and active depth. If the layer depth is less or equal than the active depth, layer is composited normally with the previous layers and active depth is updated to match the layer depth. Otherwise the layer pixel is discarded, and compositor should move to composite the next layer.
Example

Mixed reality applications may want to show hands on top of the rendered VR content. For this purpose the application should enable environment depth estimation (see XR_VARJO_environment_depth_estimation extension) and depth testing with range 0m to 1m.

The following code illustrates how to enable depth testing:

```c
XrCompositionLayerProjection layer; // previously populated

XrCompositionLayerDepthTestVARJO depthTest{XR_TYPE_COMPOSITION_LAYER_DEPTH_TEST_VARJO,
layer.next};
depthTest.depthTestRangeNearZ = 0.0f; // in meters
depthTest.depthTestRangeFarZ = 1.0f; // in meters
layer.next = &depthTest;
```

New Structures

Applications can enable depth testing by adding XrCompositionLayerDepthTestVARJO to the next chain for all XrCompositionLayerProjectionView structures in the given layer in addition to XrCompositionLayerDepthInfoKHR. Missing XrCompositionLayerDepthInfoKHR automatically disables the depth testing functionality.

The XrCompositionLayerDepthTestVARJO structure is defined as:

```c
typedef struct XrCompositionLayerDepthTestVARJO {
    XrStructureType type;
    const void* next;
    float depthTestRangeNearZ;
    float depthTestRangeFarZ;
} XrCompositionLayerDepthTestVARJO;
```
Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **depthTestRangeNearZ** in a non-negative distance in meters that specifies the lower bound of the range where depth testing should be performed. Must be less than `depthTestRangeFarZ`. Value of zero means that there is no lower bound.
- **depthTestRangeFarZ** is a positive distance in meters that specifies the upper bound of the range where depth testing should be performed. Must be greater than `depthTestRangeNearZ`. Value of floating point positive infinity means that there is no upper bound.

Valid Usage (Implicit)

- The `XR_VARJO_composition_layer_depth_test` extension must be enabled prior to using `XrCompositionLayerDepthTestVARJO`
- **type** must be `XR_TYPE_COMPOSITION_LAYER_DEPTH_TEST_VARJO`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

New Enum Constants

`XrStructureType` enumeration is extended with:

- `XR_TYPE_COMPOSITION_LAYER_DEPTH_TEST_VARJO`

Version History

- Revision 1, 2021-02-16 (Sergiy Dubovik)
  - Initial extension description
- Revision 2, 2021-07-15 (Ryan Pavlik, Collabora, and Sergiy Dubovik)
  - Update sample code so it is buildable

### 12.96. XR_VARJO_environment_depth_estimation

Name String

- `XR_VARJO_environment_depth_estimation`

Extension Type

- Instance extension
Overview

This extension provides a mechanism for enabling depth estimation of the environment in the runtime-supplied compositor. This is an extension to XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND mode to not only use the color but also depth for composition of the final image.

Mixed reality applications might want to mix real and virtual content based on the depth information for proper occlusion. XR hardware and runtime may offer various ways to estimate the depth of the environment inside the compositor. When this estimation is enabled, the compositor can generate properly occluded final image when layers are submitted with depth information (both XR_KHR_composition_layer_depth and XR_VARJO_composition_layer_depth_test).

This extension defines a new function, xrSetEnvironmentDepthEstimationVARJO, which can be used to toggle environment depth estimation in the compositor. Toggling depth estimation is an asynchronous operation and the feature may not be activated immediately. Function can be called immediately after the session is created. Composition of the environment layer follows the rules as described in XR_VARJO_composition_layer_depth_test.

New Structures

The xrSetEnvironmentDepthEstimationVARJO function is defined as:
XrResult xrSetEnvironmentDepthEstimationVARJO(
    XrSession session,
    XrBool32 enabled);

Parameter Descriptions

- **session** is an *XrSession* handle previously created with *xrCreateSession*.
- **enabled** is a boolean that specifies whether depth estimation functionality should be activated. Compositor will disable depth estimation functionality if environment blend mode is not *XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND* and will enable the functionality when environment blend mode is set to *XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND*.

Valid Usage (Implicit)

- The *XR_VARJO_environment_depth_estimation* extension **must** be enabled prior to calling *xrSetEnvironmentDepthEstimationVARJO*
- **session** **must** be a valid *XrSession* handle

Return Codes

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_FEATURE_UNSUPPORTED

New Functions

Version History

- Revision 1, 2021-02-16 (Sergiy Dubovik)
12.97. XR_VARJO_foveated_rendering

Name String
 XR_VARJO_foveated_rendering

Extension Type
 Instance extension

Registered Extension Number
 122

Revision
 2

Extension and Version Dependencies
• Requires OpenXR 1.0
• Requires XR_VARJO_quad_views

Last Modified Date
 2021-04-13

IP Status
 No known IP claims.

Contributors
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12.97.1. Overview

Varjo headsets provide extremely high pixel density displays in the center area of the display, blended with a high density display covering the rest of the field of view. If the application has to provide a single image per eye, that would cover the entire field of view, at the highest density it would be extremely resource intensive, and in fact impossible for the most powerful desktop GPUs to render in real time. So instead Varjo introduced the XR_VARJO_quad_views extension enabling the application to provide two separate images for the two screen areas, resulting in a significant reduction in processing, for pixels that could not even been seen.

This extension goes a step further by enabling the application to only generate the density that can be seen by the user, which is another big reduction compared to the density that can be displayed, using dedicated eye tracking.
This extension requires `XR_VARJO_quad_views` extension to be enabled.

An application using this extension to enable foveated rendering will take the following steps to prepare:

1. Enable `XR_VARJO_quad_views` and `XR_VARJO_foveated_rendering` extensions.
2. Query system properties in order to determine if system supports foveated rendering.
3. Query texture sizes for foveated rendering.

In the render loop, for each frame, an application using this extension should:

1. Check if rendering gaze is available using `xrLocateSpace`.
2. Enable foveated rendering when `xrLocateViews` is called.

### 12.97.2. Inspect system capability

An application can inspect whether the system is capable of foveated rendering by chaining an `XrSystemFoveatedRenderingPropertiesVARJO` structure to the `XrSystemProperties` structure when calling `xrGetSystemProperties`.

```c
typedef struct XrSystemFoveatedRenderingPropertiesVARJO {
  XrStructureType    type;
  void*              next;
  XrBool32           supportsFoveatedRendering;
} XrSystemFoveatedRenderingPropertiesVARJO;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **supportsFoveatedRendering** is an `XrBool32`, indicating if current system is capable of performing foveated rendering.

The runtime should return `XR_TRUE` for `supportsFoveatedRendering` when rendering gaze is available in the system. An application should avoid using foveated rendering functionality when `supportsFoveatedRendering` is `XR_FALSE`. 
Valid Usage (Implicit)

- The `XR_VARJO_foveated_rendering` extension **must** be enabled prior to using `XrSystemFoveatedRenderingPropertiesVARJO`.
- **type** **must** be `XR_TYPE_SYSTEM_FOVEATED_RENDERING_PROPERTIES_VARJO`.
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain.

12.97.3. Determine foveated texture sizes

Foveated textures **may** have different sizes and aspect ratio compared to non-foveated textures. In order to determine recommended foveated texture size, an application **can** chain `XrFoveatedViewConfigurationViewVARJO` to `XrViewConfigurationView` and set `foveatedRenderingActive` to `XR_TRUE`. Since an application using foveated rendering with this extension has to render 4 views, `XR_VARJO_quad_views` **must** be enabled along with this extension when `XrInstance` is created.

First and second views are non foveated views (covering whole field of view of HMD), third (left eye) and fourth (right eye) are foveated e.g. following gaze.

typedef struct XrFoveatedViewConfigurationViewVARJO {
    XrStructureType    type;
    void*              next;
    XrBool32           foveatedRenderingActive;
} XrFoveatedViewConfigurationViewVARJO;

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **foveatedRenderingActive** is an `XrBool32`, indicating if the runtime should return foveated view configuration view.
Valid Usage (Implicit)

- The `XR_VARJO_foveated_rendering` extension must be enabled prior to using `XrFoveatedViewConfigurationViewVARJO`
- `type` must be `XR_TYPE_FOVEATED_VIEW_CONFIGURATION_VIEW_VARJO`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain

For example:

```c
XrInstance instance; // previously populated
XrSystemId systemId; // previously populated
XrViewConfigurationType viewConfigType; // Select
XR_VIEW_CONFIGURATION_TYPE_PRIMARY_QUAD_VARJO

XrSystemFoveatedRenderingPropertiesVARJO
foveatedRenderingProperties{XR_TYPE_SYSTEM_FOVEATED_RENDERING_PROPERTIES_VARJO};
XrSystemProperties systemProperties{XR_TYPE_SYSTEM_PROPERTIES,
&foveatedRenderingProperties};
CHK_XR(xrGetSystemProperties(instance, systemId, &systemProperties));

uint32_t viewCount;
CHK_XR(xrEnumerateViewConfigurationViews(instance, systemId, viewConfigType, 0,
&viewCount, nullptr));
// Non-foveated rendering views dimensions
std::vector<XrViewConfigurationView> configViews(viewCount,
{XR_TYPE_VIEW_CONFIGURATION_VIEW});
CHK_XR(xrEnumerateViewConfigurationViews(instance, systemId, viewConfigType, viewCount,
&viewCount, configViews.data()));

// Foveated rendering views dimensions
std::vector<XrViewConfigurationView> foveatedViews;
if (foveatedRenderingProperties.supportsFoveatedRendering && viewConfigType ==
XR_VIEW_CONFIGURATION_TYPE_PRIMARY_QUAD_VARJO) {
    std::vector<XrFoveatedViewConfigurationViewVARJO> requestFoveatedConfig{4,
{XR_TYPE_FOVEATED_VIEW_CONFIGURATION_VIEW_VARJO, nullptr, XR_TRUE}};
    foveatedViews = std::vector<XrViewConfigurationView>{4,
{XR_TYPE_VIEW_CONFIGURATION_VIEW}};
    for (size_t i = 0; i < 4; i++) {
        foveatedViews[i].next = &requestFoveatedConfig[i];
    }
    CHK_XR(xrEnumerateViewConfigurationViews(instance, systemId, viewConfigType, viewCount,
&viewCount, foveatedViews.data()));
}
```
Example 2. Note

Applications using this extension are encouraged to create 2 sets of swapchains or one big enough set of swapchains and 2 sets of viewports. One set will be used when rendering gaze is not available and other one will be used when foveated rendering and rendering gaze is available. Using foveated textures may not provide optimal visual quality when rendering gaze is not available.

12.97.4. Rendering gaze status

Extension defines new reference space type - XR_REFERENCE_SPACE_TYPE_COMBINED_EYE_VARJO which should be used to determine whether rendering gaze is available. After calling xrLocateSpace, application should inspect XR_SPACE_LOCATION_ORIENTATION_TRACKED_BIT bit. If it's set, rendering gaze is available otherwise not.
XrSession session; // previously populated

// Create needed spaces
XrSpace viewSpace;
XrReferenceSpaceCreateInfo createViewSpaceInfo{XR_TYPE_REFERENCE_SPACE_CREATE_INFO};
createViewSpaceInfo.referenceSpaceType = XR_REFERENCE_SPACE_TYPE_VIEW;
createViewSpaceInfo.poseInReferenceSpace.orientation.w = 1.0f;
CHK_XR(xrCreateReferenceSpace(session, &createViewSpaceInfo, &viewSpace));

XrSpace renderGazeSpace;
XrReferenceSpaceCreateInfo createReferenceSpaceInfo{XR_TYPE_REFERENCE_SPACE_CREATE_INFO};
createReferenceSpaceInfo.referenceSpaceType = XR_REFERENCE_SPACE_TYPE_COMBINED_EYE_VARJO;
createReferenceSpaceInfo.poseInReferenceSpace.orientation.w = 1.0f;
CHK_XR(xrCreateReferenceSpace(session, &createReferenceSpaceInfo, &renderGazeSpace));

// ...
// in frame loop
// ...

XrFrameState frameState; // previously populated by xrWaitFrame

// Query rendering gaze status
XrSpaceLocation renderGazeLocation{XR_TYPE_SPACE_LOCATION};
CHK_XR(xrLocateSpace(renderGazeSpace, viewSpace, frameState.predictedDisplayTime,
&renderGazeLocation));

const bool foveationActive = (renderGazeLocation.locationFlags &
XR_SPACE_LOCATION_ORIENTATION_TRACKED_BIT) != 0;

if (foveationActive) {
    // Rendering gaze is available
} else {
    //Rendering gaze is not available
}

12.97.5. Request foveated field of view

For each frame, the application indicates if the runtime will return foveated or non-foveated field of view. This is done by chaining XrViewLocateFoveatedRenderingVARJO to XrViewLocateInfo.
typedef struct XrViewLocateFoveatedRenderingVARJO {
    XrStructureType type;
    const void* next;
    XrBool32 foveatedRenderingActive;
} XrViewLocateFoveatedRenderingVARJO;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **foveatedRenderingActive** is an XrBool32, indicating if runtime should return foveated FoV.

The runtime **must** return foveated field of view when **foveatedRenderingActive** is **XR_TRUE**.

**Valid Usage (Implicit)**

- The **XR_VARJO_foveated_rendering** extension **must** be enabled prior to using XrViewLocateFoveatedRenderingVARJO
- **type** **must** be **XR_TYPE_VIEW_LOCATE_FOVEATED_RENDERING_VARJO**
- **next** **must** be **NULL** or a valid pointer to the **next structure in a structure chain**
XrSession session; // previously populated
XrSpace appSpace; // previously populated
XrFrameState frameState; // previously populated by xrWaitFrame
std::vector<XrView> views; // previously populated/resized to the correct size
bool foveationActive; // previously populated, as in the previous example

XrViewState viewState{XR_TYPE_VIEW_STATE};
uint32_t viewCapacityInput = static_cast<uint32_t>(views.size());
uint32_t viewCountOutput;
XrViewLocateInfo viewLocateInfo{XR_TYPE_VIEW_LOCATE_INFO};
viewLocateInfo.displayTime = frameState.predictedDisplayTime;
viewLocateInfo.space = appSpace;
XrViewLocateFoveatedRenderingVARJO
viewLocateFoveatedRendering{XR_TYPE_VIEW_LOCATE_FOVEATED_RENDERING_VARJO};
viewLocateFoveatedRendering.foveatedRenderingActive = foveationActive;
viewLocateInfo.next = &viewLocateFoveatedRendering;

CHK_XR(xrLocateViews(session, &viewLocateInfo, &viewState, viewCapacityInput,
&viewCountOutput, views.data()));

New Structures

- XrViewLocateFoveatedRenderingVARJO
- XrFoveatedViewConfigurationViewVARJO
- XrSystemFoveatedRenderingPropertiesVARJO

New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_VIEW_LOCATE_FOVEATED_RENDERING_VARJO
- XR_TYPE_FOVEATED_VIEW_CONFIGURATION_VIEW_VARJO
- XR_TYPE_SYSTEM_FOVEATED_RENDERING_PROPERTIES_VARJO

XrReferenceSpaceType enumeration is extended with:

- XR_REFERENCE_SPACE_TYPE_COMBINED_EYE_VARJO

Version History

- Revision 1, 2020-12-16 (Sergiy Dubovik)
12.98. XR_VARJO_marker_tracking

Name String
XR_VARJO_marker_tracking

Extension Type
Instance extension

Registered Extension Number
125

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2021-09-30

IP Status
No known IP claims.

Contributors
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12.98.1. Overview

Varjo Markers are physical markers tracked by the video cameras of the HMD. Different types of markers can be used for different purposes. As an example, Varjo Markers can be used as cheap replacements for electronic trackers. The cost per printed tracker is significantly lower and the markers require no power to function.

This extension provides the tracking interface to a set of marker types and sizes. Markers can be printed out from the PDF documents and instructions freely available at https://developer.varjo.com/docs/get-started/varjo-markers#printing-varjo-markers. Note that the printed marker must have the exact physical size for its ID.
Object markers are used to track static or dynamic objects in the user environment. You may use object markers in both XR and VR applications. Each marker has a unique ID, and you must not use the same physical marker more than once in any given environment. For added precision, an application may use multiple markers to track a single object. For example, you could track a monitor by placing a marker in each corner.

There is a set of marker IDs recognized by runtime and if the application uses ID which is not in the set then runtime must return XR_ERROR_MARKER_ID_INVALID_VARJO.

New Object Types

New Flag Types

New Enums

New Functions

The `xrSetMarkerTrackingVARJO` function is defined as:

```c
XrResult xrSetMarkerTrackingVARJO(
    XrSession session,
    XrBool32 enabled);
```

**Parameter Descriptions**

- `session` is an `XrSession` handle previously created with `xrCreateSession`.
- `enabled` is the flag to enable or disable marker tracking.

The `xrSetMarkerTrackingVARJO` function enables or disables marker tracking functionality. As soon as feature is become disabled all trackable markers become inactive and corresponding events will be generated. An application may call any of the functions in this extension regardless if the marker tracking functionality is enabled or disabled.

**Valid Usage (Implicit)**

- The `XR_VARJO_marker_tracking` extension must be enabled prior to calling `xrSetMarkerTrackingVARJO`
- `session` must be a valid `XrSession` handle
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_FEATURE_UNSUPPORTED

The `xrSetMarkerTrackingTimeoutVARJO` function is defined as:

```
XrResult xrSetMarkerTrackingTimeoutVARJO(
    XrSession                                   session,
    uint64_t                                    markerId,
    XrDuration                                  timeout);
```

Parameter Descriptions

• `session` is an `XrSession` handle previously created with `xrCreateSession`.
• `markerId` is the unique identifier of the marker for which the timeout will be updated.
• `timeout` is the desired lifetime duration for a specified marker.

The `xrSetMarkerTrackingTimeoutVARJO` function sets a desired lifetime duration for a specified marker. The default value is `XR_NO_DURATION`. Negative value will be clamped to `XR_NO_DURATION`. It defines the time period during which the runtime must keep returning poses of previously tracked markers. The tracking may be lost if the marker went outside of the trackable field of view. In this case the runtime still will try to predict marker's pose for the timeout period. The runtime must return `XR_ERROR_MARKER_ID_INVALID_VARJO` if the supplied `markerId` is invalid.
Valid Usage (Implicit)

• The `XR_VARJO_marker_tracking` extension must be enabled prior to calling `xrSetMarkerTrackingTimeoutVARJO`
• `session` must be a valid `XrSession` handle

Return Codes

Success

• `XR_SUCCESS`
• `XR_SESSION_LOSS_PENDING`

Failure

• `XR_ERROR_FUNCTION_UNSUPPORTED`
• `XR_ERROR_RUNTIME_FAILURE`
• `XR_ERROR_HANDLE_INVALID`
• `XR_ERROR_INSTANCE_LOST`
• `XR_ERROR_SESSION_LOST`
• `XR_ERROR_MARKER_ID_INVALID_VARJO`
• `XR_ERROR_FEATURE_UNSUPPORTED`

The `xrSetMarkerTrackingPredictionVARJO` function is defined as:

```c
XrResult xrSetMarkerTrackingPredictionVARJO(  
    XrSession session,  
    uint64_t markerId,  
    XrBool32 enabled);
```

Parameter Descriptions

• `session` is an `XrSession` handle previously created with `xrCreateSession`.
• `markerId` is the unique identifier of the marker which should be tracked with prediction.
• `enabled` is whether to enable the prediction feature.

The `xrSetMarkerTrackingPredictionVARJO` function enables or disables the prediction feature for a
specified marker. By default, markers are created with disabled prediction. This works well for markers that are supposed to be stationary. The prediction can be used to improve tracking of movable markers. The runtime must return XR_ERROR_MARKER_ID_INVALID_VARJO if the supplied markerId is invalid.

**Valid Usage (Implicit)**

- The XR_VARJO_marker_tracking extension must be enabled prior to calling xrSetMarkerTrackingPredictionVARJO
- session must be a valid XrSession handle

**Return Codes**

**Success**

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_MARKER_ID_INVALID_VARJO
- XR_ERROR_FEATURE_UNSUPPORTED

The xrGetMarkerSizeVARJO function is defined as:

```c
XrResult xrGetMarkerSizeVARJO(
    XrSession                                   session,
    uint64_t                                    markerId,
    XrExtent2Df*                                size);
```
Parameter Descriptions

- `session` is an `XrSession` handle previously created with `xrCreateSession`.
- `markerId` is the unique identifier of the marker for which size is requested.
- `size` is pointer to the size to populate by the runtime with the physical size of plane marker in meters.

The `xrGetMarkerSizeVARJO` function retrieves the height and width of an active marker. The runtime must return `XR_ERROR_MARKER_NOT_TRACKED_VARJO` if marker tracking functionality is disabled or the marker with given `markerId` is inactive. The runtime must return `XR_ERROR_MARKER_ID_INVALID_VARJO` if the supplied `markerId` is invalid.

Valid Usage (Implicit)

- The `XR_VARJO_marker_tracking` extension must be enabled prior to calling `xrGetMarkerSizeVARJO`
- `session` must be a valid `XrSession` handle
- `size` must be a pointer to an `XrExtent2Df` structure

Return Codes

**Success**

- `XR_SUCCESS`
- `XR_SESSION_LOSS_PENDING`

**Failure**

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_MARKER_NOT_TRACKED_VARJO`
- `XR_ERROR_MARKER_ID_INVALID_VARJO`
- `XR_ERROR_FEATURE_UNSUPPORTED`

The `xrCreateMarkerSpaceVARJO` function is defined as:
XrResult xrCreateMarkerSpaceVARJO(
    XrSession session,
    const XrMarkerSpaceCreateInfoVARJO* createInfo,
    XrSpace* space);

Parameter Descriptions

- **session** is an XrSession handle previously created with xrCreateSession.
- **createInfo** is the structure containing information about how to create the space based on marker.
- **space** is a pointer to a handle in which the created XrSpace is returned.

The xrCreateMarkerSpaceVARJO function creates marker XrSpace for pose relative to the marker specified in XrMarkerSpaceCreateInfoVARJO. The runtime must return XR_ERROR_MARKER_ID_INVALID_VARJO if the supplied markerId is invalid.

Valid Usage (Implicit)

- The XR_VARJO_marker_tracking extension must be enabled prior to calling xrCreateMarkerSpaceVARJO
- **session** must be a valid XrSession handle
- **createInfo** must be a pointer to a valid XrMarkerSpaceCreateInfoVARJO structure
- **space** must be a pointer to an XrSpace handle
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_LIMIT_REACHED
• XR_ERROR_POSE_INVALID
• XR_ERROR_MARKER_ID_INVALID_VARJO
• XR_ERROR_FEATURE_UNSUPPORTED

New Structures

The `XrSystemMarkerTrackingPropertiesVARJO` structure is defined as:

```c
typedef struct XrSystemMarkerTrackingPropertiesVARJO {
    XrStructureType    type;
    void*              next;
    XrBool32           supportsMarkerTracking;
} XrSystemMarkerTrackingPropertiesVARJO;
```

Member Descriptions

• `type` is the `XrStructureType` of this structure.
• `next` is `NULL` or a pointer to the next structure in a structure chain.
• `supportsMarkerTracking` is an `XrBool32`, indicating if current system is capable of performing marker tracking.
An application may inspect whether the system is capable of marker tracking by chaining an XrSystemMarkerTrackingPropertiesVARJO structure to the XrSystemProperties structure when calling xrGetSystemProperties.

The runtime should return XR_TRUE for supportsMarkerTracking when marker tracking is available in the system, otherwise XR_FALSE. Marker tracking calls must return XR_ERROR_FEATURE_UNSUPPORTED if marker tracking is not available in the system.

### Valid Usage (Implicit)

- The XR_VARJO_marker_tracking extension must be enabled prior to using XrSystemMarkerTrackingPropertiesVARJO
- `type` must be XR_TYPE_SYSTEM_MARKER_TRACKING_PROPERTIES_VARJO
- `next` must be NULL or a valid pointer to the next structure in a structure chain

The XrEventDataMarkerTrackingUpdateVARJO structure is defined as:

```c
typedef struct XrEventDataMarkerTrackingUpdateVARJO {
    XrStructureType    type;
    const void*        next;
    uint64_t           markerId;
    XrBool32           isActive;
    XrBool32           isPredicted;
    XrTime             time;
} XrEventDataMarkerTrackingUpdateVARJO;
```

### Member Descriptions

- `type` is the XrStructureType of this structure.
- `next` is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- `markerId` unique identifier of the marker that has been updated.
- `isActive` the tracking state of the marker.
- `time` the time of the marker update.

Receiving the XrEventMarkerTrackingUpdateVARJO event structure indicates that the tracking information has changed. The runtime must not send more than one event per frame per marker. The runtime must send an event if the marker has changed its state (active or inactive). The runtime must
send an event if it has detected pose change of the active marker.

Valid Usage (Implicit)
- The XR_VARJO_marker_tracking extension must be enabled prior to using XrEventDataMarkerTrackingUpdateVARJO
- type must be XR_TYPE_EVENT_DATA_MARKER_TRACKING_UPDATE_VARJO
- next must be NULL or a valid pointer to the next structure in a structure chain

The XrMarkerSpaceCreateInfoVARJO structure is defined as:

```c
typedef struct XrMarkerSpaceCreateInfoVARJO {
    XrStructureType    type;
    const void*        next;
    uint64_t           markerId;
    XrPosef            poseInMarkerSpace;
} XrMarkerSpaceCreateInfoVARJO;
```

Member Descriptions
- type is the XrStructureType of this structure.
- next is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- markerId unique identifier of the marker.
- poseInMarkerSpace is an XrPosef defining the position and orientation of the new space’s origin relative to the marker’s natural origin.

Valid Usage (Implicit)
- The XR_VARJO_marker_tracking extension must be enabled prior to using XrMarkerSpaceCreateInfoVARJO
- type must be XR_TYPE_MARKER_SPACE_CREATE_INFO_VARJO
- next must be NULL or a valid pointer to the next structure in a structure chain

New Enum Constants

XrStructureType enumeration is extended with:

---

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XrResult enumeration is extended with:

- XR_ERROR_MARKER_ID_INVALID_VARJO
- XR_ERROR_MARKER_NOT_TRACKED_VARJO

Issues

Version History

- Revision 1, 2021-09-30 (Roman Golovanov)
  - Initial extension description

12.98.2. Example

The example below represents the routine which enables marker tracking feature and then polls events. The event type XR_TYPE_EVENT_DATA_MARKER_TRACKING_UPDATE_VARJO has a special handler to process marker state change.

```cpp
XrSession session; // previously initialized
if(XR_SUCCESS != xrSetMarkerTrackingVARJO(session, XR_TRUE)) {
   return;
}

XrInstance instance; // previously initialized
XrFrameState frameState; // previously initialized
XrSpace baseSpace; // previously initialized
XrSpaceLocation location; // previously initialized

// Collection of tracked markers and their space handlers
std::unordered_map<uint64_t, XrSpace> markerSpaces;
// Initialize an event buffer to hold the output.
XrEventDataBuffer event{XR_TYPE_EVENT_DATA_BUFFER};
XrResult result = xrPollEvent(instance, &event);
if (result == XR_SUCCESS) {
   switch (event.type) {
      case XR_TYPE_EVENT_DATA_MARKER_TRACKING_UPDATE_VARJO: {
         const auto& marker_update =
            *reinterpret_cast<XrEventDataMarkerTrackingUpdateVARJO*>(&event);

         const auto id = marker_update.markerId;
```
// If marker appeared for the first time then set some settings and add it to collection
if(0 == markerSpaces.count(id)) {
    XrMarkerSpaceCreateInfoVARJO spaceInfo{0};
    spaceInfo.type = XR_TYPE_MARKER_SPACE_CREATE_INFO_VARJO;
    spaceInfo.markerId = id;
    spaceInfo.poseInMarkerSpace = XrPosef{0};
    spaceInfo.poseInMarkerSpace.orientation.w = 1.0f;
    XrSpace markerSpace;
    // Set 1 second timeout
    if(XR_SUCCESS != xrSetMarkerTrackingTimeoutVARJO(
        session, id, 1000000000))
    {
        break;
    }
    // Enable prediction for markers with 'odd' ids.
    if(XR_SUCCESS != xrSetMarkerTrackingPredictionVARJO(
        session, id, id % 2))
    {
        break;
    }
    if(XR_SUCCESS != xrCreateMarkerSpaceVARJO(session, &spaceInfo,
        &markerSpace)) {
        break;
    }
    markerSpaces[id] = markerSpace;
}

if(marker_update.isActive) {
    if(XR_SUCCESS != xrLocateSpace(markerSpaces.at(id), baseSpace,
        frameState.predictedDisplayTime, &location)){
        break;
    }
    if(marker_update.isPredicted) {
        // Process marker as dynamic
    } else {
        // Process marker as stationary
    }
} else {
    // Remove previously tracked marker
    markerSpaces.erase(id);
}

// ...
12.99. XR_VARJO_quad_views

Name String
XR_VARJO_quad_views

Extension Type
Instance extension

Registered Extension Number
38

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2019-04-16

IP Status
No known IP claims.

Contributors
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12.99.1. Overview

This extension adds a new view configuration type - XR_VIEW_CONFIGURATION_TYPE_PRIMARY_QUAD_VARJO to XrViewConfigurationType which can be returned by xrEnumerateViewConfigurations to indicate that the runtime supports 4 viewports.

In this configuration each eye consists of two viewports of which one is smaller (in terms of field of view) of the other and fully included inside of the larger FoV one. The small FoV viewport however can have a higher resolution with respect to the same field of view in the outer viewport. The motivation is special hardware which superimposes a smaller, high resolution screen for the fovea region onto a larger screen for the periphery.

The runtime guarantees that the inner viewport of each eye is fully inside of the outer viewport.

To enumerate the 4 views xrEnumerateViewConfigurationViews can be used. The first two views
(XrViewConfigurationView) will be for the left and right eyes for the outer viewport. The views 2 and 3 are for the left and right eyes for the inner viewport.

The relative position of the inner views relative to the outer views can change at run-time.

The runtime might blend between the views at the edges, so the application should not omit the inner field of view from being generated in the outer view.

**New Object Types**

**New Flag Types**

**New Enum Constants**

XrViewConfigurationType enumeration is extended with:

- XR_VIEW_CONFIGURATION_TYPE_PRIMARY_QUAD_VARJO

**New Enums**

**New Structures**

**New Functions**

**Issues**

**Version History**

- Revision 1, 2019-04-16 (Sergiy Dubovik)
  - Initial draft

### 12.100. XR_VARJO_view_offset

**Name String**

XR_VARJO_view_offset

**Extension Type**

Instance extension

**Registered Extension Number**

126

**Revision**

1

**Extension and Version Dependencies**

- Requires OpenXR 1.0
Overview

Varjo headsets use video pass-through cameras to create the mixed reality (MR) image. The cameras are located around 10 cm (3.9 inches) in front of the user’s eyes, which leads to an offset in depth perception so that real-world objects in the video pass-through image appear larger than they are in real life. The image below gives a visualization of the difference between what the camera sees and what the user would see in real life.

This magnification effect is pronounced for objects that are close to the user – for example, their hands may appear unnaturally large in the image. The effect decreases with distance, so that objects at a distance of 2 meters already appear close to their actual size, and the sizes eventually converge at infinity. Note that while the objects' sizes may differ, their geometry, relative sizes, locations, etc. remain accurate. The extent of the magnification effect ultimately depends both on the application itself and the user’s physiology, as the human visual system is highly adaptive in this type of setting.
When blending the video pass-through image with virtual content, it is important that their relative geometries – position, size, and disparity – match one another. To achieve this, Varjo’s runtime automatically places the virtual reality cameras in the same position as the physical cameras when the video pass-through feature is enabled (see `XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND`). This allows virtual and real-world content to appear at the same distance and on the same plane when viewed together. While this can be observed as an apparent jump in the location of virtual objects compared to VR-only content, this does not cause any distortion in the object geometry or location; it is only the viewer's location that changes.

In some cases, moving the VR content to match the real-world position may not be desirable. This extension enable the application to control where the VR content is rendered from the location of the user's eyes while the video pass-through image uses the camera locations. For example, if the virtual object is close the user, or if the application is switching between VR and MR modes. Offset values between 0.0 and 1.0 are supported. You can use this to create a smooth, animated transition between the two rendering positions in case you need to change from one to the other during a session.

**New Functions**

The `xrSetViewOffsetVARJO` function is defined as:

```
XrResult  xrSetViewOffsetVARJO(
    XrSession  session,
    float      offset);
```

### Parameter Descriptions

- **session** is an `XrSession` handle previously created with `xrCreateSession`.
- **offset** is the view offset to be applied. Must be between 0 and 1.

The `xrSetViewOffsetVARJO` function takes a float between 0.0 and 1.0. 0.0 means the pose returned by `xrLocateViews` will be at the eye location, a value of 1.0 means the pose will be at the camera location. A value between 0.0 and 1.0 will interpolate the pose to be in between the eye and the camera location. A value less than 0.0 or more than 1.0 will fail and return error `XR_ERROR_VALIDATION_FAILURE`.

Note that by default the offset is set to 0 if the pass-through cameras are not active, a.k.a. in VR (`XR_ENVIRONMENT_BLEND_MODE_OPAQUE`), and 1 if the cameras are active, a.k.a. in MR (`XR_ENVIRONMENT_BLEND_MODE_ALPHA_BLEND` or `XR_ENVIRONMENT_BLEND_MODE_ADDITIVE`).
Valid Usage (Implicit)

- The XR_VARJO_view_offset extension must be enabled prior to calling xrSetViewOffsetVARJO
- session must be a valid XrSession handle

Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_FEATURE_UNSUPPORTED

Version History

- Revision 1, 2022-02-08 (Remi Arnaud)
  - extension specification
Chapter 13. List of Provisional Extensions

- XR_EXTX_overlay
- XR_HTCX_vive_tracker_interaction
- XR_MNDX_egl_enable
13.1. XR_EXTX_overlay

Name String
XR_EXTX_overlay

Extension Type
Instance extension

Registered Extension Number
34

Revision
5

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2021-01-13

IP Status
No known IP claims.

Contributors
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Overview

Application developers may desire to implement an OpenXR application that renders content on top of another OpenXR application. These additional applications will execute in a separate process, create a separate session, generate separate content, but want the OpenXR runtime to composite their content on top of the main OpenXR application. Examples of these applications might include:

• A debug environment outputting additional content
• A Store application that hovers to one side of the user’s view
• A interactive HUD designed to expose additional chat features

This extension introduces the concept of "Overlay Sessions" in order to expose this usage model.

This extension allows:
• An application to identify when the current sessions composition layers will be applied during composition
• The ability for an overlay session to get information about what is going on with the main application

To enable the functionality of this extension, an application must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo::enabledExtensionNames parameter as indicated in the Extensions section.

To create an overlay session, an application must pass an XrSessionCreateInfoOverlayEXTX structure to xrCreateSession via the XrSessionCreateInfo structure's next parameter.

An overlay application should not assume that the values returned to it by xrWaitFrame in predictedDisplayTime in XrFrameState will be the same as the values returned to the main application or even correlated.

### 13.1.1. Overlay Session Layer Placement

Since one or more sessions may be active at the same time, this extension provides the ability for the application to identify when the frames of the current session will be composited into the final frame.

The XrSessionCreateInfoOverlayEXTX sessionLayersPlacement parameter provides information on when the sessions composition layers should be applied to the final composition frame. The larger the value passed into sessionLayersPlacement, the closer to the front this session's composition layers will appear (relative to other overlay session's composition layers). The smaller the value of sessionLayersPlacement, the further to the back this session's composition's layers will appear. The main session's composition layers will always be composited first, resulting in any overlay content being composited on top of the main application's content.

If sessionLayersPlacement is 0, then the runtime will always attempt to composite that session's composition layers first. If sessionLayersPlacement is UINT32_MAX, then the runtime will always attempt to composite that session's composition layers last. If two or more overlay sessions are created with the same sessionLayersPlacement value, then the newer session's will be treated as if they had a slightly higher value of sessionLayersPlacement than the previous sessions with the same value. This should result in the newest overlay session being composited closer to the user than the older session.

The following image hopefully will provide any further clarification you need:
13.1.2. Main Session Behavior Event

Since an overlay session's intends to work in harmony with a main session, some information needs to be provided from that main session to the overlay session.

The XrEventDataMainSessionVisibilityChangedEXTX event structure provides information on the visibility of the main session as well as some additional flags which can be used to adjust overlay behavior.

If XR_KHR_composition_layer_depth is enabled in the main session, then XrEventDataMainSessionVisibilityChangedEXTX flags should contain the value: XR_OVERLAY_MAIN_SESSION_ENABLED_COMPOSITION_LAYER_INFO_DEPTH_BIT_EXTX. If the overlay session also enables XR_KHR_composition_layer_depth, then when both sessions are visible, the runtime can integrate their projection layer content together using depth information as described in the extension. However, if either the main session or the overlay do not enable the extension, then composition behavior will continue as if neither one enabled the extension.

13.1.3. Modifications to the OpenXR Specification

When this extension is enabled, certain core behaviors defined in the OpenXR specification must change as defined below:

Modifications to Composition

The Compositing section description of the composition process will be changed if this extension is enabled. If this extension is enabled, and there is only one active session, then there is no change. However, if this extension is enabled, and there are multiple active sessions, then the composition will
occur in order based on the overlay session’s XrSessionCreateInfoOverlayEXTX::sessionLayersPlacement value as described in the table below:

<table>
<thead>
<tr>
<th>Session Type</th>
<th>XrSessionCreateInfoOverlayEXTX::sessionLayersPlacement</th>
<th>Composed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overlay Session</td>
<td>UINT32_MAX</td>
<td>Composited last, appears in front of all other XrSessions</td>
</tr>
<tr>
<td>Overlay Session</td>
<td>&lt;Positive value&gt;</td>
<td></td>
</tr>
<tr>
<td>Overlay Session</td>
<td>0</td>
<td>Composited first, appears behind all other XrSessions</td>
</tr>
<tr>
<td>Non-overlay Session</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

The above change only applies to when a session’s composition layers are applied to the resulting image. The order in which composition layers are handled internal to a session does not change. However, once the sessions have been properly ordered, the runtime should behave as if all the composition layers have been placed into a single list (maintaining the separation of viewport images) and treat them as if they were from one original session. From this point forward, the composition behavior of the resulting composition layers is the same whether or not this extension is enabled.

If the overlay session is created as part of an XrInstance which has enabled the XR_KHR_composition_layer_depth extension, and a XrCompositionLayerDepthInfoKHR structure has been provided to one or more composition layers, then it intends for those layers to be composited into the final image using that depth information. This composition occurs as defined in the XR_KHR_composition_layer_depth extension. However, this is only possible if the main session has provided depth buffer information as part of its swapchain. In the event that a main session does not provide depth buffer information as part of its swapchain, then overlay application’s composition layers containing depth information will be composited as if they did not contain that information.

**Modifications to xrEndFrame Behavior**

Frame Submission currently states that if xrEndFrame is called with no layers, then the runtime should clear the VR display.

If this extension is enabled, the above statement is now only true if the session is not an overlay session. If the session is an overlay session, and it provides 0 layers in the call to xrEndFrame, then the runtime will just ignore the overlay session for the current frame.

**Modifications to Input Synchronization**

If a runtime supports this extension, it must separate input tracking on a per-session basis. This means that reading the input from one active session does not disturb the input information that can be read...
by another active session. This may require duplicating events to more than one session.

**New Object Types**

None

**New Flag Types**

```c
typedef XrFlags64 XrOverlayMainSessionFlagsEXTX;
```

```c
// Flag bits for XrOverlayMainSessionFlagsEXTX
static const XrOverlayMainSessionFlagsEXTX
XR_OVERLAY_MAIN_SESSION_ENABLED_COMPOSITION_LAYER_INFO_DEPTH_BIT_EXTX = 0x00000001;
```

```c
typedef XrFlags64 XrOverlaySessionCreateFlagsEXTX;
```

```c
// Flag bits for XrOverlaySessionCreateFlagsEXTX
```

**New Enum Constants**

- `XrStructureType` enumeration is extended with:
  - `XR_TYPE_SESSION_CREATE_INFO_OVERLAY_EXTX`
  - `XR_TYPE_EVENT_DATA_MAIN_SESSION_VISIBILITY_CHANGED_EXTX`

**New Enums**

- `XR_OVERLAY_MAIN_SESSION_ENABLED_COMPOSITION_LAYER_INFO_DEPTH_BIT_EXTX`

**New Structures**
typedef struct XrSessionCreateInfoOverlayEXTX {
    XrStructureType                    type;
    const void*                        next;
    XrOverlaySessionCreateFlagsEXTX    createFlags;
    uint32_t                           sessionLayersPlacement;
} XrSessionCreateInfoOverlayEXTX;

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **createFlags** is 0 or one or more XrOverlaySessionCreateFlagBitsEXTX which indicate various characteristics desired for the overlay session.
- **sessionLayersPlacement** is a value indicating the desired placement of the session's composition layers in terms of other sessions.

Valid Usage (Implicit)

- The XR_EXTX_overlay extension must be enabled prior to using XrSessionCreateInfoOverlayEXTX
- **type** must be XR_TYPE_SESSION_CREATE_INFO_OVERLAY_EXTX
- **next** must be NULL or a valid pointer to the next structure in a structure chain
- **createFlags** must be 0

typedef struct XrEventDataMainSessionVisibilityChangedEXTX {
    XrStructureType                  type;
    const void*                      next;
    XrBool32                         visible;
    XrOverlayMainSessionFlagsEXTX    flags;
} XrEventDataMainSessionVisibilityChangedEXTX;

Receiving the XrEventDataMainSessionVisibilityChangedEXTX event structure indicates that the main session has gained or lost visibility. This can occur in many cases, one typical example is when a user switches from one OpenXR application to another. See XrEventDataMainSessionVisibilityChangedEXTX for more information on the standard behavior. This structure contains additional information on the main session including **flags** which indicate additional state information of the main session.
Currently, the only flag value supplied is `XR_OVERLAY_MAIN_SESSION_ENABLED_COMPOSITION_LAYER_INFO_DEPTH_BIT_EXTX` which indicates if the main session has enabled the `XR_KHR_composition_layer_depth` extension.

### Member Descriptions

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **visible** is an `XrBool32` which indicates if *session* is now visible or is not.
- **flags** is 0 or one or more `XrOverlayMainSessionFlagBitsEXTX` which indicates various state information for the main session.

### Valid Usage (Implicit)

- The `XR_EXTX_overlay` extension **must** be enabled prior to using `XrEventDataMainSessionVisibilityChangedEXTX`
- **type** **must** be `XR_TYPE_EVENT_DATA_MAIN_SESSION_VISIBILITY_CHANGED_EXTX`
- **next** **must** be `NULL` or a valid pointer to the next structure in a structure chain
- **flags** **must** be a valid combination of `XrOverlayMainSessionFlagBitsEXTX` values
- **flags** **must** not be 0

### New Functions

None

### New Function Pointers

None

### Issues

None

### Version History

- Revision 1, 2018-11-05 (Mark Young)
  - Initial draft
- Revision 2, 2020-02-12 (Brad Grantham)
  - Name change, remove overlay bool, add flags
13.2. XR_HTCX_vive_tracker_interaction

Name String
XR_HTCX_vive_tracker_interaction

Extension Type
Instance extension

Registered Extension Number
104

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2021-09-23

IP Status
No known IP claims.

Contributors
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Chris Kuo, HTC

Overview
This extension defines a new interaction profile for HTC VIVE Tracker. HTC VIVE Tracker is a generic tracked device which can be attached to anything to make them trackable. For example, it can be attached to user's hands or feet to track the motion of human body. It can also be attached to any other devices the user wants to track and interact with.

In order to enable the functionality of this extension, you must pass the name of the extension into xrCreateInstance via the XrInstanceCreateInfo enabledExtensionNames parameter as indicated in the
This extension allows:

- An application to enumerate the subpaths of all current connected VIVE trackers.
- An application to receive notification of the top level paths of a VIVE tracker when it is connected.

The paths of a VIVE tracker contains two paths below:

- VIVE tracker persistent path indicate a specific tracker whose lifetime lasts longer than an instance, which means it must not change during its hardware lifetime. The format of this path string is unspecified and should be treated as an opaque string.

- VIVE tracker role path may be constructed as "/user/vive_tracker_htcx/role/ROLE_VALUE", where ROLE_VALUE takes one of the following values. The role path may be assigned from the tool provided by the runtime and is XR_NULL_PATH if it has not been assigned. If this role path refers to more than one tracker, the runtime should choose one of them to be currently active. The role path may be changed during the lifetime of instance. Whenever it is changed, the runtime must send event XR_TYPE_EVENT_DATA_VIVE_TRACKER_CONNECTED_HTCX to provide the new role path of that tracker.

**ROLE_VALUE**

- XR_NULL_PATH
- handheld_object
- left_foot
- right_foot
- left_shoulder
- right_shoulder
- left_elbow
- right_elbow
- left_knee
- right_knee
- waist
- chest
- camera
- keyboard

- Either the persistent path or the role path can be be passed as a subaction path to indicate a specific tracker. For example, XrActionCreateInfo::subactionPath into function xrCreateAction or XrActionSpaceCreateInfo::subactionPath into function xrCreateActionSpace. Please see Example 1 below.
As with other controllers, if a VIVE tracker is connected and bound to a top-level user path, or disconnected while bound to top-level user path, the runtime **must** send event `XR_TYPE_EVENT_DATA_INTERACTION_PROFILE_CHANGED`, and the application **may** call `xrGetCurrentInteractionProfile` to check if the tracker is active or not.

The device that a tracker is attached to probably has a different motion model than what the tracker assumes. The motion tracking might not be as expected in this case.

**VIVE Tracker interaction profile**

Interaction profile path:

```
/interaction_profiles/htc/vive_tracker_htcx
```

This interaction profile represents the input sources and haptics on the VIVE Tracker.

Supported component paths:

- `.../input/system/click` (may not be available for application use)
- `.../input/menu/click`
- `.../input/trigger/click`
- `.../input/squeeze/click`
- `.../input/trigger/value`
- `.../input/trackpad/x`
- `.../input/trackpad/y`
- `.../input/trackpad/click`
- `.../input/trackpad/touch`
- `.../input/grip/pose`
- `.../output/haptic`

**New Object Types**

**New Flag Types**

**New Enum Constants**

`XrStructureType` enumeration is extended with:

- `XR_TYPE_VIVE_TRACKER_PATHS_HTCX`
- `XR_TYPE_EVENT_DATA_VIVE_TRACKER_CONNECTED_HTCX`

**New Enums**
New Structures

The `XrViveTrackerPathsHTCX` structure is defined as:

```c
typedef struct XrViveTrackerPathsHTCX {
    XrStructureType    type;
    void*              next;
    XrPath             persistentPath;
    XrPath             rolePath;
} XrViveTrackerPathsHTCX;
```

**Member Descriptions**

- **type** is the `XrStructureType` of this structure.
- **next** is `NULL` or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **persistentPath** is the unique path of the VIVE tracker which is persistent over the lifetime of the hardware.
- **rolePath** is the path of the VIVE tracker role. This **may** be `XR_NULL_PATH` if the role is not assigned.

The `XrViveTrackerPathsHTCX` structure contains two paths of VIVE tracker.

**Valid Usage (Implicit)**

- The `XR_HTCX_vive_tracker_interaction` extension **must** be enabled prior to using `XrViveTrackerPathsHTCX`
- **type** must be `XR_TYPE_VIVE_TRACKER_PATHS_HTCX`
- **next** must be `NULL` or a valid pointer to the next structure in a structure chain

The `XrEventDataViveTrackerConnectedHTCX` structure is defined as:
typedef struct XrEventDataViveTrackerConnectedHTCX {
    XrStructureType            type;
    const void*                next;
    XrViveTrackerPathsHTCX*    paths;
} XrEventDataViveTrackerConnectedHTCX;

**Member Descriptions**

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **paths** contains two paths of the connected VIVE tracker.

Receiving the **XrEventDataViveTrackerConnectedHTCX** event structure indicates that a new VIVE tracker was connected or its role changed. It is received via **xrPollEvent**.

**Valid Usage (Implicit)**

- The **XR_HTCX_vive_tracker_interaction** extension **must** be enabled prior to using **XrEventDataViveTrackerConnectedHTCX**
- **type** **must** be **XR_TYPE_EVENT_DATA_VIVE_TRACKER_CONNECTED_HTCX**
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain
- **paths** **must** be a pointer to an **XrViveTrackerPathsHTCX** structure

**New Functions**

The **xrEnumerateViveTrackerPathsHTCX** function is defined as:

```
XrResult xrEnumerateViveTrackerPathsHTCX(
    XrInstance                                  instance,
    uint32_t                                    pathCapacityInput,
    uint32_t*                                   pathCountOutput,
    XrViveTrackerPathsHTCX*                     paths);
```
**Parameter Descriptions**

- `instance` is an instance previously created.

- `pathsCapacityInput` is the capacity of the `viveTrackerPaths`, or `0` to retrieve the required capacity.

- `pathsCountOutput` is a pointer to the count of `XrViveTrackerPathsHTCX viveTrackerPaths` written, or a pointer to the required capacity in the case that `pathsCapacityInput` is insufficient.

- `viveTrackerPaths` is a pointer to an array of `XrViveTrackerPathsHTCX` VIVE tracker paths, but can be `NULL` if `pathsCapacityInput` is `0`.

- See [Buffer Size Parameters](#) chapter for a detailed description of retrieving the required `viveTrackerPaths` size.

`xrEnumerateViveTrackerPathsHTCX` enumerates all connected VIVE trackers to retrieve their paths under current instance.

**Valid Usage (Implicit)**

- The `XR_HTCX_vive_tracker_interaction` extension must be enabled prior to calling `xrEnumerateViveTrackerPathsHTCX`

- `instance` must be a valid `XrInstance` handle

- `pathCountOutput` must be a pointer to a `uint32_t` value

- If `pathCapacityInput` is not `0`, `paths` must be a pointer to an array of `pathCapacityInput` `XrViveTrackerPathsHTCX` structures
Return Codes

Success

• XR_SUCCESS

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SIZE_INSUFFICIENT

Examples

Example 1

This example illustrates how to locate a VIVE tracker which is attached on the chest. First of all, create an action with /user/vive_tracker_htcx/role/chest as the subaction path. Then, submit a suggested binding for that action to the role path plus .../input/grip/pose, for the interaction profile /interaction_profiles/htc/vive_tracker_htcx, using xrSuggestInteractionProfileBindings. To locate the tracker, create an action space from that action, with /user/vive_tracker_htcx/role/chest once again specified as the subaction path.

```c
extern XrInstance instance;  // previously initialized
extern XrSession session;  // previously initialized
extern XrActionSet actionSet;  // previously initialized

// Create the action with subaction path
XrPath chestTrackerRolePath;
CHK_XR(xrStringToPath(instance, "/user/vive_tracker_htcx/role/chest",
    &chestTrackerRolePath));

XrAction chestPoseAction;
XrActionCreateInfo actionInfo{XR_TYPE_ACTION_CREATE_INFO};
actionInfo.actionType = XR_ACTION_TYPE_POSE_INPUT;
actionInfo.countSubactionPaths = 1;
actionInfo.subactionPaths = &chestTrackerRolePath;
CHK_XR(xrCreateAction(actionSet, &actionInfo, &chestPoseAction));

// Describe a suggested binding for that action and subaction path.
XrPath suggestedBindingPath;
CHK_XR(xrStringToPath(instance,
```
std::vector<XrActionSuggestedBinding> actionSuggBindings;
XrActionSuggestedBinding actionSuggBinding;
actionSuggBinding.action = chestPoseAction;
actionSuggBinding.binding = suggestedBindingPath;
actionSuggBindings.push_back(actionSuggBinding);

// Suggest that binding for the VIVE tracker interaction profile
XrPath viveTrackerInteractionProfilePath;
CHK_XR(xrStringToPath(instance, "/interaction_profiles/htc/vive_tracker_htcx",
             &viveTrackerInteractionProfilePath));

XrInteractionProfileSuggestedBinding profileSuggBindings{
    XR_TYPE_INTERACTION_PROFILE_SUGGESTED_BINDING};
profileSuggBindings.interactionProfile =
    viveTrackerInteractionProfilePath;
profileSuggBindings.suggestedBindings =
    actionSuggBindings.data();
profileSuggBindings.countSuggestedBindings =
    (uint32_t)actionSuggBindings.size();

CHK_XR(xrSuggestInteractionProfileBindings(instance, &profileSuggBindings));

// Create action space for locating tracker
XrSpace chestTrackerSpace;
XrActionSpaceCreateInfo actionSpaceInfo{XR_TYPE_ACTION_SPACE_CREATE_INFO};
actionSpaceInfo.action = chestPoseAction;
actionSpaceInfo.subactionPath = chestTrackerRolePath;
CHK_XR(xrCreateActionSpace(session, &actionSpaceInfo, &chestTrackerSpace));

Example 2

This example illustrates how to handle the VIVE tracker when it is connected or disconnected. When a VIVE tracker is connected or its role changed, event XR_TYPE_EVENT_DATA_VIVE_TRACKER_CONNECTED_HTCX will be received. The role path and persistent path of this tracker can be retrieved with this event. When a VIVE tracker is connected or disconnected, event XR_TYPE_EVENT_DATA_INTERACTION_PROFILE_CHANGED will also be received. The XrInteractionProfileState::interactionProfile will be XR_NULL_PATH if the tracker represented by that top level path is not connected.
extern XrInstance instance; // previously initialized
extern XrSession session; // previously initialized
extern XrEventDataBuffer xrEvent; // previously received from xrPollEvent

switch ( xrEvent.type )
{
    case XR_TYPE_EVENT_DATA_VIVE_TRACKER_CONNECTED_HTGX: {
        const XrEventDataViveTrackerConnectedHTGX& viveTrackerConnected =
            *reinterpret_cast<XrEventDataViveTrackerConnectedHTGX*>(&xrEvent);
        uint32_t nCount;
        char sPersistentPath[XR_MAX_PATH_LENGTH];
        CHK_XR(xrPathToString(instance,
            viveTrackerConnected.paths->persistentPath,
            sizeof(sPersistentPath), &nCount, sPersistentPath));
        std::printf("Vive Tracker connected: %s \n", sPersistentPath);
        if (viveTrackerConnected.paths->rolePath != XR_NULL_PATH) {
            char sRolePath[XR_MAX_PATH_LENGTH];
            CHK_XR(xrPathToString(instance,
                viveTrackerConnected.paths->rolePath, sizeof(sRolePath),
                &nCount, sRolePath));
            std::printf(" New role is: %s\n\n", sRolePath);
        } else {
            std::printf(" No role path.\n\n");
        }
        break;
    }
    case XR_TYPE_EVENT_DATA_INTERACTION_PROFILE_CHANGED: {
        XrPath chestTrackerRolePath;
        XrInteractionProfileState xrInteractionProfileState {
            XR_TYPE_INTERACTION_PROFILE_STATE};

        CHK_XR(xrStringToPath(instance, "/user/vive_tracker_htcx/role/chest",
            &chestTrackerRolePath));
        CHK_XR(xrGetCurrentInteractionProfile(session, chestTrackerRolePath,
            &xrInteractionProfileState));
        break;
    }
}

Issues

Version History
13.3. XR_MNDX_egl_enable

Name String

XR_MNDX_egl_enable

Extension Type

Instance extension

Registered Extension Number

49

Revision

1

Extension and Version Dependencies

• Requires OpenXR 1.0

Last Modified Date

2020-05-21

IP Status

No known IP claims.

Contributors

Jakob Bornecrantz, Collabora
Drew DeVault, Individual
Simon Ser, Individual

Overview

This extension must be provided by runtimes supporting applications using the EGL API to create rendering contexts.

• XR_USE_PLATFORM_EGL

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:
• **XR_TYPE_GRAPHICS_BINDING_EGL_MNDX**

New Enums

New Structures

The **XrGraphicsBindingEGLMNDX** structure is defined as:

```c
typedef struct XrGraphicsBindingEGLMNDX {
    XrStructureType             type;
    const void*                 next;
    PFNEGLGETPROCADDRESSPROC    getProcAddress;
    EGLDisplay                  display;
    EGLConfig                   config;
    EGLContext                  context;
} XrGraphicsBindingEGLMNDX;
```

**Member Descriptions**

- **type** is the **XrStructureType** of this structure.
- **next** is **NULL** or a pointer to the next structure in a structure chain. No such structures are defined in core OpenXR or this extension.
- **getProcAddress** is a valid function pointer to **eglGetProcAddress**.
- **display** is a valid EGL **EGLDisplay**.
- **config** is a valid EGL **EGLConfig**.
- **context** is a valid EGL **EGLContext**.

When creating an EGL based **XrSession**, the application will provide a pointer to an **XrGraphicsBindingEGLMNDX** structure in the **next** chain of the **XrSessionCreateInfo**.

The required window system configuration define to expose this structure type is **XR_USE_PLATFORM_EGL**.
Valid Usage (Implicit)

- The `XR_MNDX_egl_enable` extension must be enabled prior to using `XrGraphicsBindingEGLMNDX`
- `type` must be `XR_TYPE_GRAPHICS_BINDING_EGL_MNDX`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `getProcAddress` must be a valid `PFNGLGETPROCADDRESSPROC` value
- `display` must be a valid `EGLDisplay` value
- `config` must be a valid `EGLConfig` value
- `context` must be a valid `EGLContext` value

New Functions

Issues

Version History

- Revision 1, 2020-05-20 (Jakob Bornecrantz)
  - Initial draft
Chapter 14. List of Deprecated Extensions

- XR_KHR_swapchain_usage_input_attachment_bit
14.1. XR_MND_swapchain_usage_input_attachment_bit

Name String
  XR_MND_swapchain_usage_input_attachment_bit

Extension Type
  Instance extension

Registered Extension Number
  97

Revision
  2

Extension and Version Dependencies
  • Requires OpenXR 1.0

Deprecation state
  • Promoted to XR_KHR_swapchain_usage_input_attachment_bit extension

Last Modified Date
  2020-07-24

IP Status
  No known IP claims.

Contributors
  Jakob Bornecrantz, Collabora

Overview
This extension enables an application to specify that swapchain images should be created in a way so that they can be used as input attachments. At the time of writing this bit only affects Vulkan swapchains.

New Object Types

New Flag Types

New Enum Constants

XrSwapchainUsageFlagBits enumeration is extended with:
  • XR_SWAPCHAIN_USAGE_INPUT_ATTACHMENT_BIT_MND

New Enums
New Structures

New Functions

Issues

Version History

• Revision 1, 2020-07-23 (Jakob Bornecrantz)
  ◦ Initial draft

• Revision 2, 2020-07-24 (Jakob Bornecrantz)
  ◦ Added note about only affecting Vulkan
  ◦ Changed from MNDX to MND
Appendix

Code Style Conventions

These are the code style conventions used in this specification to define the API.

**Conventions**

- Enumerants and defines are all upper case with words separated by an underscore.
- Neither type, function or member names contain underscores.
- Structure members start with a lower case character and each consecutive word starts with a capital.
- A structure that has a pointer to an array includes a structure member named `fooCount` of type `uint32_t` to denote the number of elements in the array of `foo`.
- A structure that has a pointer to an array lists the `fooCount` member first and then the array pointer.
- Unless a negative value has a clearly defined meaning all `fooCount` variables are unsigned.
- Function parameters that are modified are always listed last.

Prefixes are used in the API to denote specific semantic meaning of names, or as a label to avoid name clashes, and are explained here:

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_</td>
<td>Enumerants and defines are prefixed with these characters.</td>
</tr>
<tr>
<td>Xr</td>
<td>Non-function-pointer types are prefixed with these characters.</td>
</tr>
<tr>
<td>xr</td>
<td>Functions are prefixed with these characters.</td>
</tr>
<tr>
<td>PFN_xr</td>
<td>Function pointer types are prefixed with these characters.</td>
</tr>
</tbody>
</table>

Application Binary Interface

This section describes additional definitions and conventions that define the application binary interface.
typedef enum XrStructureType {
    XR_TYPE_UNKNOWN = 0,
    XR_TYPE_API_LAYER_PROPERTIES = 1,
    XR_TYPE_EXTENSION_PROPERTIES = 2,
    XR_TYPE_INSTANCE_CREATE_INFO = 3,
    XR_TYPE_SYSTEM_PROPERTIES = 4,
    XR_TYPE_SYSTEM_GET_INFO = 5,
    XR_TYPE_VIEW_LOCATE_INFO = 6,
    XR_TYPE_VIEW = 7,
    XR_TYPE_SESSION_CREATE_INFO = 8,
    XR_TYPE_SWAPCHAIN_CREATE_INFO = 9,
    XR_TYPE_SESSION_BEGIN_INFO = 10,
    XR_TYPE_VIEW_STATE = 11,
    XR_TYPE_FRAME_END_INFO = 12,
    XR_TYPE_HAPTIC_VIBRATION = 13,
    XR_TYPE_EVENT_DATA_BUFFER = 16,
    XR_TYPE_EVENT_DATA_INSTANCE_LOSS_PENDING = 17,
    XR_TYPE_EVENT_DATA_SESSION_STATE_CHANGED = 18,
    XR_TYPE_ACTION_STATE_BOOLEAN = 23,
    XR_TYPE_ACTION_STATE_FLOAT = 24,
    XR_TYPE_ACTION_STATE_VECTOR2F = 25,
    XR_TYPE_ACTION_STATE_POSE = 27,
    XR_TYPE_ACTION_SET_CREATE_INFO = 28,
    XR_TYPE_ACTION_CREATE_INFO = 29,
    XR_TYPE_INSTANCE_PROPERTIES = 32,
    XR_TYPE_FRAME_WAIT_INFO = 33,
    XR_TYPE_COMPOSITION_LAYER_PROJECTION = 35,
    XR_TYPE_COMPOSITION_LAYER QUAD = 36,
    XR_TYPE_REFERENCE_SPACE_CREATE_INFO = 37,
    XR_TYPE_ACTION_SPACE_CREATE_INFO = 38,
    XR_TYPE_EVENT_DATA_REFERENCE_SPACE_CHANGE_PENDING = 40,
    XR_TYPE_VIEW_CONFIGURATION_VIEW = 41,
    XR_TYPE_SPACE_LOCATION = 42,
    XR_TYPE_SPACE_VELOCITY = 43,
    XR_TYPE_FRAME_STATE = 44,
    XR_TYPE_VIEW_CONFIGURATION_PROPERTIES = 45,
    XR_TYPE_FRAME_BEGIN_INFO = 46,
    XR_TYPE_COMPOSITION_LAYER_PROJECTION_VIEW = 48,
    XR_TYPE_EVENT_DATA_EVENTS_LOST = 49,
    XR_TYPE_INTERACTION_PROFILE_SUGGESTED_BINDING = 51,
    XR_TYPE_EVENT_DATA_INTERACTION_PROFILE_CHANGED = 52,
    XR_TYPE_INTERACTION_PROFILE_STATE = 53,
    XR_TYPE_SWAPCHAIN_IMAGE_ACQUIRE_INFO = 55,
};
XR_TYPE_SWAPCHAIN_IMAGE_WAIT_INFO = 56,
XR_TYPE_SWAPCHAIN_IMAGE_RELEASE_INFO = 57,
XR_TYPE_ACTION_STATE_GET_INFO = 58,
XR_TYPE_HAPTIC_ACTION_INFO = 59,
XR_TYPE_SESSION_ACTION_SETS_ATTACH_INFO = 60,
XR_TYPE_ACTIONS_SYNC_INFO = 61,
XR_TYPE_BOUND_SOURCES_FOR_ACTION_ENUMERATE_INFO = 62,
XR_TYPE_INPUT_SOURCE_LOCALIZED_NAME_GET_INFO = 63,
XR_TYPE_COMPOSITION_LAYER_CUBE_KHR = 1000006000,
XR_TYPE_INSTANCE_CREATE_INFO_ANDROID_KHR = 1000008000,
XR_TYPE_COMPOSITION_LAYER_DEPTH_INFO_KHR = 1000010000,
XR_TYPE_VULKAN_SWAPCHAIN_FORMAT_LIST_CREATE_INFO_KHR = 1000014000,
XR_TYPE_EVENT_DATA_PERF_SETTINGS_EXT = 1000015000,
XR_TYPE_COMPOSITION_LAYER_CYLINDER_KHR = 1000017000,
XR_TYPE_COMPOSITION_LAYER_EQUIRECT_KHR = 1000018000,
XR_TYPE_DEBUG_UTILS_OBJECT_NAME_INFO_EXT = 1000019000,
XR_TYPE_DEBUG_UTILS_MESSENGER_CALLBACK_DATA_EXT = 1000019001,
XR_TYPE_DEBUG_UTILS_MESSENGER_CREATE_INFO_EXT = 1000019002,
XR_TYPE_DEBUG_UTILS_LABEL_EXT = 1000019003,
XR_TYPE_GRAPHICS_BINDING_OPENGL_WIN32_KHR = 1000023000,
XR_TYPE_GRAPHICS_BINDING_OPENGL_XLIB_KHR = 1000023001,
XR_TYPE_GRAPHICS_BINDING_OPENGL_XCB_KHR = 1000023002,
XR_TYPE_GRAPHICS_BINDING_OPENGL_WAYLAND_KHR = 1000023003,
XR_TYPE_SWAPCHAIN_IMAGE_OPENGL_KHR = 1000023004,
XR_TYPE_GRAPHICS_REQUIREMENTS_OPENGL_KHR = 1000023005,
XR_TYPE_GRAPHICS_BINDING_OPENGL_ES_ANDROID_KHR = 1000024001,
XR_TYPE_SWAPCHAIN_IMAGE_OPENGL_ES_KHR = 1000024002,
XR_TYPE_GRAPHICS_REQUIREMENTS_OPENGL_ES_KHR = 1000024003,
XR_TYPE_GRAPHICS_BINDING_VULKAN_KHR = 1000025000,
XR_TYPE_SWAPCHAIN_IMAGE_VULKAN_KHR = 1000025001,
XR_TYPE_GRAPHICS_REQUIREMENTS_VULKAN_KHR = 1000025002,
XR_TYPE_GRAPHICS_BINDING_D3D11_KHR = 1000027000,
XR_TYPE_SWAPCHAIN_IMAGE_D3D11_KHR = 1000027001,
XR_TYPE_GRAPHICS_REQUIREMENTS_D3D11_KHR = 1000027002,
XR_TYPE_GRAPHICS_BINDING_D3D12_KHR = 1000028000,
XR_TYPE_SWAPCHAIN_IMAGE_D3D12_KHR = 1000028001,
XR_TYPE_GRAPHICS_REQUIREMENTS_D3D12_KHR = 1000028002,
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XR_TYPE_EYE_GAZE_SAMPLE_TIME_EXT = 1000030001,
XR_TYPE_VISIBILITY_MASK_KHR = 1000030002,
XR_TYPE_EVENT_DATA_VISIBILITY_MASK_CHANGED_KHR = 1000030003,
XR_TYPE_SESSION_CREATE_INFO_OVERLAY_EXTX = 1000033000,
XR_TYPE_EVENT_DATA_MAIN_SESSION_VISIBILITY_CHANGED_EXTX = 1000033003,
XR_TYPE_COMPOSITION_LAYER_COLOR_SCALE_BIAS_KHR = 1000030004,
XR_TYPE_SPATIAL_ANCHOR_CREATE_INFO_MSFT = 1000039000,
XR_TYPE_SPATIAL_ANCHOR_SPACE_CREATE_INFO_MSFT = 1000039001,
XR_TYPE_COMPOSITION_LAYER_IMAGE_LAYOUT_FB = 1000040000,
XR_TYPE_COMPOSITION_LAYER_IMAGE_LAYOUT_FB = 1000040001,
XR_TYPE_VIEW_CONFIGURATION_DEPTH_RANGE_EXT = 1000046000,
XR_TYPE_GRAPHICS_BINDING_EGL_MNDX = 1000048004,
XR_TYPE_SPATIAL_GRAPH_NODE_SPACE_CREATE_INFO_MSFT = 1000049000,
XR_TYPE_SPATIAL_GRAPH_STATIC_NODE_BINDING_CREATE_INFO_MSFT = 1000049001,
XR_TYPE_SPATIAL_GRAPH_NODE_BINDING_PROPERTIES_GET_INFO_MSFT = 1000049002,
XR_TYPE_SPATIAL_GRAPH_NODE_BINDING_PROPERTIES_MSFT = 1000049003,
XR_TYPE_SYSTEM_HAND_TRACKING_PROPERTIES_EXT = 1000051000,
XR_TYPE_HAND_TRACKER_CREATE_INFO_EXT = 1000051001,
XR_TYPE_HAND_JOINTS_LOCATE_INFO_EXT = 1000051002,
XR_TYPE_HAND_JOINT_LOCATIONS_EXT = 1000051003,
XR_TYPE_HAND_JOINT_VELOCITIES_EXT = 1000051004,
XR_TYPE_SYSTEM_HAND_TRACKING_MESH_PROPERTIES_MSFT = 1000052000,
XR_TYPE_HAND_MESH_SPACE_CREATE_INFO_MSFT = 1000052001,
XR_TYPE_HAND_MESH_UPDATE_INFO_MSFT = 1000052002,
XR_TYPE_HAND_MESH_MSFT = 1000052003,
XR_TYPE_HAND_POSE_TYPE_INFO_MSFT = 1000052004,
XR_TYPE_SECONDARY_VIEW_CONFIGURATION_SESSION_BEGIN_INFO_MSFT = 1000053000,
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XR_TYPE_CONTROLLER_MODEL_NODE_PROPERTIES_MSFT = 1000055001,
XR_TYPE_CONTROLLER_MODEL_PROPERTIES_MSFT = 1000055002,
XR_TYPE_CONTROLLER_MODEL_NODE_STATE_MSFT = 1000055003,
XR_TYPE_CONTROLLER_MODEL_STATE_MSFT = 1000055004,
XR_TYPE_VIEW_CONFIGURATION_VIEW_FOV_EPIC = 1000059000,
XR_TYPE_HOLOGRAPHIC_WINDOW_ATTACHMENT_MSFT = 1000063000,
XR_TYPE_COMPOSITION_LAYER_REPROJECTION_INFO_MSFT = 1000066000,
XR_TYPE_COMPOSITION_LAYER_REPROJECTION_PLANE_OVERRIDE_MSFT = 1000066001,
XR_TYPE_ANDROID_SURFACE_SWAPCHAIN_CREATE_INFO_FB = 1000070000,
XR_TYPE_COMPOSITION_LAYER_SECURE_CONTENT_FB = 1000072000,
XR_TYPE_INTERACTION_PROFILE_DPAD_BINDING_EXT = 1000078000,
XR_TYPE_INTERACTION_PROFILE_ANALOG_THRESHOLD_VALUE = 1000079000,
XR_TYPE_HAND_JOINTS_MOTION_RANGE_INFO_EXT = 1000080000,
XR_TYPE_LOADER_INIT_INFO_ANDROID_KHR = 1000089000,
XR_TYPE_VULKAN_INSTANCE_CREATE_INFO_KHR = 1000090000,
XR_TYPE_VULKAN_DEVICE_CREATE_INFO_KHR = 1000090001,
XR_TYPE_VULKAN_GRAPHICS_DEVICE_GET_INFO_KHR = 1000090003,
XR_TYPE_COMPOSITION_LAYER_EQUIRECT2_KHR = 1000091000,
XR_TYPE_SCENE_OBSERVER_CREATE_INFO_MSFT = 1000097000,
XR_TYPE_SCENE_CREATE_INFO_MSFT = 1000097001,
XR_TYPE_NEW_SCENE_COMPUTE_INFO_MSFT = 1000097002,
XR_TYPE_VISUAL_MESH_COMPUTE_LOD_INFO_MSFT = 1000097003,
XR_TYPE_SCENE_COMPONENTS_MSFT = 1000097004,
XR_TYPE_SCENE_COMPONENTS_GET_INFO_MSFT = 1000097005,
XR_TYPE_SCENE_COMPONENT_LOCATIONS_MSFT = 1000097006,
XR_TYPE_SCENE_COMPONENTS_LOCATE_INFO_MSFT = 1000097007,
XR_TYPE_SCENE_OBJECTS_MSFT = 1000097008,
XR_TYPE_SCENE_COMPONENT_PARENT_FILTER_INFO_MSFT = 1000097009,
XR_TYPE_SCENE_OBJECT_TYPES_FILTER_INFO_MSFT = 1000097010,
XR_TYPE_SCENE_PLANES_MSFT = 1000097011,
XR_TYPE_SCENE_PLANE_ALIGNMENT_FILTER_INFO_MSFT = 1000097012,
XR_TYPE_SCENE_MESHES_MSFT = 1000097013,
XR_TYPE_SCENE_MESH_BUFFERS_GET_INFO_MSFT = 1000097014,
XR_TYPE_SCENE_MESH_BUFFERS_MSFT = 1000097015,
XR_TYPE_SCENE_MESH_VERTEX_BUFFER_MSFT = 1000097016,
XR_TYPE_SCENE_MESH_INDICES_UINT32_MSFT = 1000097017,
XR_TYPE_SCENE_MESH_INDICES_UINT16_MSFT = 1000097018,
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XR_TYPE_SCENE_DESERIALIZE_INFO_MSFT = 1000098001,
XR_TYPE_EVENT_DATA_DISPLAY_REFRESH_RATE_CHANGED_FB = 1000101000,
XR_TYPE_VIVE_TRACKER_PATHS_HTCX = 1000103000,
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XR_TYPE_FACIAL_TRACKER_CREATE_INFO_HTC = 1000104001,
XR_TYPE_FACIAL_EXPRESSIONS_HTC = 1000104002,
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XR_TYPE_HAND_TRACKING_SCALE_FB = 1000110003,
XR_TYPE_HAND_TRACKING_AIM_STATE_FB = 1000110001,
XR_TYPE_HAND_TRACKING_CAPSULES_STATE_FB = 1000112000,
XR_TYPE_SYSTEM_SPATIAL_ENTITY_PROPERTIES_FB = 1000113004,
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XR_TYPE_SPACE_COMPONENT_STATUS_FB = 1000113001,
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XR_TYPE_EVENT_DATA_SPACE_SET_STATUS_COMPLETE_FB = 1000113006,
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XR_TYPE_SWAPCHAIN_CREATE_INFO_FOVEATION_FB = 1000114001,
XR_TYPE_SWAPCHAIN_STATE_FOVEATION_FB = 1000114002,
XR_TYPE_FOVEATION_LEVEL_PROFILE_CREATE_INFO_FB = 1000115000,
XR_TYPE_KEYBOARD_SPACE_CREATE_INFO_FB = 1000116009,
XR_TYPE_KEYBOARD_TRACKING_QUERY_FB = 1000116004,
XR_TYPE_SYSTEM_KEYBOARD_TRACKING_PROPERTIES_FB = 1000116002,
XR_TYPE_TRIANGLE_MESH_CREATE_INFO_FB = 1000117001,
XR_TYPE_SYSTEM_PASSTHROUGH_PROPERTIES_FB = 1000118000,
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XR_TYPE_PASSTHROUGH_COLOR_MAP_MONO_TO_MONO_FB = 1000118022,
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XR_TYPE_FOVEATED_VIEW_CONFIGURATION_VIEW_VARJO = 1000121001,
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XR_TYPE_COMPOSITION_LAYER_DEPTH_TEST_VARJO = 1000122000,
XR_TYPE_SYSTEM_MARKER_TRACKING_PROPERTIES_VARJO = 1000124000,
XR_TYPE_EVENT_DATAMarker_TRACKING_UPDATE_VARJO = 1000124001,
XR_TYPE_MARKER_SPACE_CREATE_INFO_VARJO = 1000124002,
XR_TYPE_SPATIAL_ANCHOR_PERSISTENCE_INFO_MSFT = 1000142000,
XR_TYPE_SPATIAL_ANCHOR_FROM_PERSISTED_ANCHOR_CREATE_INFO_MSFT = 1000142001,
XR_TYPE_SPACE_QUERY_INFO_FB = 1000156001,
XR_TYPE_SPACE_QUERY_RESULTS_FB = 1000156002,
XR_TYPE_SPACE_STORAGE_LOCATION_FILTER_INFO_FB = 1000156003,
XR_TYPE_SPACE_UUID_FILTER_INFO_FB = 1000156054,
XR_TYPE_SPACE_COMPONENT_FILTER_INFO_FB = 1000156052,
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XR_TYPE_EVENT_DATA_SPACE_QUERY_COMPLETE_FB = 1000156104,
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XR_TYPE_SPACE_ERASE_INFO_FB = 1000158001,
XR_TYPE_EVENT_DATA_SPACE_SAVE_COMPLETE_FB = 1000158106,
XR_TYPE_EVENT_DATA_SPACE_ERASE_COMPLETE_FB = 1000158107,
XR_TYPE_SWAPCHAIN_IMAGE_FOVEATION_VULKAN_FB = 1000160000,
XR_TYPE_SWAPCHAIN_STATEANDROID_SURFACE_DIMENSIONS_FB = 1000161000,
XR_TYPE_SWAPCHAIN_STATE_SAMPLER_OPENGL_ES_FB = 1000162000,
XR_TYPE_SWAPCHAIN_STATE_SAMPLER_VULKAN_FB = 1000163000,
XR_TYPE_COMPOSITION_LAYER_SPACE_WARP_INFO_FB = 1000171000,
XR_TYPE_SYSTEM_SPACE_WARP_PROPERTIES_FB = 1000171001,
XR_TYPE_SEMANTIC_LABELS_FB = 1000175000,
XR_TYPE_ROOM_LAYOUT_FB = 1000175001,
XR_TYPE_BOUNDARY_2D_FB = 1000175002,
XR_TYPE_DIGITAL_LENS_CONTROL_ALMALENCE = 1000196000,
XR_TYPE_SPACE_CONTAINER_FB = 1000199000,
XR_TYPE_PASSTHROUGH_KEYBOARD_HANDS_INTENSITY_FB = 1000203002,
XR_TYPE_COMPOSITION_LAYER_SETTINGS_FB = 1000204000,
XR_TYPE_VULKAN_SWAPCHAIN_CREATE_INFO_META = 1000227000,
XR_TYPE_PERFORMANCE_METRICS_STATE_META = 1000232001,
XR_TYPE_PERFORMANCE_METRICS_COUNTER_META = 1000232002,
XR_TYPE_GRAPHICS_BINDING_VULKAN2_KHR = XR_TYPE_GRAPHICS_BINDING_VULKAN_KHR,
XR_TYPE_SWAPCHAIN_IMAGE_VULKAN2_KHR = XR_TYPE_SWAPCHAIN_IMAGE_VULKAN_KHR,
XR_TYPE_GRAPHICS_REQUIREMENTS_VULKAN2_KHR = XR_TYPE_GRAPHICS_REQUIREMENTS_VULKAN_KHR,
Most structures containing type members have a value of type matching the type of the structure, as described more fully in Valid Usage for Structure Types.

Note that all extension enums begin at the extension enum base of \(1^{10}\) (base 10). Each extension is assigned a block of 1000 enums, starting at the enum base and arranged by the extension’s index.

For example, if an extension with index 5 wants to use an enum value of 3, the final enum is computed by:

\[
\text{enum} = \text{enum\_base} + (\text{enum\_index} - 1) \times 1000 + \text{enum\_value} = 1000000000 + 4 \times 1000 + 3
\]

**Flag Types**

Flag types are all bitmasks aliasing the base type \texttt{XrFlags64} and with corresponding bit flag types defining the valid bits for that flag, as described in Valid Usage for Flags. Flag types supported by the API include:

```c
typedef XrFlags64 XrCompositionLayerFlags;
```

```c
typedef XrFlags64 XrInputSourceLocalizedNameFlags;
```

```c
typedef XrFlags64 XrInstanceCreateFlags;
```

```c
typedef XrFlags64 XrSessionCreateFlags;
```

```c
typedef XrFlags64 XrSpaceLocationFlags;
```
typedef XrFlags64 XrSpaceVelocityFlags;

typedef XrFlags64 XrSwapchainCreateFlags;

typedef XrFlags64 XrSwapchainUsageFlags;

typedef XrFlags64 XrViewStateFlags;

**General Macro Definitions**

This API is defined in C and uses "C" linkage. The openxr.h header file is opened with:

```c
#ifdef __cplusplus
extern "C" {
#endif
```

and closed with:

```c
#ifdef __cplusplus
}
#endif
```

The supplied openxr.h header defines a small number of C preprocessor macros that are described below.

**Version Number Macros**

Two version numbers are defined in openxr.h. Each is packed into a 32-bit integer as described in API Version Number Function-like Macros.
// OpenXR current version number.
#define XR_CURRENT_API_VERSION XR_MAKE_VERSION(1, 0, 24)

**XR_CURRENT_API_VERSION** is the current version of the OpenXR API.

**API Version Number Function-like Macros**

API Version Numbers are three components, packed into a single 64-bit integer. The following macros manipulate version components and packed version numbers.

```c
#define XR_MAKE_VERSION(major, minor, patch) 
   (((major) & 0xffffULL) << 48) | (((minor) & 0xffffULL) << 32) | ((patch) & 0xffffffffULL)
```

**Parameter Descriptions**

- **major** is the major version number, packed into the most-significant 16 bits.
- **minor** is the minor version number, packed into the second-most-significant group of 16 bits.
- **patch** is the patch version number, in the least-significant 32 bits.

**XR_MAKE_VERSION** constructs a packed 64-bit integer API version number from three components. The format used is described in **API Version Numbers and Semantics**.

This macro can be used when constructing the `XrApplicationInfo::apiVersion` parameter passed to `xrCreateInstance`.

```c
#define XR_VERSION_MAJOR(version) (uint16_t)(((uint64_t)(version) >> 48)& 0xffffULL)
```

**Parameter Descriptions**

- **version** is a packed version number, such as those produced with **XR_MAKE_VERSION**.

**XR_VERSION_MAJOR** extracts the API major version number from a packed version number.
Parameter Descriptions

- `version` is a packed version number, such as those produced with `XR_MAKE_VERSION`.

`XR_VERSION_MINOR` extracts the API minor version number from a packed version number.

Parameter Descriptions

- `version` is a packed version number, such as those produced with `XR_MAKE_VERSION`.

`XR_VERSION_PATCH` extracts the API patch version number from a packed version number.

Handle and Atom Macros

```c
#if !defined(XR_DEFINE_HANDLE)
#if (XR_PTR_SIZE == 8)
    #define XR_DEFINE_HANDLE(object) typedef struct object##_T* object;
#else
    #define XR_DEFINE_HANDLE(object) typedef uint64_t object;
#else
#endif
#endif
```

Parameter Descriptions

- `object` is the name of the resulting C type.

`XR_DEFINE_HANDLE` defines a handle type, which is an opaque 64 bit value, which *may* be implemented as an opaque, distinct pointer type on platforms with 64 bit pointers.

For further details, see `Handles`. 
#if !defined(XR_NULL_HANDLE)
#if (XR_PTR_SIZE == 8) && XR_CPP_NULLPTR_SUPPORTED
    #define XR_NULL_HANDLE nullptr
#else
    #define XR_NULL_HANDLE 0
#endif
#endif

XR_NULL_HANDLE is a reserved value representing a non-valid object handle. It may be passed to and returned from API functions only when specifically allowed.

#if !defined(XR_DEFINE_ATOM)
    #define XR_DEFINE_ATOM(object) typedef uint64_t object;
#endif

Parameter Descriptions

- object is the name of the resulting C type.

XR_DEFINE_ATOM defines an atom type, which is an opaque 64 bit integer.

Platform-Specific Macro Definitions

Additional platform-specific macros and interfaces are defined using the included openxr_platform.h file. These macros are used to control platform-dependent behavior, and their exact definitions are under the control of specific platform implementations of the API.

Platform-Specific Calling Conventions

On many platforms the following macros are empty strings, causing platform- and compiler-specific default calling conventions to be used.

XRAPI_ATTR is a macro placed before the return type of an API function declaration. This macro controls calling conventions for C++11 and GCC/Clang-style compilers.

XRAPI_CALL is a macro placed after the return type of an API function declaration. This macro controls calling conventions for MSVC-style compilers.

XRAPI_PTR is a macro placed between the ( and * in API function pointer declarations. This macro also controls calling conventions, and typically has the same definition as XRAPI_ATTR or XRAPI_CALL, depending on the compiler.
Examples:

Function declaration:

```c
XRAPI_ATTR <return_type> XRAPI_CALL <function_name>(<function_parameters>);
```

Function pointer type declaration:

```c
typedef <return_type> (XRAPI_PTR *PFN_<function_name>(<function_parameters>);
```

**Platform-Specific Header Control**

If the `XR_NO_STDINT_H` macro is defined by the application at compile time, before including any OpenXR header, extended integer types normally found in `<stdint.h>` and used by the OpenXR headers, such as `uint8_t`, must also be defined (as `typedef` or with the preprocessor) before including any OpenXR header. Otherwise, `openxr.h` and related headers will not compile. If `XR_NO_STDINT_H` is not defined, the system-provided `<stdint.h>` is used to define these types. There is a fallback path for Microsoft Visual Studio version 2008 and earlier versions (which lack this header) that is automatically activated as needed.

**Graphics API Header Control**

<table>
<thead>
<tr>
<th>Compile Time Symbol</th>
<th>Graphics API Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_USE_GRAPHICS_API_OPENGL</td>
<td>OpenGL</td>
</tr>
<tr>
<td>XR_USE_GRAPHICS_API_OPENGL_ES</td>
<td>OpenGL ES</td>
</tr>
<tr>
<td>XR_USE_GRAPHICS_API_VULKAN</td>
<td>Vulkan</td>
</tr>
<tr>
<td>XR_USE_GRAPHICS_API_D3D11</td>
<td>Direct3D 11</td>
</tr>
<tr>
<td>XR_USE_GRAPHICS_API_D3D12</td>
<td>Direct3D 12</td>
</tr>
</tbody>
</table>

**Window System Header Control**

<table>
<thead>
<tr>
<th>Compile Time Symbol</th>
<th>Window System Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR_USE_PLATFORM_WIN32</td>
<td>Microsoft Windows</td>
</tr>
<tr>
<td>XR_USE_PLATFORM_XLIB</td>
<td>X Window System Xlib</td>
</tr>
<tr>
<td>XR_USE_PLATFORM_XCB</td>
<td>X Window System Xcb</td>
</tr>
<tr>
<td>XR_USE_PLATFORM_WAYLAND</td>
<td>Wayland</td>
</tr>
<tr>
<td>XR_USE_PLATFORM_ANDROID</td>
<td>Android Native</td>
</tr>
</tbody>
</table>
Android Notes

Android specific notes for using the OpenXR specification.

Android Runtime category tag for immersive mode selection

Android applications should add the `<category android:name="org.khronos.openxr.intent.category.IMMERSIVE_HMD" />` tag inside the intent-filter to indicate that the activity starts in an immersive OpenXR mode and will not touch the native Android 2D surface.

The HMD suffix indicates the preferred form-factor used by the application and can be used by launchers to filter applications listed.

For example:

```
<intent-filter>
  <action android:name="android.intent.action.MAIN" />
  <category android:name="android.intent.category.LAUNCHER" />
  <category android:name="org.khronos.openxr.intent.category.IMMERSIVE_HMD" />
</intent-filter>
```

Glossary

The terms defined in this section are used throughout this Specification. Capitalization is not significant for these definitions.

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>The XR application which calls the OpenXR API to communicate with an OpenXR runtime.</td>
</tr>
<tr>
<td>Deprecated</td>
<td>A feature/extension is deprecated if it is no longer recommended as the correct or best way to achieve its intended purpose. Generally a newer feature/extension will have been created that solves the same problem - in cases where no newer alternative feature exists, justification should be provided.</td>
</tr>
<tr>
<td>Handle</td>
<td>An opaque integer or pointer value used to refer to an object. Each object type has a unique handle type.</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Haptic</td>
<td>Haptic or kinesthetic communication recreates the sense of touch by applying forces, vibrations, or motions to the user.</td>
</tr>
<tr>
<td>In-Process</td>
<td>Something that executes in the application’s process.</td>
</tr>
<tr>
<td>Instance</td>
<td>The top-level object, which represents the application’s connection to the runtime. Represented by an <code>XrInstance</code> object.</td>
</tr>
<tr>
<td>Normalized</td>
<td>A value that is interpreted as being in the range [0,1], or a vector whose norm is in that range, as a result of being implicitly divided or scaled by some other value.</td>
</tr>
<tr>
<td>Out-Of-Process</td>
<td>Something that executes outside the application’s process.</td>
</tr>
<tr>
<td>Promoted</td>
<td>A feature is promoted if it is taken from an older extension and made available as part of a new core version of the API, or a newer extension that is considered to be either as widely supported or more so. A promoted feature may have minor differences from the original such as:</td>
</tr>
<tr>
<td></td>
<td>• It may be renamed</td>
</tr>
<tr>
<td></td>
<td>• A small number of non-intrusive parameters may have been added</td>
</tr>
<tr>
<td></td>
<td>• The feature may be advertised differently by device features</td>
</tr>
<tr>
<td></td>
<td>• The author ID suffixes will be changed or removed as appropriate</td>
</tr>
<tr>
<td>Provisional</td>
<td>A feature is released provisionally in order to get wider feedback on the functionality before it is finalized. Provisional features may change in ways that break backwards compatibility, and thus are not recommended for use in production applications.</td>
</tr>
<tr>
<td>Required Extensions</td>
<td>Extensions that must be enabled alongside extensions dependent on them, or that must be enabled to use given hardware.</td>
</tr>
</tbody>
</table>
## Term

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runtime</td>
<td>The software which implements the OpenXR API and allows applications to interact with XR hardware.</td>
</tr>
<tr>
<td>Swapchain</td>
<td>A resource that represents a chain of images in device memory. Represented by an <strong>XrSwapchain</strong> object.</td>
</tr>
<tr>
<td>Swapchain Image</td>
<td>Each element in a swapchain. Commonly these are simple formatted 2D images, but in other cases they may be array images. Represented by a structure related to <strong>XrSwapchainImageBaseHeader</strong>.</td>
</tr>
</tbody>
</table>

### Abbreviations

Abbreviations and acronyms are sometimes used in the API where they are considered clear and commonplace, and are defined here:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>AR</td>
<td>Augmented Reality</td>
</tr>
<tr>
<td>ER</td>
<td>Eye Relief</td>
</tr>
<tr>
<td>IAD</td>
<td>Inter Axial Distance</td>
</tr>
<tr>
<td>IPD</td>
<td>Inter Pupillary Distance</td>
</tr>
<tr>
<td>MR</td>
<td>Mixed Reality</td>
</tr>
<tr>
<td>OS</td>
<td>Operating System</td>
</tr>
<tr>
<td>TSG</td>
<td>Technical Sub-Group. A specialized sub-group within a Khronos Working Group (WG).</td>
</tr>
<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>WG</td>
<td>Working Group. An organized group of people working to define/augment an API.</td>
</tr>
<tr>
<td>XR</td>
<td>VR + AR + MR</td>
</tr>
</tbody>
</table>
In memory of Johannes van Waveren: a loving father, husband, son, brother, colleague, and dear friend.

Johannes, known to his friends as "JP", had a great sense of humor, fierce loyalty, intense drive, a love of rainbow unicorns, and deep disdain for processed American cheese. Perhaps most distinguishing of all, though, was his love of technology and his extraordinary technical ability.

JP's love of technology started at an early age --- instead of working on his homework, he built train sets, hovercrafts, and complex erector sets from scratch; fashioned a tool for grabbing loose change out of street grates; and played computer games. The passion for computer games continued at Delft University of Technology, where, armed with a T1 internet connection and sheer talent, he regularly destroyed his foes in arena matches without being seen, earning him the moniker "MrElusive". During this time, he wrote the Gladiator-bot AI, which earned him acclaim in the community and led directly to a job at the iconic American computer game company, id Software. From there, he quickly became an expert in every system he touched, contributing significantly to every facet of the technology: AI, path navigation, networking, skeletal animation, virtual texturing, advanced rendering, and physics. He became a master of all. He famously owned more lines of code than anyone else, but he was also a generous mentor, helping junior developers hone their skills and make their own contributions.

When the chance to work in the VR industry arose, he saw it as an opportunity to help shape the future. Having never worked on VR hardware did not phase him; he quickly became a top expert in the field. Many of his contributions directly moved the industry forward, most recently his work on asynchronous timewarp and open-standards development.

Time was not on his side. Even in his final days, JP worked tirelessly on the initial proposal for this specification. The treatments he had undergone took a tremendous physical toll, but he continued to work because of his love of technology, his dedication to the craft, and his desire to get OpenXR started on a solid footing. His focus was unwavering.

His proposal was unofficially adopted several days before his passing - and upon hearing, he mustered the energy for a smile. While it was his great dream to see this process through, he would be proud of the spirit of cooperation, passion, and dedication of the industry peers who took up the torch to drive this specification to completion.

JP lived a life full of accomplishment, as evidenced by many publications, credits, awards, and nominations where you will find his name. A less obvious accomplishment --- but of equal importance --- is the influence he had on people through his passionate leadership. He strove for excellence in everything that he did. He was always excited to talk about technology and share the discoveries made while working through complex problems. He created excitement and interest around engineering and technical excellence. He was a mentor and teacher who inspired those who knew him and many continue to benefit from his hard work and generosity.
JP was a rare gem; fantastically brilliant intellectually, but also warm, compassionate, generous, humble, and funny. Those of us lucky enough to have crossed paths with him knew what a privilege and great honor it was to know him. He is certainly missed.
Contributors (Informative)

OpenXR is the result of contributions from many people and companies participating in the Khronos OpenXR Working Group. Members of the Working Group, including the company that they represented at the time of their most recent contribution, are listed below.

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