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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

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.

```c
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:

### Version Numbers

- The major version number is a 16-bit integer packed into bits 63-48.
- The minor version number is a 16-bit integer packed into bits 47-32.
- The patch version number is a 32-bit integer packed into bits 31-0.

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 `handTracker` parameter, and any child handles, in `xrDestroyHandTrackerEXT`

Implicit Externally Synchronized Parameters

- The `session` parameter by any other `xrWaitFrame` call in `xrWaitFrame`
- The `XrInstance` used to create `messenger`, and all of its child handles in `xrDestroyDebugUtilsMessengerEXT`

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.
As a convenience, some types and pointers that are known at specification time to alias values of different types have been annotated with the `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 **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 **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 **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 **must** be a valid object handle, unless otherwise specified. An object handle is valid if and only if:
Object Handle Validity Conditions

- it has been created or allocated by a previous, successful call to the API,
- it has not been destroyed by a previous call to the API, and
- its parent handle is also valid.

There are contexts in which an object handle is optional or otherwise unspecified. In those cases, the API uses XR_NULL_HANDLE, which has the integer value 0.

Valid Usage for Pointers

Any parameter that is a pointer 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 \( Xr*\text{Flags} \) type as the \( Xr*\text{Flags} \) 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 \text{type} member \textbf{must} have a value of \text{type} which is a valid \( Xr\text{StructureType} \) 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 \( XR\_\text{TYPE} \).

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 \( \Rightarrow _{\text{OPENGL}} \)
- OpenGLES \( \Rightarrow _{\text{OPENGL}\_\text{ES}} \)
- EGL \( \Rightarrow _{\text{EGL}} \)
- D3D \( \Rightarrow _{\text{D3D}} \)
- VULKAN \( \Rightarrow _{\text{VULKAN}} \)

Valid Usage for Structure Pointer Chains

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

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

Most extension structures are described in the base OpenXR Specification under the List of Extensions. Vendor-specific extensions \textbf{may} be found there as well, or \textbf{may} only be available from the vendor's website or internal document repositories.

Unless otherwise specified: Extension structs which are output structs \textbf{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 \textbf{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 an extension-specific structure.

`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 an extension-specific structure.

`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_ENVIRONMENT_BLEND_MODE_UNSUPPORTED = -42,
XR_ERROR_NAME_Duplicated = -44,
XR_ERROR_NAME_INVALID = -45,
XR_ERROR_ACTIONSET_NOT_ATTACHED = -46,
XR_ERROR_ACTIONSETS_ALREADY_ATTACHED = -47,
All return codes in the API are reported via \texttt{XrResult} return values.

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

- \texttt{_INVALID}: The specified handle, atom or value is formatted incorrectly, or the specified handle was never created or has been destroyed.
- \texttt{_UNSUPPORTED}: The specified handle, atom, enumerant or value is formatted correctly but cannot be used for the lifetime of this function’s parent handle.
- \texttt{_UNAVAILABLE}: The specified handle, atom, enumerant or value is supported by this function’s parent handle but not at this moment.

### 2.8.1. 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>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>
</tbody>
</table>

### 2.8.2. 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>Enum</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------------------------------------------------------------------</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 <strong>XrInstance</strong> 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 <strong>XrSession</strong> was lost. It will need to be destroyed and optionally recreated.</td>
</tr>
<tr>
<td>XR_ERROR_SYSTEM_INVALID</td>
<td>The provided <strong>XrSystemId</strong> was invalid.</td>
</tr>
<tr>
<td>XR_ERROR_PATH_INVALID</td>
<td>The provided <strong>XrPath</strong> was not valid.</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>Enum</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-----------------------------------------------------------------------------</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>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>Enum</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>XR_ERROR_LOCALIZED_NAME_INVALID</td>
<td>The localized name provided was invalid.</td>
</tr>
<tr>
<td>XR_ERROR_ANDROID_THREAD_SETTINGS_ID_INVALID_KHR</td>
<td>xrSetAndroidApplicationThreadKHR failed as thread id is invalid. (Added by the XR_KHR_android_thread_settings extension)</td>
</tr>
<tr>
<td>XR_ERROR_ANDROID_THREAD_SETTINGS_FAILURE_KHR</td>
<td>xrSetAndroidApplicationThreadKHR failed setting the thread attributes/priority. (Added by the XR_KHR_android_thread_settings 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 XR_MSFT_spatial_anchor extension)</td>
</tr>
<tr>
<td>XR_ERROR_SECONDARY_VIEW_CONFIGURATION_TYPE_NOT_E NABLED_MSFT</td>
<td>The secondary view configuration was not enabled when creating the session. (Added by the XR_MSFT_secondary_view_configuration extension)</td>
</tr>
</tbody>
</table>

### 2.8.3. 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.

```c
#define XR_FAILED(result) ((result) < 0)
```

A convenience macro that can be used to test if a function has failed in some way.

```c
#define XR_UNQUALIFIED_SUCCESS(result) ((result) == 0)
```

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.

### 2.8.4. 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.

```c
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_HAND_TRACKER_EXT = 1000051000,
    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><code>XrObjectType</code></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
struct XrBuffer {
  uint32_t              elementCapacityInput;
  uint32_t              elementCountOutput;
  float*                elements;
};
XrResult xrFunction(XrBuffer* buffer);
```

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. 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.

2.15. 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. When using `XrPosef` the rotation described by `orientation` is always applied before the translation described by `position`.

A two-dimensional vector is defined by the `XrVector2f` structure:

```c
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:

```c
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:

```c
typedef struct XrVector4f {
    float x;
    float y;
    float z;
    float w;
} XrVector4f;
```
Member Descriptions

• \textit{x} is the \textit{x} coordinate of the vector.
• \textit{y} is the \textit{y} coordinate of the vector.
• \textit{z} is the \textit{z} coordinate of the vector.
• \textit{w} is the \textit{w} coordinate of the vector.

If used to represent physical distances, \textit{x}, \textit{y}, and \textit{z} values \textbf{must} be in meters.

Rotation is represented by a unit quaternion defined by the \texttt{XrQuaternionf} structure:

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

Member Descriptions

• \textit{x} is the \textit{x} coordinate of the quaternion.
• \textit{y} is the \textit{y} coordinate of the quaternion.
• \textit{z} is the \textit{z} coordinate of the quaternion.
• \textit{w} is the \textit{w} coordinate of the quaternion.

A pose is defined by the \texttt{XrPosef} structure:

```c
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.

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

### 2.16. 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:

```c
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:
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.

### 2.17. 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.

### 2.18. 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.

### 2.19. 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

```cpp
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`

```cpp
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_INSTANCE_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE

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

The **XrEventDataBaseHeader** structure is defined as:

```c
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 an extension-specific structure.

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_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_PERF_SETTINGS_EXT`, `XR_TYPE_EVENT_DATA_REFERENCE_SPACE_CHANGE_PENDING`, `XR_TYPE_EVENT_DATA_SESSION_STATE_CHANGED`, `XR_TYPE_EVENT_DATA_VISIBILITY_MASK_CHANGED_KHR`.
- **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.
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 an extension-specific structure.
- **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:

```c
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 an extension-specific structure.
- **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.
Chapter 3. API Initialization

Before using an OpenXR runtime, an application **must** initialize it by creating a `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,           // instance, or NULL for functions not dependent on any instance.
    const char* name,              // name of the function to obtain.
    PFN_xrVoidFunction* function, // address of the function pointer to get.
);
```

**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:

**No Instance Required**

- 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.

xrGetInstanceProcAddr must return XR_ERROR_FUNCTION_UNSUPPORTED if instance is a valid instance and the string specified in name is not the name of an OpenXR core or enabled extension function.

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>
<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>
</tbody>
</table>

The table defines the various use cases for xrGetInstanceProcAddr and return value ("fp" is “function pointer”) for each case.
<table>
<thead>
<tr>
<th>instance parameter</th>
<th>name parameter</th>
<th>return value</th>
</tr>
</thead>
<tbody>
<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>fp¹</td>
</tr>
<tr>
<td>instance</td>
<td>enabled extension function for instance</td>
<td>fp¹</td>
</tr>
<tr>
<td>instance</td>
<td>* (any name not covered above)</td>
<td>NULL</td>
</tr>
</tbody>
</table>

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

Parameter Descriptions

• no parameters.

PFN_xrVoidFunction is a dummy pointer returned by queries, specifically those to xrGetInstanceProcAddr.
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:

```
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 0.
- `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_OUT_OF_MEMORY
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_SIZE_INSUFFICIENT

The XrApiLayerProperties structure is defined as:

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 an extension-specific structure.
• 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 0.

- `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_OUT_OF_MEMORY
  • XR_ERROR_API_LAYER_NOT_PRESENT
  • XR_ERROR_RUNTIME_FAILURE
  • XR_ERROR_VALIDATION_FAILURE
  • XR_ERROR_SIZE_INSUFFICIENT

The XrExtensionProperties structure is defined as:

```c
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` must be `NULL` or a pointer to an extension-specific structure.
• `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
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_OUT_OF_MEMORY
• XR_ERROR_LIMIT_REACHED
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_INITIALIZATION_FAILED
• XR_ERROR_API_VERSION_UNSUPPORTED
• XR_ERROR_API_LAYER_NOT_PRESENT
• XR_ERROR_EXTENSION_NOT_PRESENT
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_NAME_INVALID

The XrInstanceCreateInfo structure is defined as:

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 an extension-specific structure.
- **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:

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`


**Note**

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_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_VALIDATION_FAILURE

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 an extension-specific structure.
• 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 extension structures. 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

```c
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_INSTANCE_LOST 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 an extension-specific structure.
- **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_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_VALIDATION_FAILURE`

The `xrStructureTypeToString` function is defined as:

```c
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_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_VALIDATION_FAILURE
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.

```
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

```c
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_HANDLE_INVALID*
- *XR_ERROR_INSTANCE_LOST*
- *XR_ERROR_RUNTIME_FAILURE*
- *XR_ERROR_FORM_FACTOR_UNAVAILABLE*
- *XR_ERROR_FORM_FACTOR_UNSUPPORTED*
- *XR_ERROR_VALIDATION_FAILURE*

The *XrSystemGetInfo* structure is defined as:
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 an extension-specific structure.
- **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_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_SYSTEM_INVALID
• XR_ERROR_VALIDATION_FAILURE

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 an extension-specific structure.
• 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: `XrSystemEyeGazeInteractionPropertiesEXT`, `XrSystemHandTrackingMeshPropertiesMSFT`, `XrSystemHandTrackingPropertiesEXT`

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.

The `XrSystemTrackingProperties` structure is defined as:

```c
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 (uint64_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 \textit{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, \textit{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 \textit{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 \textit{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_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_PATH_FORMAT_INVALID
- XR_ERROR_PATH_COUNT_EXCEEDED
- XR_ERROR_VALIDATION_FAILURE

6.2.2. xrPathToString

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 0.
- 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_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_PATH_INVALID
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_VALIDATION_FAILURE

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** - 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.

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 (forward from left palm, backward from right palm).
  ◦ The grip orientation’s -Z axis: When you close your hand partially (as if holding the controller), the ray that points "forward" through the tube formed by your non-thumb fingers.
  ◦ The grip orientation’s +Y axis: The right-handed Up axis implied by the +X (Right) and -Z (Forward) definitions.

• 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.

**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. 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>

### 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`
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
• /output/haptic_left_trigger
• /output/haptic_right_trigger

6.4.7. Oculus Go Controller Profile

Path: /interaction_profiles/oculus/go_controller

Valid for user paths:

• /user/hand/left
• /user/hand/right

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

Supported component paths:

• /input/system/click (may not be available for application use)
• /input/trigger/click
• /input/back/click
• /input/trackpad/x
• /input/trackpad/y
• /input/trackpad/click
• /input/trackpad/touch
• /input/grip/pose
• /input/aim/pose

6.4.8. Oculus Touch Controller Profile

Path: /interaction_profiles/oculus/touch_controller

Valid for user paths:

• /user/hand/left
• /user/hand/right

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

Supported component paths:
• On /user/hand/left only:
  ◦ …/input/x/click
  ◦ …/input/x/touch
  ◦ …/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_UNBOUNDED_MSFT = 1000038000,
    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` 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 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_SPACE_BOUNDS_UNAVAILABLE
- XR_SESSION_LOSS_PENDING

### Failure
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_FUNCTION_UNSUPPORTED
- 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 forxrLocateSpace orxrLocateViews calls whoseXrTimeparameter 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 toxrCreateReferenceSpace. 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 an extension-specific structure.
- **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 **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 0.
- **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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_VALIDATION_FAILURE

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 supported.
supported by this session.

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

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 an extension-specific structure.
- **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:

```c
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 XrAction handle.
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_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_ACTION_TYPE_MISMATCH`
- `XR_ERROR_LIMIT_REACHED`
- `XR_ERROR_POSE_INVALID`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_PATH_INVALID`

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 an extension-specific structure.
- **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:

```c
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,  // Identifies the target space to locate.
    XrSpace baseSpace,  // Identifies the underlying space in which to locate space.
    XrTime time,  // Is the time for which the location should be provided.
    XrSpaceLocation* location);  // Provides the location of space in baseSpace.

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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_TIME_INVALID

The XrSpaceLocation structure is defined as:

```c
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 an extension-specific structure, 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 XrPosef 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.

- `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.

- `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 an extension-specific structure.
- **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
// 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 field contains valid data.
- **XR_SPACE_VELOCITY_ANGULAR_VALID_BIT** indicates that the angularVelocity field contains valid data.
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

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:

```c
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 0.
- **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, **viewConfigurationTypes** **must** be a pointer to an array of **viewConfigurationTypeCapacityInput** **XrViewConfigurationType** values
### Return Codes

**Success**
- XR_SUCCESS

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

### 8.2.2. xrGetViewConfigurationProperties

The `xrGetViewConfigurationProperties` function is defined as:

```
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_INSTANCE_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_SYSTEM_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED

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 an extension-specific structure.
- `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
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:

```c
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 an extension-specific structure.
- **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: 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

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

First, the application creates a session by choosing a system and a graphics API and calling `xrCreateSession`, which creates a session in the `XR_SESSION_STATE_IDLE` state. The application then sets up an `xrPollEvent` loop to monitor for session state changes delivered through the `XrEventDataSessionStateChanged` event. When the runtime determines that the system is ready to start transitioning to this session’s XR content, it notifies the application that its session has moved into the `XR_SESSION_STATE_READY` state. When the application is ready to proceed and display its XR content, it calls `xrBeginSession`, which starts its session running. While the session is running, the application is expected to continuously run its frame loop by calling `xrWaitFrame`, `xrBeginFrame` and `xrEndFrame` each frame, to establish synchronization with the runtime. Once the runtime is synchronized with the application’s frame loop and ready to display its frames, the session will move into the `XR_SESSION_STATE_SYNCHRONIZED` state. For frames where `xrWaitFrame` returns an `XrFrameState` with `shouldRender` set to true, the application should render its composition layers and submit them to `xrEndFrame`. If the application desires to leave a running session, it should call the `xrRequestExitSession` function to request that the runtime transition its session to the `XR_SESSION_STATE_STOPPING` state as soon as possible. Once the application reaches the `XR_SESSION_STATE_STOPPING` state, it can call `xrEndSession` to stop the XR session, after which the session will transition through `XR_SESSION_STATE_IDLE` to the `XR_SESSION_STATE_EXITING` state.

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.
9.1. Session Lifecycle

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. Unless specified differently in the graphics API extension, the application is responsible for creating a valid graphics device binding (for details refer to the extension specification of the graphics API).

The xrCreateSession function is defined as:

```
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.

**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
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 an extension-specific structure. 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`, `XrGraphicsBindingOpenGLWin32_KHR`, `XrGraphicsBindingOpenGLXcb_KHR`, `XrSessionCreateInfoOverlayEXTX`
- `createFlags` must be 0

The `XrSessionCreateInfoOverlayEXTX` include:

```c
// 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`

## 9.2. 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 \texttt{xrWaitFrame/xrBeginFrame/xrEndFrame} calls.

If the session is already running when the application calls \texttt{xrBeginSession}, the runtime must return error \texttt{XR_ERROR_SESSION_RUNNING}. If the session is not running when the application calls \texttt{xrBeginSession}, but the session is not yet in the \texttt{XR_SESSION_STATE_READY} state, the runtime must return error \texttt{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 \texttt{xrWaitFrame} returns an \texttt{XrFrameState} with \texttt{shouldRender} set to true before rendering a given frame to determine whether that frame will be visible to the user.

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

Valid Usage (Implicit)

- \texttt{session} must be a valid \texttt{XrSession} handle
- \texttt{beginInfo} must be a pointer to a valid \texttt{XrSessionBeginInfo} structure

Return Codes

**Success**

- \texttt{XR_SUCCESS}
- \texttt{XR_SESSION_LOSS_PENDING}

**Failure**

- \texttt{XR_ERROR_INSTANCE_LOST}
- \texttt{XR_ERROR_SESSION_LOST}
- \texttt{XR_ERROR_RUNTIME_FAILURE}
- \texttt{XR_ERROR_HANDLE_INVALID}
- \texttt{XR_ERROR_VALIDATION_FAILURE}
- \texttt{XR_ERROR_SESSION_NOT_READY}
- \texttt{XR_ERROR_SESSION_RUNNING}
- \texttt{XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED}

The \texttt{XrSessionBeginInfo} structure is defined as:
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 an extension-specific structure.
- **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. 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 session that is running but not in the XR_SESSION_STATE_STOPPING state, the application should call xrRequestExitSession. This requests that the runtime transition to the XR_SESSION_STATE_STOPPING state, so that the application can call xrEndSession, after which the session will transition through XR_SESSION_STATE_IDLE to the XR_SESSION_STATE_EXITING state and quit the XR experience seamlessly.

Valid Usage (Implicit)

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

Return Codes

Success

- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

Failure

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

The `xrRequestExitSession` function is defined as:

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

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

An application can only call `xrEndSession` when the session is in the `XR_SESSION_STATE_STOPPING` state, which allows runtimes to seamlessly transition from one application’s session to another. When an application wishes to exit a running session, the application can call `xrRequestExitSession`, requesting that the runtime transition the session to the `XR_SESSION_STATE_STOPPING` state. When the application receives an `XrEventDataSessionStateChanged` event indicating that the session has reached the `XR_SESSION_STATE_STOPPING` state, the application can then call `xrEndSession` to quit the XR experience seamlessly, transitioning the session through `XR_SESSION_STATE_IDLE` to the `XR_SESSION_STATE_EXITING` state.

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_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_SESSION_NOT_RUNNING`
- `XR_ERROR_VALIDATION_FAILURE`

9.3. 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.

### 9.3.1. 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 an extension-specific structure.
- **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:

```c
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_STATELOSS_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 xrWaitFrame, xrBeginFrame and xrEndFrame 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 xrBeginSession. After returning from the xrBeginSession 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 xrWaitFrame, xrBeginFrame and xrEndFrame, 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 `xrWaitFrame` 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 `xrEndSession` 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 the device.

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_SRGB, 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

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:

```c
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 0.
- **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 format 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.

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_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_SIZE_INSUFFICIENT
• XR_ERROR_VALIDATION_FAILURE

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;
Flag Descriptions

- **XR_SWAPCHAIN_USAGE_COLOR_ATTACHMENT_BIT** indicates that the image may be a color rendering target.
- **XR_SWAPCHAIN_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT** indicates that the image may be a depth/stencil rendering target.
- **XR_SWAPCHAIN_USAGE_UNORDERED_ACCESS_BIT** indicates that the image may be used as data source.
- **XR_SWAPCHAIN_USAGE_TRANSFER_SRC_BIT** indicates that the image may be the source of a copy operation.
- **XR_SWAPCHAIN_USAGE_TRANSFER_DST_BIT** indicates that the image may be the destination of a copy operation.
- **XR_SWAPCHAIN_USAGE_SAMPLED_BIT** indicates that the image may be sampled by a shader.
- **XR_SWAPCHAIN_USAGE_MUTABLE_FORMAT_BIT** indicates that the image format may be reinterpreted.

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 runtime. The **XrSwapchain** handle **must** be eventually freed 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_ERRORINSTANCE_LOST
- XR_ERRORSESSION_LOST
- XR_ERRORRUNTIME_FAILURE
- XR_ERRORLIMIT_REACHED
- XR_ERRORHANDLE INVALID
- XR_ERROROUTOF_MEMORY
- XR_ERRORSWAPCHAINFORMAT_UNSUPPORTED
- XR_ERRORFEATURE_UNSUPPORTED
- XR_ERRORVALIDATION_FAILURE

The XrSwapchainCreateInfo structure is defined as:
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 an extension-specific structure.
- **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: `XrSecondaryViewConfigurationSwapchainCreateInfoMSFT`
- **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:

```cpp
// 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:

```c
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:

```c
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 0.
- `images` is a pointer to an array of graphics API-specific `XrSwapchainImage` structures based off of `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.

### 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`, `XrSwapchainImageOpenGL_KHR`, `XrSwapchainImageVulkanKHR`
Return Codes

Success
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

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

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 an extension-specific structure.

The **XrSwapchainImageBaseHeader** is a base structure that can be overridden by a graphics API-specific **XrSwapchainImage** child structure.
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 \texttt{xrAcquireSwapchainImage} function is defined as:

\begin{verbatim}
XrResult xrAcquireSwapchainImage(
    XrSwapchain swapchain,
    const XrSwapchainImageAcquireInfo* acquireInfo,
    uint32_t* index);
\end{verbatim}

### Parameter Descriptions

- \texttt{swapchain} is the swapchain from which to acquire an image.
- \texttt{acquireInfo} exists for extensibility purposes, it is \texttt{NULL} or a pointer to a valid \texttt{XrSwapchainImageAcquireInfo}.
- \texttt{index} is a pointer to the image index that was acquired.

Acquires the image corresponding to the \texttt{index} position in the array returned by \texttt{xrEnumerateSwapchainImages}. The runtime must return \texttt{XR_ERROR_CALL_ORDER_INVALID} if \texttt{index} has already been acquired and not yet released with \texttt{xrReleaseSwapchainImage}. If the \texttt{swapchain} was created with the \texttt{XR_SWAPCHAIN_CREATE_STATIC_IMAGE_BIT} set in \texttt{XrSwapchainCreateInfo::createFlags}, this function must not have been previously called for this swapchain. The runtime must return \texttt{XR_ERROR_CALL_ORDER_INVALID} if a \texttt{swapchain} created with the \texttt{XR_SWAPCHAIN_CREATE_STATIC_IMAGE_BIT} set in \texttt{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_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_VALIDATION_FAILURE`
- `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 an extension-specific structure.

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, it **must** be released 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.

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_TIMEOUT_EXPIRED
- XR_SESSION_LOSS_PENDING

Failure
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_CALL_ORDER_INVALID

The XrSwapchainImageWaitInfo structure describes a swapchain image wait operation. It is defined as:

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 an extension-specific structure.
- **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 writing to a swapchain image, it is released. `xrReleaseSwapchainImage` will implicitly release the oldest swapchain image which has been acquired. The swapchain image **must** have been successfully waited on 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 `xrWaitSwapchainImage`.

### 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_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_CALL_ORDER_INVALID

The XrSwapchainImageReleaseInfo structure is defined as:

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 an extension-specific structure.

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 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
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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_VALIDATION_FAILURE
- 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
- **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 an extension-specific structure.
• 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:

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 an extension-specific structure.
• 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. **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. 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 `xrWaitFrame`.

The `xrWaitFrame` function is defined as:

```c
XrResult xrWaitFrame(
    XrSession session,
    const XrFrameWaitInfo* frameWaitInfo,
    XrFrameState* frameState);
```

**Parameter Descriptions**

- `session` is a valid `XrSession` handle.
- `frameWaitInfo` exists for extensibility purposes, it is `NULL` or a pointer to a valid `XrFrameWaitInfo`.
- `frameState` is a pointer to a valid `XrFrameState`, an output parameter.

`xrWaitFrame` throttles the application frame loop in order to synchronize application frame submissions with the display. `xrWaitFrame` returns a predicted display time for the next time that the runtime predicts a composited frame will be displayed. The runtime may affect this computation by changing the return values and throttling of `xrWaitFrame` in response to feedback from frame submission and completion times in `xrEndFrame`. An application must eventually match each `xrWaitFrame` call with one call to `xrBeginFrame`. A subsequent `xrWaitFrame` call must block until the previous frame has been begun with `xrBeginFrame` and must unblock independently of the corresponding call to `xrEndFrame`. When less than one frame interval has passed since the previous return from `xrWaitFrame`, the runtime should block until the beginning of the next frame interval. If more than one frame interval has passed since the last return from `xrWaitFrame`, the runtime 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 should compute the appropriate target display time using both the predicted display time and predicted display interval. The application should use the computed target display time when requesting space and view locations for rendering.

The `XrFrameState::predictedDisplayTime` returned by `xrWaitFrame` must be monotonically increasing.

The runtime 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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_SESSION_NOT_RUNNING
- XR_ERROR_VALIDATION_FAILURE

The XrFrameWaitInfo structure is defined as:

```c
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 an extension-specific structure.

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 an extension-specific structure.
- **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`.

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

Return Codes

**Success**
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING
- XR_FRAME_DISCARDED

**Failure**
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_CALL_ORDER_INVALID
- XR_ERROR_SESSION_NOT_RUNNING
- XR_ERROR_VALIDATION_FAILURE

The `XrFrameBeginInfo` structure is defined as:

```c
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 an extension-specific structure.

Because this structure only exists to support extension-specific structures, `xrBeginFrame` will accept a
**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 `xreEndFrame` function is defined as:

```c
XrResult xreEndFrame(
    XrSession session,
    const XrFrameEndInfo* frameEndInfo);
```

**Parameter Descriptions**

- `session` is a valid `XrSession` handle.
- `frameEndInfo` is a pointer to a valid `XrFrameEndInfo`.

`xreEndFrame` **may** return immediately to the application. `XrFrameEndInfo::displayTime` **should** be computed using values returned by `xreWaitFrame`. The runtime **should** be robust against variations in the timing of calls to `xreWaitFrame`, since a pipelined system may call `xreWaitFrame` on a separate thread from `xreBeginFrame` and `xreEndFrame` 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 `xreEndFrame` **must** be preceded by a successful call to `xreBeginFrame`. Failure to do so **must** result in `XR_ERROR_CALL_ORDER_INVALID` being returned by `xreEndFrame`. `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 `xreReleaseSwapchainImage`. 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.

---

### Valid Usage (Implicit)

- **session** must be a valid `XrSession` handle
- **frameEndInfo** must be a pointer to a valid `XrFrameEndInfo` structure
Return Codes

Success

• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure

• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_CALL_ORDER_INVALID
• XR_ERROR_LAYER_INVALID
• XR_ERROR_SWAPCHAIN_RECT_INVALID
• XR_ERROR_ENVIRONMENT_BLEND_MODE_UNSUPPORTED
• XR_ERROR_SESSION_NOT_RUNNING
• XR_ERROR_LAYER_LIMIT_EXCEEDED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_TIME_INVALID
• XR_ERROR_POSE_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 an extension-specific structure.
- **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, 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 optical chromatic aberration
correction for the layer when not done by default.
- **XR_COMPOSITION_LAYER_BLEND_TEXTURE_SOURCE_ALPHA_BIT** enables the layer's texture alpha
channel.
- **XR_COMPOSITION_LAYER_UNPREMULTIPLIED_ALPHA_BIT** indicates that the layer's color components
have not been premultiplied with the layer's alpha component.

### 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:

```c
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 an extension-specific structure.
- **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_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
- **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:

```c
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. Note that the composito**r 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

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:

```c
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 an extension-specific structure.
- **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
- **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:
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 an extension-specific structure.
- **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`
- **subImage** must be a valid `XrSwapchainSubImage` structure

**Quad Layer Composition**

The `XrCompositionLayerQuad` structure defined as:
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 an extension-specific structure.
- **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 composited 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_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 0.
- **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
Return Codes

Success
  • XR_SUCCESS

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

The possible blend modes are specified by the `XrEnvironmentBlendMode` enumeration:

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};
strcpy(actionSetInfo.actionSetName, "gameplay");
strcpy(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};
strcpy(actioninfo.actionName, "teleport");
actioninfo.actionType = XR_ACTION_TYPE_BOOLEAN_INPUT;
strcpy(actioninfo.localizedActionName, "Teleport");
XrAction teleportAction;
CHK_XR(xrCreateAction(inGameActionSet, &actioninfo, &teleportAction));

// create a "player_hit" output action
XrActionCreateInfo hapticsactioninfo{XR_TYPE_ACTION_CREATE_INFO};
strcpy(hapticsactioninfo.actionName, "player_hit");
hapticsactioninfo.actionType = XR_ACTION_TYPE_VIBRATION_OUTPUT;
strcpy(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:

```c
XrResult 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_INSTANCE_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_NAME_DUPLICATED
- XR_ERROR_LOCALIZED_NAME_DUPLICATED
- XR_ERROR_NAME_INVALID
- XR_ERROR_LOCALIZED_NAME_INVALID
- XR_ERROR_PATH_FORMAT_INVALID

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 an extension-specific structure.

• **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 session, 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.
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 action 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
Return Codes

Success
• XR_SUCCESS

Failure
• XR_ERROR_HANDLE_INVALID

11.3. Creating Actions

XR_DEFINE_HANDLE(XrAction)

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_INSTANCE_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_ACTIONSETS_ALREADY_ATTACHED`
- `XR_ERROR_LIMIT_REACHED`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_NAME_DUPLICATED`
- `XR_ERROR_LOCALIZED_NAME_DUPLICATED`
- `XR_ERROR_NAME_INVALID`
- `XR_ERROR_LOCALIZED_NAME_INVALID`
- `XR_ERROR_PATH_FORMAT_INVALID`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_HANDLE_INVALID`

The `XrActionCreateInfo` structure is defined as:
```c
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 an extension-specific structure.
- **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:
  - `/user/head`
- /user/hand/left
- /user/hand/right
- /user/gamepad
- /user

- No path appears in the list more than once

Including /user in the list of subaction paths creates an 'other' bucket for action data to be filtered into. When /user is included in the list passed to xrGetActionState* the runtime must include data for all devices which are not included in the other subaction paths into the /user bucket. Extensions may append additional top level user paths to the above list.

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.

### Valid Usage (Implicit)
- **action** **must** be a valid **XrAction** handle

### Thread Safety
- Access to **action**, and any child handles, **must** be externally synchronized

### Return Codes

#### Success
- **XR_SUCCESS**

#### Failure
- **XR_ERROR_HANDLE_INVALID**

### 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 threshold may vary from device to device or component to component and is 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/value` instead of `.../example/path` if it is available and apply the same thresholding that would be applied to any scalar input. If a parent path does not have a `.../value` subpath, the runtime must use `.../click`. 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 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:

```c
typedef struct XrEventDataInteractionProfileChanged {
    XrStructureType    type;
    const void*        next;
    XrSession          session;
} XrEventDataInteractionProfileChanged;
```
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 whitelist defined in Interaction Profile Paths, the runtime must return XR_ERROR_PATH_UNSUPPORTED. A runtime must accept every valid binding in the whitelist 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_INSTANCE_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_ACTIONSETS_ALREADY_ATTACHED
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_PATH_INVALID

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 an extension-specific structure.
- **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
- **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:

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 `xCreatAction` and `xrSuggestInteractionProfileBindings` for details.

The runtime must return `XR_ERROR_ACTIONSETS_ALREADY_ATTACHED` if `xrAttachSessionActionSets` is called more than once for a given `session`. The runtime must return `XR_ERROR_ACTIONSET_NOT_ATTACHED` for any action created after `xrAttachSessionActionSets` is called for a given `session` if that handle is used with any call for the same `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_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_ACTIONSETS_ALREADY_ATTACHED`

The `XrSessionActionSetsAttachInfo` structure is defined as:

```c
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 an extension-specific structure.
- `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`. 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_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_ACTIONSET_NOT_ATTACHED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_PATH_UNSUPPORTED`
- `XR_ERROR_PATH_INVALID`

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 an extension-specific structure.
- **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 running, the runtime **must** set the isActive value to XR_FALSE and suppress all haptic output.

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 an extension-specific structure.
- **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 an extension-specific structure.
- **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_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_ACTIONSET_NOT_ATTACHED`
- `XR_ERROR_ACTION_TYPE_MISMATCH`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_PATH_UNSUPPORTED`

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 an extension-specific structure.
- **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:

```c
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_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_ACTIONSET_NOT_ATTACHED`
- `XR_ERROR_ACTION_TYPE_MISMATCH`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_PATH_UNSUPPORTED`

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 an extension-specific structure.
- **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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_ACTIONSET_NOT_ATTACHED
- XR_ERROR_ACTION_TYPE_MISMATCH
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_PATH_INVALID
- XR_ERROR_PATH_UNSUPPORTED

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 an extension-specific structure.
• 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:

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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_Runtime_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_ACTIONSET_NOT_ATTACHED
- XR_ERROR_ACTION_TYPE_MISMATCH
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_PATH_INVALID
- XR_ERROR_PATH_UNSUPPORTED

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 an extension-specific structure.
- **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 active.

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 \texttt{xrApplyHapticFeedback} function is defined as:

```c
XrResult xrApplyHapticFeedback(
    XrSession                                   session,
    const XrHapticActionInfo*                   hapticActionInfo,
    const XrHapticBaseHeader*                   hapticFeedback);
```

\textbf{Parameter Descriptions}

- \texttt{session} is the \texttt{XrSession} to start outputting to.
- \texttt{hapticActionInfo} is a pointer to \texttt{XrHapticActionInfo} to provide action and subaction paths information.
- \texttt{hapticFeedback} is a pointer to a haptic event structure which starts with an \texttt{XrHapticBaseHeader}.

Triggers a haptic event through the specified action of type \texttt{XR_TYPE_HAPTIC_VIBRATION}. The runtime \textbf{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 \textbf{may} ignore this request for haptic feedback.

If another haptic event from this session is currently happening on the device bound to this action, the runtime \textbf{must} interrupt that other event and replace it with the new one.

\textbf{Valid Usage (Implicit)}

- \texttt{session} \textbf{must} be a valid \texttt{XrSession} handle
- \texttt{hapticActionInfo} \textbf{must} be a pointer to a valid \texttt{XrHapticActionInfo} structure
- \texttt{hapticFeedback} \textbf{must} be a pointer to a valid \texttt{XrHapticBaseHeader}-based structure. See also: \texttt{XrHapticVibration}
Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_ACTIONSET_NOT_ATTACHED
• XR_ERROR_ACTION_TYPE_MISMATCH
• XR_ERROR_PATH_INVALID
• XR_ERROR_PATH_UNSUPPORTED

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 an extension-specific structure.

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
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 an extension-specific structure.
- **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.

#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.

**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

**Failure**
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_ACTIONSET_NOT_ATTACHED
- XR_ERROR_ACTION_TYPE_MISMATCH
- XR_ERROR_PATH_INVALID
- XR_ERROR_PATH_UNSUPPORTED

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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_ACTIONSET_NOT_ATTACHED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_PATH_INVALID
- XR_ERROR_PATH_UNSUPPORTED

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 an extension-specific structure.
- **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 `xrSyncActions` function.
11.8. Action Sources

An application can use the `xrEnumerateBoundSourcesForAction` and `xrGetInputSourceLocalizedName` calls to prompt the user which physical inputs to use in order to perform an action. A source is the physical control that the action is bound to within the current interaction profile as returned by `xrGetCurrentInteractionProfile`. An action may be bound to multiple sources at one time, for example an action named `hold` could be bound to both the X and A buttons.

Once the semantic paths for the action's source are obtained, the application can gather additional information about the source. `xrGetInputSourceLocalizedName` returns a localized human-readable string describing the source, e.g. 'A Button'.

The `xrEnumerateBoundSourcesForAction` function is defined as:

```c
XrResult xrEnumerateBoundSourcesForAction(
    XrSession session,
    const XrBoundSourcesForActionEnumerateInfo* enumerateInfo,
    uint32_t sourceCapacityInput,
    uint32_t* sourceCountOutput,
    XrPath* sources);
```

### 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 0.
- **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`.

### 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_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_ACTIONSET_NOT_ATTACHED`
- `XR_ERROR_SIZE_INSUFFICIENT`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_PATH_INVALID`

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 an extension-specific structure.
- **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 0.
- **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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_PATH_INVALID
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_ACTIONSET_NOT_ATTACHED

The XrInputSourceLocalizedNameGetInfo structure is defined as:

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 an extension-specific structure.
- **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 Extensions

- XR_KHR_android_create_instance
- XR_KHR_android_surface_swapchain
- XR_KHR_android_thread_settings
- XR_KHR_composition_layer_cube
- XR_KHR_composition_layer_cylinder
- XR_KHR_composition_layer_depth
- XR_KHR_composition_layer_equirect
- XR_KHR_convert_timespec_time
- XR_KHR_D3D11_enable
- XR_KHR_D3D12_enable
- XR_KHR_opengl_enable
- XR_KHR_opengl_es_enable
- XR_KHR_visibility_mask
- XR_KHR_vulkan_enable
- XR_KHR_vulkan_swapchain_format_list
- XR_KHR_win32_convert_performance_counter_time
- XR_EXT_conformance_automation
- XR_EXT_debug_utils
- XR_EXT_eye_gaze_interaction
- XR_EXT_hand_tracking
- XR_EXT_performance_settings
- XR_EXT_thermal_query
- XR_EXT_view_configuration_depth_range
- XR_EXT_win32_appcontainer_compatible
- XR_EPIC_view_configuration_fov
- XR_HUAWEI_controller_interaction
- XR_MND_headless
- XR_MSFT_first_person_observer
- XR_MSFT_hand_interaction
- XR_MSFT_hand_tracking_mesh
• XR_MSFT_secondary_view_configuration
• XR_MSFT_spatial_anchor
• XR_MSFT_spatial_graph_bridge
• XR_MSFT_unbounded_reference_space
• XR_OCULUS_android_session_state_enable
• XR_VARJO_quad_views
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
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IP Status
No known IP claims.

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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 \texttt{XrInstanceCreateInfoAndroidKHR} structure is defined as:

\begin{verbatim}
typedef struct XrInstanceCreateInfoAndroidKHR {
    XrStructureType    type;
    const void*        next;
    void*              applicationVM;
    void*              applicationActivity;
} XrInstanceCreateInfoAndroidKHR;
\end{verbatim}

**Member Descriptions**

- \texttt{type} is the \texttt{XrStructureType} of this structure.
- \texttt{next} is \texttt{NULL} or a pointer to an extension-specific structure.
- \texttt{applicationVM} is a pointer to the JNI's opaque \texttt{JavaVM} structure, cast to a void pointer.
- \texttt{applicationActivity} is a JNI reference to an \texttt{android.app.Activity} that will drive the session lifecycle of this instance, cast to a void pointer.

\texttt{XrInstanceCreateInfoAndroidKHR} contains additional Android specific information needed when calling \texttt{xrCreateInstance}. The \texttt{applicationVM} field should be populated with the \texttt{JavaVM} structure received by the \texttt{JNI_OnLoad} function, while the \texttt{applicationActivity} field will typically contain a reference to a Java activity object received through an application-specific native method. The \texttt{XrInstanceCreateInfoAndroidKHR} structure must be provided in the \texttt{next} chain of the \texttt{XrInstanceCreateInfo} structure when calling \texttt{xrCreateInstance}.

**Valid Usage (Implicit)**

- The \texttt{XR_KHR_android_create_instance} extension must be enabled prior to using \texttt{XrInstanceCreateInfoAndroidKHR}
- \texttt{type} must be \texttt{XR_TYPE_INSTANCE_CREATE_INFO_ANDROID_KHR}
- \texttt{next} must be \texttt{NULL} or a valid pointer to the next structure in a structure chain
- \texttt{applicationVM} must be a pointer value
- \texttt{applicationActivity} must be a pointer value

New Functions
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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_LIMIT_REACHED
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_FUNCTION_UNSUPPORTED

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
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:

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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_ANDROID_THREAD_SETTINGS_ID_INVALID_KHR
- XR_ERROR_ANDROID_THREAD_SETTINGS_FAILURE_KHR
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_FUNCTION_UNSUPPORTED

### Version History
12.4. 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

Johannes van Waveren, Oculus
Cass Everitt, Oculus
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Sam Martin, ARM
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 an extension-specific structure.
- **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).
• Revision 8, 2019-01-24 (Martin Renschler)
  ◦ Updated struct to use XrSwapchainSubImage, reformat and spec language changes, eye parameter description update

12.5. 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.
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:

```c
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 3. 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 an extension-specific structure.
- **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, 2π). 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 x 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

12.6. 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 valid depth buffers along with images submitted in projection layers, i.e. `XrCompositionLayerProjection`.

The XR runtime may use this information to perform more accurate reprojections taking depth into account.

New Object Types

New Flag Types

New Enum Constants

`XrStructureType` enumeration is extended with:

- `XR_TYPE_COMPOSITION_LAYER_DEPTH_INFO_KHR`

New Enums

New Structures

When submitting depth buffers 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 an extension-specific structure.
- **subImage** identifies the depth image XrSwapchainSubImage to be associated with the color swapchain. The contained imageRect specifies the valid portion of the depth image to use, in pixels. It also implicitly defines the transform from normalized image coordinates into pixel coordinates. The contained imageArrayIndex is the depth image array index, with 0 meaning the first or only array element.
- **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 ≥ 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. Applications **must** not use the same value as nearZ.

XrCompositionLayerDepthInfoKHR contains the information needed to specify an extra layer with depth information. When submitting depth buffers along with projection layers, add the XrCompositionLayerDepthInfoKHR to the next chain for all XrCompositionLayerProjectionView structures in the given layer.
Valid Usage (Implicit)

- The `XR_KHR_composition_layer_depth` extension must be enabled prior to using `XrCompositionLayerDepthInfoKHR`
- `type` must be `XR_TYPE_COMPOSITION_LAYER_DEPTH_INFO_KHR`
- `next` must be `NULL` or a valid pointer to the next structure in a structure chain
- `subImage` must be a valid `XrSwapchainSubImage` structure

New Functions

Issues

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

12.7. `XR_KHR_composition_layer_equirect`

Name String

`XR_KHR_composition_layer_equirect`

Extension Type

Instance extension

Registered Extension Number

19
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 an extension-specific structure.
- **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.

12.8. XR_KHR_convert timespec_time

Name String

`XR_KHR_convert timespec_time`

Extension Type

Instance extension

Registered Extension Number

37

Revision

1
Overview

This extension provides two functions for converting between timespec monotonic time and \texttt{XrTime}. The \texttt{xrConvertTimespecTimeToTimeKHR} function converts from timespec time to \texttt{XrTime}, while the \texttt{xrConvertTimeToTimespecTimeKHR} function converts \texttt{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}
Parameter Descriptions

- **instance** is an `XrInstance` handle previously created with `xrCreateInstance`.
- **unixTime** is a `timespec` obtained from `clock_gettime` with `CLOCK_MONOTONIC`.
- **time** is the resulting `XrTime` that is equivalent to the `unixTime`.

The `xrConvertTimespecTimeToTimeKHR` function converts a time obtained by the `clock_gettime` function to the equivalent `XrTime`.

If the output `time` cannot represent the input `unixTime`, the runtime **must** return `XR_ERROR_TIME_INVALID`.

Valid Usage (Implicit)

- The `XR_KHR_convert_timespec_time` extension **must** be enabled prior to calling `xrConvertTimespecTimeToTimeKHR`
- **instance** **must** be a valid `XrInstance` handle
- **timespecTime** **must** be a pointer to a valid `timespec` value
- **time** **must** be a pointer to an `XrTime` value

Return Codes

**Success**

- `XR_SUCCESS`

**Failure**

- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_TIME_INVALID`
- `XR_ERROR_FUNCTION_UNSUPPORTED`

To convert from `XrTime` to timespec monotonic time, call:
XrResult xrConvertTimeToTimespecTimeKHR(
    XrInstance instance,
    XrTime time,
    struct timespec* timespecTime);

Parameter Descriptions

- **instance** is an XrInstance handle previously created with xrCreateInstance.
- **time** is an XrTime.
- **unixTime** 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 unixTime 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_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_TIME_INVALID
- XR_ERROR_FUNCTION_UNSUPPORTED
12.9. XR_KHR_D3D11_enable

Name String

XR_KHR_D3D11_enable

Extension Type

Instance extension

Registered Extension Number

28

Revision

4

Extension and Version Dependencies

• Requires OpenXR 1.0

Last Modified Date

2018-11-16

IP Status

No known IP claims.

Contributors

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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 XrGraphicsBindingD3D11KHR structure in order to create a D3D11-based 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 `xrEnumerateSwapchainImages`.

In order to expose the structures, types, and functions of this extension, you must define `XR_USE_GRAPHICS_API_D3D11` before including the OpenXR platform header `openxr_platform.h`, in all portions of your library or application that include it.

**New Object Types**

**New Flag Types**

**New Enum Constants**

`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 an extension-specific structure.
- `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 `next` chain of the `XrSessionCreateInfo`. 
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 an extension-specific structure.
- **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 an extension-specific structure.
- **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. `xrGetD3D11GraphicsRequirementsKHR` must be called prior to calling `xrCreateSession`, and the LUID and feature level that `xrGetD3D11GraphicsRequirementsKHR` returns should 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_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_SYSTEM_INVALID
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_FUNCTION_UNSUPPORTED

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

12.10. XR_KHR_D3D12_enable

Name String

XR_KHR_D3D12_enable

Extension Type

Instance extension

Registered Extension Number

29
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 graphics device and queue 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, 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 behaviour.

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 an extension-specific structure.
- **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 next chain of the `XrSessionCreateInfo`.

## 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 an extension-specific structure.
- **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 an extension-specific structure.
- **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. `xrGetD3D12GraphicsRequirementsKHR` must be called prior to calling `xrCreateSession`, and the LUID and feature level that `xrGetD3D12GraphicsRequirementsKHR` returns should 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_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_SYSTEM_INVALID`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_FUNCTION_UNSUPPORTED`

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.

12.11. XR_KHR_opengl_enable

Name String
XR_KHR_opengl_enable

Extension Type
Instance extension

Registered Extension Number
24

Revision
8

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2019-07-02

IP Status
No known IP claims.

Contributors
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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 XrGraphicsBindingOpenGLKHR 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.

**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 an extension-specific structure.
- **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 an extension-specific structure.
- **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 **XR_USE_PLATFORM_XLIB**.
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 an extension-specific structure.
- `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

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 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 an extension-specific structure.
- 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 \textbf{XR\_USE\_PLATFORM\_WAYLAND}.

\begin{center}
\textbf{Valid Usage (Implicit)}
\end{center}

- The \texttt{XR\_KHR\_opengl\_enable} extension \textbf{must} be enabled prior to using \texttt{XrGraphicsBindingOpenGLWaylandKHR}
- \texttt{type} \textbf{must} be \texttt{XR\_TYPE\_GRAPHICS\_BINDING\_OPENGL\_WAYLAND\_KHR}
- \texttt{next} \textbf{must} be \texttt{NULL} or a valid pointer to the \texttt{next} structure in a structure chain
- \texttt{display} \textbf{must} be a pointer to a \texttt{wl\_display} value

The \texttt{XrSwapchainImageOpenGLKHR} structure is defined as:

\begin{verbatim}
typedef struct XrSwapchainImageOpenGLKHR {
    XrStructureType    type;
    void*              next;
    uint32_t           image;
} XrSwapchainImageOpenGLKHR;
\end{verbatim}

\begin{center}
\textbf{Member Descriptions}
\end{center}

- \texttt{type} is the \texttt{XrStructureType} of this structure.
- \texttt{next} is \texttt{NULL} or a pointer to an extension-specific structure.
- \texttt{image} is the OpenGL texture handle associated with this swapchain image.

If a given session was created with a \texttt{XrGraphicsBindingOpenGLGL\_KHR}, the following conditions \textbf{must} apply.

- Calls to \texttt{xrEnumerateSwapchainImages} on an \texttt{XrSwapchain} in that session \textbf{must} return an array of \texttt{XrSwapchainImageOpenGLKHR} structures.
- Whenever an OpenXR function accepts an \texttt{XrSwapchainImageBaseHeader} pointer as a parameter in that session, the runtime \textbf{must} also accept a pointer to an \texttt{XrSwapchainImageOpenGLKHR}.

The OpenXR runtime \textbf{must} interpret the bottom-left corner of the swapchain image as the coordinate origin unless specified otherwise by extension functionality.

The OpenXR runtime \textbf{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:

```c
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 an extension-specific structure.
- `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. `xrGetOpenGLGraphicsRequirementsKHR` must be called prior to calling `xrCreateSession`.

**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_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_SYSTEM_INVALID
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_FUNCTION_UNSUPPORTED

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
• Revision 5, 2019-01-25 (Robert Menzel)
  ◦ Description updated
• Revision 6, 2019-07-02 (Robert Menzel)
  ◦ Minor fixes
• Revision 7, 2019-07-08 (Ryan Pavlk)
  ◦ Adjusted member name in XCB struct
• Revision 8, 2019-11-28 (Jakob Bornecrantz)
  ◦ Added note about context not allowed to be current in a different thread.
12.12. XR_KHR_opengl_es_enable

Name String
XR_KHR_opengl_es_enable

Extension Type
Instance extension

Registered Extension Number
25

Revision
6

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2019-07-12

IP Status
No known IP claims.

Contributors
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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`

New Object Types

New Flag Types

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 an extension-specific structure.
- **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 XR_USE_PLATFORM_ANDROID.

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_ES_ANDROID_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 an extension-specific structure.
- **image** is an index indicating the current OpenGL ES swapchain image to use.

If a given session was created with a XrGraphicsBindingOpenGLES*KHR, 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 an extension-specific structure.
- **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. `xrGetOpenGLESGraphicsRequirementsKHR` must be called prior to calling `xrCreateSession`.

**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_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_SYSTEM_INVALID`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_FUNCTION_UNSUPPORTED`

**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
12.13. **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**

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**Overview**

This extension support 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.

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 an extension-specific structure.

- **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 0.

- **vertices** is an array of vertices filled in by the runtime that specifies mask coordinates in the z=-1 plane of the view.

- **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 0.

- **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.

```c
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 an extension-specific structure.
- `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:

```
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_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_VIEW_CONFIGURATION_TYPE_UNSUPPORTED
- XR_ERROR_SIZE_INSUFFICIENT
- XR_ERROR_SESSION_LOST
- XR_ERROR_FUNCTION_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.
12.14. XR_KHR_vulkan_enable

Name String
XR_KHR_vulkan_enable

Extension Type
Instance extension

Registered Extension Number
26

Revision
6

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2019-01-25

IP Status
No known IP claims.

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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
**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 xrGetVulkanDeviceExtensionsKHR.

In order to satisfy the VkPhysicalDevice requirements, the application can query xrGetVulkanGraphicsDeviceKHR to identify the correct VkPhysicalDevice.

Populating an XrGraphicsBindingVulkanKHR with a VkInstance, VkDevice, or VkPhysicalDevice that does not meet the requirements outlined by this extension may result in undefined behaviour by the OpenXR runtime.

The API version, instance extension, device extension and physical device requirements only apply to the VkInstance, VkDevice, and VkPhysicalDevice objects which the application wishes to associate with an XrGraphicsBindingVulkanKHR.

**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 XrGraphicsBindingVulkanKHR must also be externally synchronized.

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.

**Swapchain Image Layout**

When an application acquires a swapchain image by calling xrAcquireSwapchainImage in a session create using XrGraphicsBindingVulkanKHR, the OpenXR runtime must guarantee that:
• The image has a memory layout compatible with `VK_IMAGE_LAYOUT_COLOR_ATTACHMENT_OPTIMAL`
• The `VkQueue` specified in `XrGraphicsBindingVulkanKHR` has ownership of the image.

When an application releases a swapchain image by calling `xrReleaseSwapchainImage`, in a session create using `XrGraphicsBindingVulkanKHR`, the OpenXR runtime **must** interpret the image as:

• Having a memory layout compatible with `VK_IMAGE_LAYOUT_COLOR_ATTACHMENT_OPTIMAL`,
• Being owned by the `VkQueue` specified in `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 behaviour.

**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 an extension-specific structure.
- **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 instance 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:
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 an extension-specific structure.
- **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
- **image** **must** be a valid VkImage value

The XrGraphicsRequirementsVulkanKHR structure is defined as:
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 an extension-specific structure.
- **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.

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:

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. `xrGetVulkanGraphicsRequirementsKHR` **must** be called prior to calling `xrCreateSession`.

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_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_SYSTEM_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_FUNCTION_UNSUPPORTED

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,                     instance,
    XrSystemId systemId,                    systemId,
    VkInstance vkInstance,                 vkInstance,
    VkPhysicalDevice* 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_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_SYSTEM_INVALID
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_FUNCTION_UNSUPPORTED

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 0.
• 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` null-terminated UTF-8 strings

Return Codes

Success

• `XR_SUCCESS`

Failure

• `XR_ERROR_INSTANCE_LOST`
• `XR_ERROR_RUNTIME_FAILURE`
• `XR_ERROR_HANDLE_INVALID`
• `XR_ERROR_SYSTEM_INVALID`
• `XR_ERROR_VALIDATION_FAILURE`
• `XR_ERROR_SIZE_INSUFFICIENT`
• `XR_ERROR_FUNCTION_UNSUPPORTED`

```
xrResult xrGetVulkanDeviceExtensionsKHR(
    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 0.
- `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` null-terminated UTF-8 strings

Return Codes

Success

- `XR_SUCCESS`

Failure

- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_SYSTEM_INVALID`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_SIZE_INSUFFICIENT`
- `XR_ERROR_FUNCTION_UNSUPPORTED`
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

12.15. XR_KHR_vulkan_swapchain_format_list

Name String
  XR_KHR_vulkan_swapchain_format_list

Extension Type
  Instance extension

Registered Extension Number
  15

Revision
  2

Extension and Version Dependencies
  • Requires OpenXR 1.0
  • Requires XR_KHR_vulkan_enable
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_USAGE_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` extension and add `VK_KHR_image_format_list` to the list returned by `xrGetVulkanDeviceExtensionsKHR`, as the runtime will need to use that Vulkan extension.

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
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 an extension-specific structure.
- **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`.

12.16.

**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 XrTime. The xrConvertWin32PerformanceCounterToTimeKHR function converts from Windows performance counter time stamps to XrTime, while the xrConvertTimeToWin32PerformanceCounterKHR function converts 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.

New Object Types

New Flag Types

New Enum Constants

New Enums

New Structures

New Functions

To convert from a Windows performance counter time stamp to XrTime, call:
XrResult xrConvertWin32PerformanceCounterToTimeKHR(
    XrInstance instance,
    const LARGE_INTEGER* performanceCounter,
    XrTime* time);

Parameter Descriptions

- **instance** is an *XrInstance* handle previously created with *xrCreateInstance*.
- **performanceCounter** is a time returned by *QueryPerformanceCounter*.
- **time** is the resulting *XrTime* that is equivalent to the *performanceCounter*.

The `xrConvertWin32PerformanceCounterToTimeKHR` function converts a time stamp obtained by the *QueryPerformanceCounter* Windows function to the equivalent *XrTime*.

If the output **time** cannot represent the input **performanceCounter**, 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 `xrConvertWin32PerformanceCounterToTimeKHR`
- **instance** must be a valid *XrInstance* handle
- **performanceCounter** must be a pointer to a valid *LARGE_INTEGER* value
- **time** must be a pointer to an *XrTime* value
Return Codes

Success

• XR_SUCCESS

Failure

• XR_ERROR_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_TIME_INVALID
• XR_ERROR_FUNCTION_UNSUPPORTED

To convert from XrTime to a Windows performance counter time stamp, call:

```c
XrResult xrConvertTimeToWin32PerformanceCounterKHR(
    XrInstance instance,
    XrTime time,
    LARGE_INTEGER* performanceCounter);
```

Parameter Descriptions

• instance is an XrInstance handle previously created with xrCreateInstance.
• time is an XrTime.
• performanceCounter is the resulting Windows performance counter time stamp that is equivalent to the 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_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_TIME_INVALID`
- `XR_ERROR_FUNCTION_UNSUPPORTED`

Issues

Version History

- Revision 1, 2019-01-24 (Paul Pedriana)
  - Initial draft

12.17. XR_EXT_conformance_automation

Name String

XR_EXT_conformance_automation

Extension Type

- Instance extension

Registered Extension Number

48
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.

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.

New Object Types

New Flag Types

New Enum Constants

New Enums
New Structures

New Functions

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

Failure

• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_SESSION_LOST
• XR_SESSION_LOSS_PENDING
• XR_ERROR_PATH_INVALID
• XR_ERROR_PATH_UNSUPPORTED

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).
• 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.
• 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`

Failure
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_SESSION_LOST`
- `XR_SESSION_LOSS_PENDING`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_PATH_UNSUPPORTED`

```c
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`).
- `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.
- `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`

Failure

- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_SESSION_LOST`
- `XR_SESSION_LOSS_PENDING`
- `XR_ERROR_PATH_INVALID`
- `XR_ERROR_PATH_UNSUPPORTED`

```c
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).
- **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.
- **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

**Failure**

- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_SESSION_LOST
- XR_SESSION_LOSS_PENDING
- XR_ERROR_PATH_INVALID
- XR_ERROR_PATH_UNSUPPORTED
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).
- **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.
- **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

**Failure**
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_SESSION_LOST
- XR_SESSION_LOSS_PENDING
- XR_ERROR_PATH_INVALID
- XR_ERROR_PATH_UNSUPPORTED
- XR_ERROR_POSE_INVALID

New Function Pointers

**Issues**

None

**Version History**

- Revision 1, 2019-10-01 (Lachlan Ford)
  - Initial draft

### 12.18. XR_EXT_debug_utils

**Name String**

XR_EXT_debug_utils

**Extension Type**

Instance extension

**Registered Extension Number**

20

**Revision**

3
Extension and Version Dependencies

- Requires OpenXR 1.0

Last Modified Date

2018-11-16

IP Status

No known IP claims.

Contributors

Mark Young, LunarG
Karl Schultz, LunarG

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.

12.18.1. 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.
12.18.2. 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.

12.18.3. 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 <strong>may</strong> 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>XR_DEBUG_UTILS_MESSAGE_SEVERITY_WARNING_BIT_EXT</td>
<td>Specifies use of OpenXR that could be an application bug. Such cases may not be immediately harmful, such as providing too many swapchain images. Other cases may 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 may 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.

### 12.18.4. 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_DECLARE_HANDLE(XrDebugUtilsMessengerEXT)
```

`XrDebugUtilsMessengerEXT` represents a callback function and associated filters registered with the runtime.

#### New Flag Types

```c
typedef XrFlags64 XrDebugUtilsMessageSeverityFlagsEXT;
```
// 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 an extension-specific structure.
- **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 an extension-specific structure.
- **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 an extension-specific structure.
- **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.
**Note**
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 an extension-specific structure.
- **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_OUT_OF_MEMORY
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_FUNCTION_UNSUPPORTED

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_OUT_OF_MEMORY`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_LIMIT_REACHED`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_FUNCTION_UNSUPPORTED`

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_HANDLE_INVALID`
- `XR_ERROR_FUNCTION_UNSUPPORTED`

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_HANDLE_INVALID
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_FUNCTION_UNSUPPORTED

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_SESSION_LOST
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_FUNCTION_UNSUPPORTED

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_SESSION_LOST
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_FUNCTION_UNSUPPORTED

This function ends the last label region begun with the \texttt{xrSessionBeginDebugUtilsLabelRegionEXT} function within the same \texttt{session}.

\begin{verbatim}
XrResult xrSessionInsertDebugUtilsLabelEXT(
    XrSession                                   session,
    const XrDebugUtilsLabelEXT*                 labelInfo);
\end{verbatim}

Parameter Descriptions

• \texttt{session} is the \texttt{XrSession} that a label region should be associated with.

• \texttt{labelInfo} is the \texttt{XrDebugUtilsLabelEXT} containing the label information for the region that should be begun.

Valid Usage (Implicit)

• The \texttt{XR_EXT_debug_utils} extension must be enabled prior to calling \texttt{xrSessionInsertDebugUtilsLabelEXT}

• \texttt{session} must be a valid \texttt{XrSession} handle

• \texttt{labelInfo} must be a pointer to a valid \texttt{XrDebugUtilsLabelEXT} structure
### Return Codes

**Success**
- XR_SUCCESS
- XR_SESSION_LOSS_PENDING

**Failure**
- XR_ERROR_SESSION_LOST
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_FUNCTION_UNSUPPORTED

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

```c
typedef XrBool32 (XRAPI_PTR *PFN_xrDebugUtilsMessengerCallbackEXT)(
    XrDebugUtilsMessageSeverityFlagsEXT              messageSeverity,
    XrDebugUtilsMessageTypeFlagsEXT                  messageTypes,
    const XrDebugUtilsMessengerCallbackDataEXT*      callbackData,
    void*                                            userData);
```
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 `XR_Bool32` 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,
    XR_DEBUG_UTILS_MESSAGE_TYPE_GENERAL_BIT_EXT |    // messageTypes
    XR_DEBUG_UTILS_MESSAGE_TYPE_VALIDATION_BIT_EXT,
    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,
    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
depend 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 its 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
depend 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
  };

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"
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

### 12.19. XR_EXT_eye_gaze_interaction

**Name String**

`XR_EXT_eye_gaze_interaction`

**Extension Type**

Instance extension

**Registered Extension Number**

31

**Revision**

1

**Extension and Version Dependencies**

- Requires OpenXR 1.0

**Last Modified Date**

2020-02-20
Overview

This extension provides a 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.
- a 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.

12.19.1. 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.

12.19.2. 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.

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 an extension-specific structure.
• 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
• type must be XR_TYPE_SYSTEM_EYE_GAZE_INTERACTION_PROPERTIES_EXT
• next must be NULL or a valid pointer to the next structure in a structure chain

12.19.3. Eye gaze input

This extension exposes a new interaction profile path /interaction_profiles/ext/eye_gaze_interaction that
is valid for the user path
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. If an XrEyeGazeSampleTimeEXT structure is passed into the xrLocateSpace call, and while neither space or baseSpace are bound to an action with toplevel path /user/eyes_ext/ the runtime must return XR_ERROR_VALIDATION_FAILURE.

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 behaviour 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.
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 an extension-specific structure.
- **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

### 12.19.4. 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");
actionInfo.actionType = XR_ACTION_TYPE_POSE_INPUT;
strcpy(actionInfo.localizedActionName, "User Intent");
XrAction userIntentAction;
```
ANCHXR(xrCreateAction(gameplayActionSet, &actionInfo, &userIntentAction));

// Create suggested bindings
XrPath eyeGazeInteractionProfilePath;
ANCHXR(xrStringToPath(instance, "/interaction_profiles/ext/eye_gaze_interaction",
&eyeGazeInteractionProfilePath));

XrPath gazePosePath;
ANCHXR(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;
ANCHXR(xrSuggestInteractionProfileBindings(instance, &suggestedBindings));

XrSessionActionSetsAttachInfo attachInfo{XR_TYPE_SESSION_ACTION_SETS_ATTACH_INFO};
attachInfo.countActionSets = 1;
attachInfo.actionSets = &gameplayActionSet;
ANCHXR(xrAttachSessionActionSets(session, &attachInfo));

XrActionSpaceCreateInfo createActionSpaceInfo{XR_TYPE_ACTION_SPACE_CREATE_INFO};
createActionSpaceInfo.action = userIntentAction;
createActionSpaceInfo.poseInActionSpace = pose_identity;
XrSpace gazeActionSpace;
ANCHXR(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;
ANCHXR(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;
ANCHXR(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

12.20. XR_EXT_hand_tracking

Name String
XR_EXT_hand_tracking

Extension Type
Instance extension

Registered Extension Number
52

Revision
2

Extension and Version Dependencies
• Requires OpenXR 1.0

Last Modified Date
2020-05-16

IP Status
No known IP claims.

Contributors
Yin Li, Microsoft
Lachlan Ford, Microsoft
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.

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.

```c
typedef struct XrSystemHandTrackingPropertiesEXT {
    XrStructureType    type;
    void*              next;
    XrBool32           supportsHandTracking;
} XrSystemHandTrackingPropertiesEXT;
```

Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to an extension-specific structure.
- **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.

Create a hand tracker handle

The XrHandTrackerEXT handle represents the resources for hand tracking of the specific hand.

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 accurate fidelity to the user’s actual hand shape. 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 holding the controller. This input can be used to render the hand shape together with rendering the controller in the hand.

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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_FUNCTION_UNSUPPORTED
- 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 a XrHandTrackerEXT handle.

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 an extension-specific structure.
- 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.
- `hand` must be a valid `XrHandEXT` value.
- `handJointSet` must be a valid `XrHandJointSetEXT` value.

The `XrHandEXT` describes which hand the `XrHandTrackerEXT` is tracking.

```c
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`.

```c
typedef enum XrHandJointSetEXT {
    XR_HAND_JOINT_SET_DEFAULT_EXT = 0,
    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_HANDLE_INVALID**
- **XR_ERROR_FUNCTION_UNSUPPORTED**
Locate hand joints

The \texttt{xrLocateHandJointsEXT} function locates an array of hand joints to a base space at given time.

\begin{verbatim}
XrResult xrLocateHandJointsEXT(
    XrHandTrackerEXT                        handTracker,
    const XrHandJointsLocateInfoEXT*       locateInfo,
    XrHandJointLocationsEXT*               locations);
\end{verbatim}

**Parameter Descriptions**

- \texttt{handTracker} is an \texttt{XrHandTrackerEXT} previously created by \texttt{xrCreateHandTrackerEXT}.
- \texttt{locateInfo} is a pointer to \texttt{XrHandJointsLocateInfoEXT} describing information to locate hand joints.
- \texttt{locations} is a pointer to \texttt{XrHandJointLocationsEXT} receiving the returned hand joint locations.

**Valid Usage (Implicit)**

- The \texttt{XR_EXT_hand_tracking} extension \textbf{must} be enabled prior to calling \texttt{xrLocateHandJointsEXT}
- \texttt{handTracker} \textbf{must} be a valid \texttt{XrHandTrackerEXT} handle
- \texttt{locateInfo} \textbf{must} be a pointer to a valid \texttt{XrHandJointsLocateInfoEXT} structure
- \texttt{locations} \textbf{must} be a pointer to an \texttt{XrHandJointLocationsEXT} structure
Return Codes

Success
• XR_SUCCESS
• XR_SESSION_LOSS_PENDING

Failure
• XR_ERROR_INSTANCE_LOST
• XR_ERROR_SESSION_LOST
• XR_ERROR_RUNTIME_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_TIME_INVALID
• XR_ERROR_FUNCTION_UNSUPPORTED

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 an extension-specific structure.
• **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
- 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 an extension-specific structure.
- isActive is a 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 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
• 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 a valid combination of `XrSpaceLocationFlagBits` values
- `locationFlags` must not be `0`

The application can chain an `XrHandJointVelocitiesEXT` structure to the `next` pointer of `XrHandJointLocationsEXT` when calling `xrLocateHandJointsEXT` to retrieve the hand joint velocities.

```c
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 an extension-specific structure.
- `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.

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

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;
}
```
// 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(xrCreateHandTrackerEXT(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_LOCATIONS_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;

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(xrLocateHandJointsEXT(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 =
            ...
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. 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 \( \ldots/input/grip/pose \) 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.

```
#define XR_HAND_JOINT_COUNT_EXT 26
```

**XR_HAND_JOINT_COUNT_EXT** defines the number of hand joint enumerants defined in XrHandJointEXT

**New Object Types**

- XrHandTrackerEXT

**New Flag Types**

**New Enum Constants**

- \( XR_HAND_JOINT_COUNT_EXT \)

**XrObjectType** enumeration is extended with:

- \( XR_OBJECT_TYPE_HAND_TRACKER_EXT \)

**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 2, 2020-04-20 (Yin LI)
  ◦ Replace hand joint spaces to locate hand joints function.
• Revision 1, 2019-09-16 (Yin LI)
  ◦ Initial extension description

12.21. XR_EXT_performance_settings

Name String

XR_EXT_performance_settings

Extension Type

Instance extension

Registered Extension Number

16

Revision

1
12.21.1. 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

12.21.2. 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):

```
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;
```
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**.

```c
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 XrSession session; ①
// before entering the high complexity section
xrPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_CPU_EXT, XR_PERF_SETTINGS_LEVEL_BOOST_EXT); ②
xrPerfSettingsSetPerformanceLevelEXT(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

xrPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_CPU_EXT, XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT); ③
xrPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_GPU_EXT, XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT);
```

① we assume that session is initialized and its handle is 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
extern XrSession session; ①
// before entering a low CPU complexity section
xrPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_CPU_EXT,
XR_PERF_SETTINGS_LEVEL_SUSTAINED_LOW_EXT);
xrPerfSettingsSetPerformanceLevelEXT(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

xrPerfSettingsSetPerformanceLevelEXT(session, XR_PERF_SETTINGS_DOMAIN_CPU_EXT,
XR_PERF_SETTINGS_LEVEL_SUSTAINED_HIGH_EXT); ③

① we assume that session is initialized and its handle is 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

12.21.3. 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.
typedef struct XrEventDataPerfSettingsEXT {
    XrStructureType                       type;
    const void*                           next;
    XrPerfSettingsDomainEXT               domain;
    XrPerfSettingsSubDomainEXT            subDomain;
    XrPerfSettingsNotificationLevelEXT    fromLevel;
    XrPerfSettingsNotificationLevelEXT    toLevel;
} XrEventDataPerfSettingsEXT;

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;

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_SESSION_LOST`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_FUNCTION_UNSUPPORTED`

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 an extension-specific structure.
• 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)

12.22. XR_EXT_thermal_query

Name String

XR_EXT_thermal_query

Extension Type

Instance extension

Registered Extension Number

17

Revision

1
12.22.1. Overview

This extension provides an API to query a domain’s current thermal warning level and current thermal trend.

12.22.2. 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);
```

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;

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_SESSION_LOST
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_FUNCTION_UNSUPPORTED

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
12.23. 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

Blake Taylor, Magic Leap
Gilles Cadet, Magic Leap
Michael Liebenow, Magic Leap
Supreet Suresh, Magic Leap
Alex Turner, Microsoft
Bryce Hutchings, Microsoft
Yin Li, Microsoft

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 \((0..+\infty]\) 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 `XrViewConfigurationView`, this extension provides additional view configuration information, as defined by `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**

`XrStructureType` enumeration is extended with:

- `XR_TYPE_VIEW_CONFIGURATION_DEPTH_RANGE_EXT`

**New Enums**

**New Structures**

The `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 an extension-specific structure.
- **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 to achieve the best user experience.
- **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.

12.24. XR_EXT_win32_appcontainer_compatible

Name String

```
XR_EXT_win32_appcontainer_compatible
```

Extension Type

Instance extension
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](https://docs.microsoft.com/en-us/windows/win32/secauthz/appcontainer-isolation). 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 ([https://docs.microsoft.com/en-us/windows/win32/secauthz/implementing-an-appcontainer](https://docs.microsoft.com/en-us/windows/win32/secauthz/implementing-an-appcontainer)).

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.

New Object Types

New Flag Types
New Enum Constants

New Enums

New Structures

New Functions

Issues

Version History

- Revision 1, 2019-12-16 (Yin Li)
  - Initial proposal.

12.25. XR_EPIC_view_configuration_fov

Name String

XR_EPIC_view_configuration_fov

Extension Type

Instance extension

Registered Extension Number

60

Revision

1

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 \texttt{xr LocateViews} to retrieve the field-of-view for rendering.

For views with \texttt{fovMutable} set to \texttt{XR_TRUE} the maximum field-of-view should specify the upper limit that runtime can support. If the view has \texttt{fovMutable} set to \texttt{XR_FALSE} the runtime must set \texttt{maxMutableFov} to be the same as \texttt{recommendedFov}.

**New Object Types**

**New Flag Types**

**New Enum Constants**

**New Enums**

**New Structures**

The \texttt{XrViewConfigurationViewFovEPIC} struct is an output struct which can be added to the next chain of \texttt{XrViewConfigurationView} to retrieve the field-of-view for that view.

```c
typedef struct XrViewConfigurationViewFovEPIC {
    XrStructureType    type;
    const void*        next;
    XrFovf             recommendedMutableFov;
    XrFovf             maxMutableFov;
} XrViewConfigurationViewFovEPIC;
```

**Member Descriptions**

- \texttt{type} is the type of this struct
- \texttt{next} is \texttt{NULL} or a pointer to an extension-specific structure.
- \texttt{recommendedFov} is the recommended field-of-view based on the current user IPD.
- \texttt{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 1, 2020-03-05 (Jules Blok)
  - Initial version.

12.26. 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
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`
- `.../output/haptic`

**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

12.27. 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.
12.28. 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

Last Modified Date
2020-05-02

IP Status
No known IP claims.

Contributors
Yin Li, Microsoft
Zonglin Wu, Microsoft
Alex Turner, Microsoft

12.28.1. 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

12.29. 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
Lachlan Ford, Microsoft
Alex Turner, Microsoft

**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**

**Issues**

**Version History**

• Revision 1, 2019-09-16 (Yin Li)
  ◦ Initial extension description

### 12.30. XR_MSFT_hand_tracking_mesh

**Name String**

XR_MSFT_hand_tracking_mesh

**Extension Type**

Instance extension

**Registered Extension Number**

53

**Revision**

2

**Extension and Version Dependencies**

• Requires OpenXR 1.0
  • Requires XR_EXT_hand_tracking
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 a XrSystemHandTrackingMeshPropertiesMSFT structure to the XrSystemProperties when calling xrGetSystemProperties.

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 an extension-specific structure.
- **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 pre-allocate 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

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.

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.
XrResult xrCreateHandMeshSpaceMSFT(XrHandTrackerEXT handTracker, const XrHandMeshSpaceCreateInfoMSFT* createInfo, XrSpace* space);

**Parameter Descriptions**

- **handTracker** is an XrHandTrackerEXT handle previously created with the xrCreateHandTrackerEXT function.
- **createInfo** is the XrHandMeshSpaceCreateInfoMSFT used to specify the hand mesh 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_INSTANCE_LOST`
- `XR_ERROR_SESSION_LOST`
- `XR_ERROR_RUNTIME_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_POSE_INVALID`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `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 an extension-specific structure.
- **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

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 a 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 pre-allocate the index buffer and vertex buffer in XrHandMeshMSFT using the maxHandMeshIndexCount and maxHandMeshVertexCount from the XrSystemHandTrackingMeshPropertiesMSFT returned from the xrGetSystemProperties function.

The application should pre-allocate 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_INSTANCE_LOST
- XR_ERROR_SESSION_LOST
- XR_ERROR_RUNTIME_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_TIME_INVALID
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_SIZE_INSUFFICIENT
- 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 an extension-specific structure.
- **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 XrHandMeshMSFT might return data that's not exactly corresponding to the time input. If the runtime cannot return any tracking data for the given time at all, it must set isActive to XR_FALSE for the call to xrUpdateHandMeshMSFT. Otherwise, if the runtime returns isActive as XR_TRUE, the data in XrHandMeshMSFT must be valid to use.

An application can choose different handPoseType values to query the hand mesh data. The returned hand mesh must be consistent to the hand joint space location on the same XrHandTrackerEXT when using the same XrHandPoseTypeMSFT.

**Valid Usage (Implicit)**

- The XR_MSFT_hand_tracking_mesh extension must be enabled prior to using XrHandMeshUpdateInfoMSFT
- **type** must be XR_TYPE_HAND_MESH_UPDATE_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

A XrHandMeshMSFT structure contains data and buffers to receive updates of hand mesh tracking data from xrUpdateHandMeshMSFT function.
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 an extension-specific structure.
- **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 counter-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 pre-allocate 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.

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** pre-allocate 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 \texttt{XrHandMeshVertexBufferMSFT} structure for each frame in frame loop and use the returned \texttt{vertexUpdateTime} to detect the changes of the content in \texttt{vertices}. The application can therefore avoid unnecessary processing of vertices, such as coping them to GPU memory.

### Valid Usage (Implicit)

- The \texttt{XR_MSFT_hand_tracking_mesh} extension must be enabled prior to using \texttt{XrHandMeshVertexBufferMSFT}
- \texttt{vertices} must be a pointer to an array of \texttt{vertexCapacityInput} \texttt{XrHandMeshVertexMSFT} structures
- The \texttt{vertexCapacityInput} parameter must be greater than 0

Each \texttt{XrHandMeshVertexMSFT} includes the position and normal of a vertex of a hand mesh.

```c
typedef struct XrHandMeshVertexMSFT {
    XrVector3f    position;
    XrVector3f    normal;
} XrHandMeshVertexMSFT;
```

### Member Descriptions

- \texttt{position} is an \texttt{XrVector3f} structure representing the position of the vertex in the hand mesh space, measured in meters.
- \texttt{normal} is an \texttt{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 \texttt{XR_MSFT_hand_tracking_mesh} extension must be enabled prior to using \texttt{XrHandMeshVertexBufferMSFT}

### Example code for hand mesh tracking

Following example code demos pre-allocating hand mesh buffers and updating the hand mesh in rendering loop
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;
}

// 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(xrCreateHandTrackerEXT(session, &createInfo, &leftHandTracker));
}

// 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(xrCreateHandMeshSpaceMSFT(leftHandTracker, &createInfo, &leftHandMeshSpace));
}

// Pre-allocate 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();
leftHandMesh.vertexBuffer.vertices = handMeshVertices.data();

while(1){
    // ...
    // For every frame in frame loop
    // ...
    XrFrameState frameState; // previously returned from xrWaitFrame
const XrTime time = frameState.predictedDisplayTime;

XrHandMeshUpdateInfoMSFT updateInfo{XR_TYPE_HAND_MESH_UPDATE_INFO_MSFT};
updateInfo.time = time;
CHK_XR(xrUpdateHandMeshMSFT(leftHandTracker, &updateInfo, &leftHandMesh));
if (!leftHandMesh.isActive) {
    // Hand input is not focused or user's hand is out of tracking range.
    // Do not process or render hand mesh.
} else {
    if (leftHandMesh.indexBufferChanged) {
        // Process indices in indexBuffer.indices
    }

    if (leftHandMesh.vertexBufferChanged) {
        // Process vertices in vertexBuffer.vertices and leftHandMeshSpace
    }
}

Get hand reference poses

By default, a 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.

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 an extension-specific structure.
- **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.

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.

*Example code for reference hand mesh update*

The following example code demonstrates detecting reference hand mesh changes and retrieving data for processing.

```c
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 pre-allocated buffers

while(1){
    // ...  
    // For every frame in frame loop
    // ...
    XrFrameState frameState;    // previously returned from xrWaitFrame  
    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(xrUpdateHandMeshMSFT(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(xrCreateHandTrackerEXT(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(xrLocateHandJointsEXT(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 2, 2020-04-20 (Yin LI)
  ◦ Change joint spaces to locate joints function.
• Revision 1, 2019-09-20 (Yin LI)
  ◦ Initial extension description

12.31. XR_MSFT_secondary_view_configuration

Name String

XR_MSFT_secondary_view_configuration

Extension Type

Instance extension

Registered Extension Number

54

Revision

1

Extension and Version Dependencies

• Requires OpenXR 1.0

Last Modified Date

2020-05-02

IP Status

No known IP claims.
12.31.1. 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 `XrSecondaryViewConfigurationSessionBeginInfoMSFT` chained extension structure.
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.

12.31.2. Enumerate supported secondary view configurations

The first step is for the application to inspect if a runtime supports certain secondary view configurations.
configurations. The app uses the existing API \texttt{xrEnumerateViewConfigurations} for this.

For example, when the \texttt{XR_MSFT_first_person_observer} extension is enabled, the application will enumerate a view configuration of type \texttt{XR_VIEW_CONFIGURATION_TYPE_SECONDARY_MONO_FIRST_PERSON_OBSERVER_MSFT}, and can use this secondary view configuration type in later functions.

### 12.31.3. Secondary view configuration properties

The application can inspect the properties of a secondary view configuration through the existing \texttt{xrGetViewConfigurationProperties}, \texttt{xrEnumerateViewConfigurationViews} and \texttt{xrEnumerateEnvironmentBlendModes} functions using a supported secondary view configuration type.

The runtime \textbf{may} change the recommended properties, such as recommended image width or height, when the secondary view configuration becomes active. The application \textbf{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 \textbf{can} chain a \texttt{XrSecondaryViewConfigurationSwapchainCreateInfoMSFT} structure to \texttt{XrSwapchainCreateInfo} when calling \texttt{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.

```c
typedef struct XrSecondaryViewConfigurationSwapchainCreateInfoMSFT {
    XrStructureType            type;
    const void*                next;
    XrViewConfigurationType    viewConfigurationType;
} XrSecondaryViewConfigurationSwapchainCreateInfoMSFT;
```

#### Member Descriptions

- \texttt{type} is the \texttt{XrStructureType} of this structure.
- \texttt{next} is \texttt{NULL} or a pointer to an extension-specific structure.
- \texttt{viewConfigurationType} is the secondary view configuration type the application is intending to use this swapchain for.

If this structure is not present in the \texttt{XrSwapchainCreateInfo} next chain when calling \texttt{xrCreateSwapchain}, the runtime \textbf{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

### 12.31.4. Enable secondary view configuration

The application indicates to the runtime which secondary view configurations it can support by enabling them during the call to `xrBeginSession` by attaching the extension structure `XrSecondaryViewConfigurationSessionBeginInfoMSFT` to the `XrSessionBeginInfo::next` pointer.

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 an extension-specific structure.
- `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

### 12.31.5. 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 an extension-specific structure.
- **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 XrSecondaryViewConfigurationSessionBeginInfoMSFT when calling xrBeginSession earlier, otherwise the runtime **must** return error XR_ERROR_VALIDATION_FAILURE.

Valid Usage (Implicit)

- The XR_MSFT_secondary_view_configuration extension **must** be enabled prior to using XrSecondaryViewConfigurationFrameStateMSFT
- **type** **must** be XR_TYPE_SECONDARY_VIEW_CONFIGURATION_FRAME_STATE_MSFT
- **next** **must** be NULL or a valid pointer to the next structure in a structure chain
- **viewConfigurationStates** **must** be a pointer to an array of **viewConfigurationCount** XrSecondaryViewConfigurationStateMSFT structures
- The **viewConfigurationCount** parameter **must** be greater than 0

The XrSecondaryViewConfigurationStateMSFT structure returns the state of an enabled secondary view configurations.

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 an extension-specific structure.
- **viewConfigurationType** is a 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 `xrLocateViews` and then submitting composition layers to `xrEndFrame` through the XrSecondaryViewConfigurationFrameEndInfoMSFT extension structure. When a secondary view configuration changes from inactive to active, the runtime **may** change 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
12.31.6. 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.

12.31.7. 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 an extension-specific structure.
- `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.
The view configuration type in each \textit{XrSecondaryViewConfigurationLayerInfoMSFT} must not be the primary view configuration in this session, or else the runtime \textbf{must} return error \textbf{XR_ERROR_LAYER_INVALID}. The primary view configuration layers continue to be submitted through \textit{XrFrameEndInfo} directly.

If the view configuration is not active, as indicated in \textit{XrSecondaryViewConfigurationFrameStateMSFT}, the composition layers submitted to this view configuration \textbf{may} be ignored by the runtime. Applications \textbf{should} avoid rendering into secondary views when the view configuration is inactive.

**Valid Usage (Implicit)**

- The \textit{XR_MSFT_secondary_view_configuration} extension \textbf{must} be enabled prior to using \textit{XrSecondaryViewConfigurationFrameEndInfoMSFT}
- \textbf{type} \textbf{must} be \textit{XR_TYPE_SECONDARY_VIEW_CONFIGURATION_FRAME_END_INFO_MSFT}
- \textbf{next} \textbf{must} be \textit{NULL} or a valid pointer to the \textit{next} structure in a structure chain
- \textbf{viewConfigurationLayersInfo} \textbf{must} be a pointer to an array of \textit{viewConfigurationCount} valid \textit{XrSecondaryViewConfigurationLayerInfoMSFT} structures
- The \textit{viewConfigurationCount} parameter \textbf{must} be greater than \textbf{0}

The application should submit an \textit{XrSecondaryViewConfigurationLayerInfoMSFT} in \textit{XrSecondaryViewConfigurationFrameEndInfoMSFT} for each active secondary view configuration type when calling \textit{xrEndFrame}.

The \textit{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 an extension-specific structure.
- **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. The runtime **must** support at least **XR_MIN_COMPOSITION_LAYERS_SUPPORTED** layers.
- **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, 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
12.32. XR_MSFT_spatial_anchor

Name String
XR_MSFT_spatial_anchor

Extension Type
Instance extension

Registered Extension Number
40

Revision
1

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.

#define XR_DEFINE_HANDLE(XrSpatialAnchorMSFT)

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

Failure
- XR_ERROR_INSTANCE_LOST
- XR_ERROR_OUT_OF_MEMORY
- XR_ERROR_FUNCTION_UNSUPPORTED
- XR_ERROR_VALIDATION_FAILURE
- XR_ERROR_HANDLE_INVALID
- XR_ERROR_POSE_INVALID
- XR_ERROR_CREATE_SPATIAL_ANCHOR_FAILED_MSFT
- XR_ERROR_TIME_INVALID
- XR_ERROR_SESSION_LOST
- XR_SESSION_LOSS_PENDING

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 an extension-specific structure.
- **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 `XrSpace` handle must be eventually freed via the `xrDestroySpace` function or by destroying the parent `XrSpatialAnchorMSFT` handle.

Valid Usage (Implicit)

• The `XR_MSFT_spatial_anchor` extension must be enabled prior to calling `xrCreateSpatialAnchorSpaceMSFT`
• `session` must be a valid `XrSession` handle
• `createInfo` must be a pointer to a valid `XrSpatialAnchorSpaceCreateInfoMSFT` structure
• `space` must be a pointer to an `XrSpace` handle
Return Codes

Success

• XR_SUCCESS

Failure

• XR_ERROR_INSTANCE_LOST
• XR_ERROR_OUT_OF_MEMORY
• XR_ERROR_FUNCTION_UNSUPPORTED
• XR_ERROR_VALIDATION_FAILURE
• XR_ERROR_HANDLE_INVALID
• XR_ERROR_POSE_INVALID
• XR_ERROR_SESSION_LOST
• XR_SESSION_LOSS_PENDING

The XrSpatialAnchorSpaceCreateInfoMSFT structure is defined as:

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 an extension-specific structure.

• 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

Return Codes

**Success**

- `XR_SUCCESS`

**Failure**

- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_FUNCTION_UNSUPPORTED`
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

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

12.33. XR_MSFT.spatial_graph_bridge

Name String

XR_MSFT.spatial_graph_bridge
Extension Type
Instance extension

Registered Extension Number
50

Revision
1

Extension and Version Dependencies
• Requires OpenXR 1.0

Contributors
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Overview
This extension enables applications to create XrSpace handles from 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.

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_MSFTSpatialGraphBridge` 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`

Failure

- `XR_ERROR_INSTANCE_LOST`
- `XR_ERROR_OUT_OF_MEMORY`
- `XR_ERROR_FUNCTION_UNSUPPORTED`
- `XR_ERROR_VALIDATION_FAILURE`
- `XR_ERROR_HANDLE_INVALID`
- `XR_ERROR_SESSION_LOST`
- `XR_SESSION_LOSS_PENDING`
- `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[16];
    XrPosef                       pose;
} XrSpatialGraphNodeSpaceCreateInfoMSFT;
Member Descriptions

- **type** is the XrStructureType of this structure.
- **next** is NULL or a pointer to an extension-specific structure.
- **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.

```c
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 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 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 XR_SPATIAL_GRAPH_NODE_TYPE_DYNAMIC_MSFT.

New Object Types

New Flag Types

New Enum Constants

XrStructureType enumeration is extended with:

- XR_TYPE_SPATIAL_GRAPH_NODE_SPACE_CREATE_INFO_MSFT

New Enums

XrSpatialGraphNodeTypeMSFT

New Structures

XrSpatialGraphNodeSpaceCreateInfoMSFT

New Functions

xrCreateSpatialGraphNodeSpaceMSFT

Issues

Version History

- Revision 1, 2019-10-31 (Yin LI)
  - Initial extension description

12.34. 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 \textbf{may} recenter the space's origin to a new location closer to the viewer. If such recentering occurs, the runtime \textbf{must} queue the \texttt{XrEventDataReferenceSpaceChangePending} event with \texttt{poseValid} set to true.

Runtimes \textbf{must} support the \texttt{UNBOUNDED_MSFT} reference space when this extension is enabled.

\textbf{New Object Types}

\textbf{New Flag Types}

\textbf{New Enum Constants}

\texttt{XrReferenceSpaceType} enumeration is extended with:

\begin{itemize}
  \item \texttt{XR_REFERENCE_SPACE_TYPE_UNBOUNDED_MSFT}
\end{itemize}

\textbf{New Enums}

\textbf{New Structures}

\textbf{New Functions}

\textbf{Issues}

\textbf{Version History}

\begin{itemize}
  \item Revision 1, 2019-07-30 (Alex Turner)
  \begin{itemize}
    \item Initial extension description
  \end{itemize}
\end{itemize}

\section*{12.35. XR_OCULUS\_android_session_state_enable}

**Name String**

\texttt{XR_OCULUS\_android_session_state_enable}

**Extension Type**

Instance extension

**Registered Extension Number**

45

**Revision**

1

**Extension and Version Dependencies**

\begin{itemize}
  \item Requires OpenXR 1.0
\end{itemize}

**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.
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

### 12.36. 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
Sergiy Dubovik, Varjo Technologies
Rémi Arnaud, Varjo Technologies
Robert Menzel, NVIDIA

12.36.1. 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
Chapter 13. List of Provisional Extensions

- XR_EXTX_overlay
- XR_MNDX_egl_enable
### 13.1. XR_EXTX_overlay

**Name String**

XR_EXTX_overlay

**Extension Type**

Instance extension

**Registered Extension Number**

34

**Revision**

4

**Extension and Version Dependencies**

- Requires OpenXR 1.0

**Last Modified Date**

2020-03-23

**IP Status**

No known IP claims.

**Contributors**

- Mark Young, LunarG
- Jules Blok, Epic
- Jared Cheshier, Pluto VR
- Nick Whiting, Epic
- Brad Grantham, LunarG

**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

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 [extension] section.

When you are ready to create an overlay session, you will need to create a XrSessionCreateInfoOverlayEXTX structure and pass it into the xrCreateSession via the XrSessionCreateInfo structure's next parameter.

A runtime will attempt to match or lock the display time between main and overlay sessions. If the overlay application's display content is not visually correlated to features in the main frame (e.g. a HUD or a notification UI) or the overlay application otherwise does not need its frames' display time to be synchronized to the main application, the application can set XR_OVERLAY_SESSION_CREATE_RELAXED_DISPLAY_TIME_BIT_EXTX in createFlags in XrSessionCreateInfoOverlayEXTX.

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 6. Overlay Session Composition Order**

<table>
<thead>
<tr>
<th>Session Type</th>
<th><code>XrSessionCreateInfoOverlayEXTX::sessionLayersPlacement</code></th>
<th>Composited</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**

`Composition Layer Behavior` currently states that if `xrEndFrame` is called with 0 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
static const XrOverlaySessionCreateFlagsEXTX
    XR_OVERLAY_SESSION_CREATE_RELAXED_DISPLAY_TIME_BIT_EXTX = 0x00000001;
```

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
- XR_OVERLAY_SESSION_CREATE_RELAXED_DISPLAY_TIME_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 an extension-specific structure.
- `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 a valid combination of `XrOverlaySessionCreateFlagBitsEXTX` values
- `createFlags` must not 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 an extension-specific structure.
- **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
• Revision 3, 2020-03-05 (Brad Grantham)
  ◦ Name change
• Revision 4, 2020-03-23 (Brad Grantham)
  ◦ Fix enums

13.2. 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 an extension-specific structure.
- `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 `PFNEGLGETPROCADDRESSPROC` 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
Appendix

Code Style Conventions

These are the code style conventions used in this specification to define the API.

<table>
<thead>
<tr>
<th>Conventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Enumerants and defines are all upper case with words separated by an underscore.</td>
</tr>
<tr>
<td>• Neither type, function or member names contain underscores.</td>
</tr>
<tr>
<td>• Structure members start with a lower case character and each consecutive word starts with a capital.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• A structure that has a pointer to an array lists the fooCount member first and then the array pointer.</td>
</tr>
<tr>
<td>• Unless a negative value has a clearly defined meaning all fooCount variables are unsigned.</td>
</tr>
<tr>
<td>• Function parameters that are modified are always listed last.</td>
</tr>
</tbody>
</table>

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_GET_INFO = 4,
    XR_TYPE_SYSTEM_PROPERTIES = 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,
XR_TYPE_SYSTEM_EYE_GAZE_INTERACTION_PROPERTIES_EXT = 1000030000,
XR_TYPE_EYE_GAZE_SAMPLE_TIME_EXT = 1000030001,
XR_TYPE_VISIBILITY_MASK_KHR = 1000031000,
XR_TYPE_EVENT_DATA_VISIBILITY_MASK_CHANGED_KHR = 1000031001,
XR_TYPE_SESSION_CREATE_INFO_OVERLAY_EXTX = 1000033000,
XR_TYPE_EVENT_DATA_MAIN_SESSION_VISIBILITY_CHANGED_EXTX = 1000033003,
XR_TYPE_SPATIAL_ANCHOR_CREATE_INFO_MSFT = 1000039000,
XR_TYPE_SPATIAL_ANCHOR_SPACE_CREATE_INFO_MSFT = 1000039001,
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,
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\text{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:

\[
\text{enum} = \text{enum}_\text{base} + (\text{enum}_\text{index} - 1) \times 1000 + \text{enum}_\text{value} = 1000000000 + 4 \times 1000 + 3
\]

**Flag Types**

Flag types are all bitmasks aliasing the base type \textit{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;
```
typedef XrFlags64 XrInstanceCreateFlags;

typedef XrFlags64 XrSessionCreateFlags;

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:

```
#ifdef __cplusplus
extern "C" {
#endif
```

and closed with:

```
#ifndef __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.

```c
// OpenXR current version number.
define XR_CURRENT_API_VERSION XR_MAKE_VERSION(1, 0, 9)
```

`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) & 0xffffFULL) << 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`.
## 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.

```c
#define XR_VERSION_MAJOR(version) (uint16_t)(((uint64_t)(version) >> 48) & 0xffffULL)
```

### XR_VERSION_MINOR

Extracts the API minor version number from a packed version number.

```c
#define XR_VERSION_MINOR(version) (uint16_t)(((uint64_t)(version) >> 32) & 0xffffULL)
```

### XR_VERSION_PATCH

Extracts the API patch version number from a packed version number.

```c
#define XR_VERSION_PATCH(version) (uint32_t)((uint64_t)(version) & 0xffffffffULL)
```

### Handle and Atom Macros

- **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.
- **XR_VERSION_MINOR** extracts the API minor version number from a packed version number.
- **XR_VERSION_PATCH** extracts the API patch version number from a packed version number.
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](#).

**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.

**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.

`XR_API_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.

`XR_API_CALL` is a macro placed after the return type of an API function declaration. This macro controls calling conventions for MSVC-style compilers.

`XR_API_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 `XR_API_ATTR` or `XR_API_CALL`, depending on the compiler.

Examples:

Function declaration:

```c
XR_API_ATTR <return_type> XR_API_CALL <function_name>(<function_parameters>);  
```

Function pointer type declaration:

```c
typedef <return_type> (XR_API_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>

**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>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>Term</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------</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 <code>[0,1]</code>, 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>
<tr>
<td>Runtime</td>
<td>The software which implements the OpenXR API and allows applications to interact with XR hardware.</td>
</tr>
</tbody>
</table>
Term | Description
---|---
Swapchain | A resource that represents a chain of images in device memory. Represented by an XrSwapchain object.
Swapchain Image | 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 XrSwapchainImageBaseHeader.

### 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>
Dedication (Informative)

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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• Trevor F. Smith, Mozilla
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• Yin Li, Microsoft
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• Zheng Qin, Microsoft
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