LIQUIDVR™ SDK TECHNICAL USER GUIDE

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Contents

1 Introduction

The LiquidVR SDK provides an interface for accessing GPU functionality for use in virtual reality(VR) applications. This guide is intended for advanced users who have a good knowledge of the DirectX® API and are familiar with general graphics and GPU compute techniques.

This guide provides sections on:

- Multi-GPU Affinity
- Late Data Latch
- Asynchronous Compute

Also included are:

- Details of the SDK contents
- The LiquidVR API reference

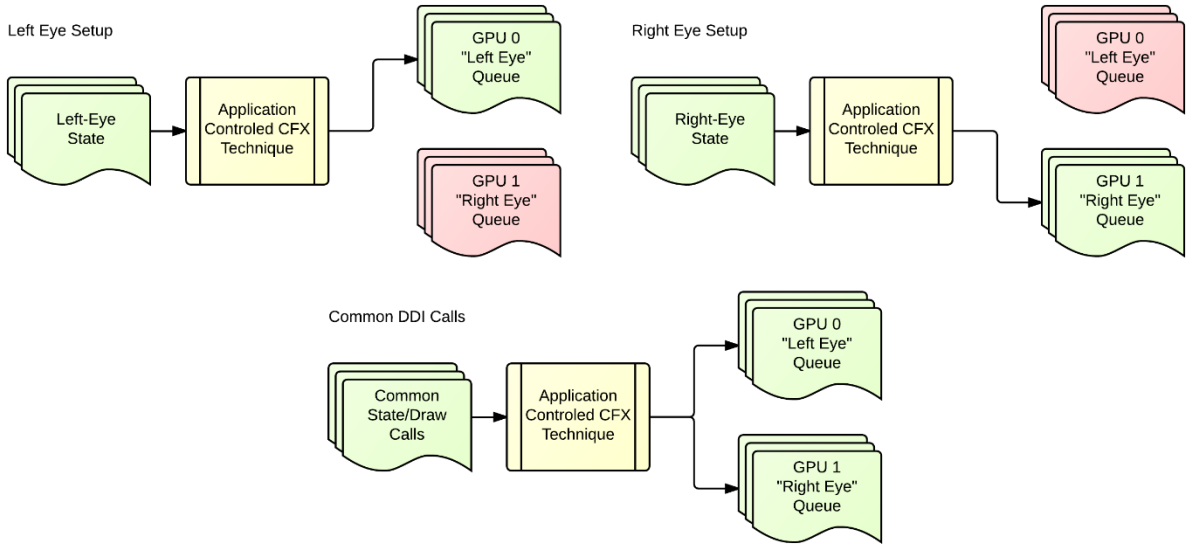
The features described in this guide will work regardless of there being a head mounted display(HMD) installed on the system.

Additional information on LiquidVR can be found at http://gpuopen.com/gaming-product/liquidvr/.

1.1 Multi-GPU Affinity

The Multi-GPU Affinity feature is intended for VR developers interested in maximizing performance of their applications in system configurations with multiple AMD graphics cards. The conventional alternate-frame rendering technique supported by CrossFire™ renders successive frames on different cards. Multi-GPU Affinity provides an interface to render the same frame or its portions on different GPUs by directing DirectX11® context rendering commands to a set of GPUs in a multi-GPU configuration, according to the selection mask. Additionally, it offers a feature to explicitly transfer resources between two GPUs. The application is responsible for all data marshalling and synchronization of data between the GPUs.

In case of a dual-GPU configuration, most of the rendering in a VR environment is the same for left and right eye, and a single DirectX® command stream can be broadcast to two GPUs, each generating an image for one eye. Specification of view dependent parameters is different between left and right eyes, and a mask selecting either of the GPUs is used in that case. Prior to presentation, the application uses the MGPU Affinity API to transfer a rendered image from the slave GPU to the master. A single image combining left and right eye rendering is used for presentation to the HMD on the master GPU. The diagram below illustrates such operation.



A particular sequence of steps has to be taken to properly enable Multi-GPU Affinity. Once the LiquidVR factory interface is initialized, the first step is to use the *ALVRFactory::CreateGPUAffinity()* function to initialize an instance of *ALVRGPUAffinity* interface . This interface can be used to enable or disable MGPU Affinity mode on a per-device basis. The affinity mode for a device is set at creation and persists for its lifetime (cannot be changed later). To create a device in MGPU Affinity mode, the affinity mode has to be enabled by calling them *ALVRGPUAffinity::EnableGPUAffinity()* method prior to device creation. If Multi-GPU Affinity is not available, the function fails with an appropriate error code. If the function succeeds, the Multi-GPU Affinity features are initialized and are ready for use.

Once a device in Multi-GPU Affinity mode is created, and another device without affinity is needed, the Multi-GPU Affinity can be disabled with *DisableGPUAffinity()* prior to creation of the second device. The Multi-GPU Affinity feature operates by wrapping the DirectX® device and context runtime objects in an effort to ensure communication from the application properly makes its way to the driver. These DirectX® object wrappers are created by calling *D3D11WrapDevice()*. Once wrapped, the original device and context must not be used. The DirectX® runtime filters duplicate states, which might affect consistency of state in Multi-GPU Affinity mode. The main intent of wrapped device context is to ensure that state filtering is subverted and the render mask is consistent with the application settings across all active GPUs.

1.2 Late Data Latch

The delay between a head movement and display of the rendered objects in VR (a.k.a. motion-to-photon latency) could cause discomfort and headaches in some individuals. The Late Data Latch is intended to increase the application responsiveness and to reduce rendering lag. For example, in a typical gaming or a VR application frames are rendered based on the user's current head position and orientation. Once a render task is submitted to the GPU, it is not possible to modify its parameters. Since CPU and GPU time domains are not synchronized, there is some lag between the moment when a frame is submitted to the GPU pipeline for rendering and the moment when the rendered frame is presented on the screen. This lag depends on the amount of time needed to batch and render a scene and in certain cases can be significant, especially when the frame rates are low. At the same time the user continues to control the application unaware that the image currently being visible on the screen has been rendered according to

the transformation matrix recorded at the moment when the render job was submitted to the GPU. This lag makes the application appear less responsive to user's actions. It is very desirable therefore to reduce lag as much as possible.

The Late Data Latch helps applications deal with this problem by continuously storing frequently updated data, such as real-time head position and orientation matrices, in a fixed-sized constant buffer, organized as a ring buffer. Each new snapshot of data is stored in its own consecutive data slot. The data ring buffer has to be large enough to ensure the buffer will not be overrun and the latched data instance will not be overwritten during the time it could be referenced by the GPU. For example, if data is updated every 2ms, a game rendering at 100fps should have more than 50 data slots in the data ring buffer. It is advised to have at least twice the minimum number of slots to avoid data corruption. Just before the data is to be consumed by the GPU, the index to the most up-to-date snapshot of data is latched. The shader could then index into the constant buffer containing the data to find the most recent matrices for rendering.

This late latching approach allows the application to get the latest transformation matrices up to the moment when the frame is about to be rendered.

It is important to note that late latching cannot increase the application's frame rate, but it can make the application appear more responsive to user's input.

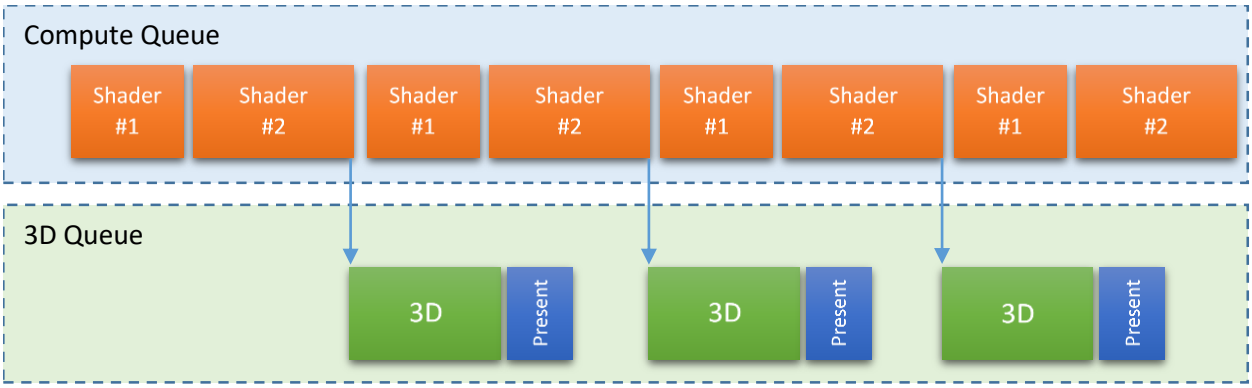
1.3 Asynchronous Compute

Asynchronous Compute is a performance-boosting feature, which allows the execution of compute jobs concurrently with graphics tasks. Since the Microsoft DirectX 11 DirectCompute™ API does not support submission of asynchronous compute jobs, the LiquidVR SDK provides a private API for Asynchronous Compute.

The following diagram demonstrates the difference between the standard DirectCompute™ and AMD Asynchronous Compute models, where compute can be run concurrently with 3D graphics:

Standard DirectX 11 Direct Compute:

AMD Asynchronous Compute:



Please note that the Asynchronous Compute scenario depicted above is only one of the countless possibilities of scheduling compute jobs relative to 3D jobs. Compute jobs may precede, follow, or be interleaved with 3D jobs for the arrangement providing the most optimal performance. Depending on the relative length of compute and 3D jobs and their interdependencies performance gains from using Asynchronous Compute can be significant compared to a serialized execution provided by Direct Compute, allowing programmers to take full advantage of the capabilities of AMD Radeon hardware.

Asynchronous Compute in LiquidVR API leverages shaders compiled for DirectCompute™.

2 SDK Contents

2.1 LiquidVR Libraries in Windows

The LiquidVR runtime is distributed as a part of the AMD graphics driver package. To use LiquidVR in the Windows® programming environment, users must have appropriate AMD graphics drivers installed. There are 32-bit and 64-bit versions of runtime libraries available. An application should not redistribute LiquidVR runtime libraries outside of the AMD driver installation.

The following dynamic libraries are available:

Table 1. Dynamically linked LiquidVR libraries

Library file name	Description
amdlvr32.dll	32-bit LiquidVR API dynamic library
amdlvr64.dll	64-bit LiquidVR API dynamic library

The LiquidVR API header is located at *./inc/LiquidVR.h*. It contains entry points for API and extension libraries.

Table 2. LiquidVR™ header files

Header file name	Description
LiquidVR.h	LiquidVR core API

3 API Reference

3.1 Common Enumerations

The LiquidVR error messages are defined as an enumerated type:

```
enum ALVR_RESULT
{
    ALVR_OK                          = 0,
    ALVR_FALSE                       = 1,
    ALVR_FAIL                        = 2,
    ALVR_INVALID_ARGUMENT            = 3,
    ALVR_NOT_INITIALIZED             = 4,
    ALVR_INSUFFICIENT_BUFFER_SIZE    = 5,
    ALVR_NOT_IMPLEMENTED             = 6,
    ALVR_NULL_POINTER                = 7,
    ALVR_ALREADY_INITIALIZED         = 8,
    ALVR_UNSUPPORTED_VERSION         = 9,
    ALVR_OUT_OF_MEMORY               = 10,
    ALVR_DISPLAY_REMOVED             = 11,
    ALVR_DISPLAY_USED                = 12,
    ALVR_DISPLAY_UNAVAILABLE         = 13,
    ALVR_DISPLAY_NOT_ENABLED         = 14,
    ALVR_OUTSTANDING_PRESENT_FRAME   = 15,
    ALVR_DEVICE_LOST                 = 16,
    ALVR_UNAVAILABLE                 = 17,
    ALVR_NOT_READY                   = 18,
    ALVR_TIMEOUT                     = 19,
    ALVR_RESOURCE_IS_NOT_BOUND       = 20,
    ALVR_UNSUPPORTED                 = 21,
    ALVR_INCOMPATIBLE_DRIVER         = 22,
    ALVR_DEVICE_MISMATCH             = 23,
    ALVR_INVALID_DISPLAY_TIMING      = 24,
    ALVR_INVALID_DISPLAY_RESOLUTION  = 25,
    ALVR_INVALID_DISPLAY_SCALING     = 26,
    ALVR_INVALID_DISPLAY_OUT_OF_SPEC= 27,
};
```

3.2 Interface Conventions

All LiquidVR SDK interfaces inherit from *IUnknown* and follow all standard COM rules for reference counting and object life cycle.

Pointers to interfaces can be returned either via parameters, or via function return values. The following conventions are followed in the LiquidVR SDK:

- When a pointer to an interface is returned via function parameters of the pointer-to-a-pointer-to-an-interface type, the reference count on the object implementing the interface is set to 1. The caller is responsible for calling the *Release()* method when the interface is no longer needed.
- When a pointer to an interface is returned as a function return value, its reference count is unaltered. The caller is responsible for calling *AddRef()* when saving the pointer and calling *Release()* when it is no longer needed.

3.3 LiquidVR Library Initialization

The LiquidVR component is initialized by loading the LiquidVR dynamic library and creating an instance of the *ALVRFactory* class. In the Windows environment, the standard DLL loading method for loading LiquidVR library is used:

```
libHandle = LoadLibraryW(ALVR_DLL_NAME);
```

Next, retrieve a function pointer to the initialization function by name using *GetProcAddress()* function:

```
fnInit = GetProcAddress(libHandle, ALVR_INIT_FUNCTION_NAME);
```

Once the initialization function pointer is available, use it to retrieve the *ALVRFactory* interface. *ALVR_DLL_NAME* and *ALVR_INIT_FUNCTION_NAME* macros are defined in the LiquidVR.h header file. The factory is then used to access LiquidVR features.

```
ALVR_RESULT (*ALVRInit_Fn)(uint64_t version, void **ppFactory);
```

Parameters

version

Constant *ALVR_FULL_VERSION* defined in the LiquidVR.h header file.

ppFactory

The address of a pointer to *ALVRFactory* to be initialized.

Return

ALVR_OK on success.

ALVR_UNSUPPORTED_VERSION when an unsupported version is requested.

ALVR_INVALID_ARGUMENT when *ppFactory* is *nullptr*.

3.4 Querying the LiquidVR version number.

A special entry point can be used to query the LiquidVR version number once the LiquidVR DLL is loaded. Use the libHandle returned by loading the LiquidVR library to look up the query entry point:

```
fnQueryVersion = GetProcAddress(libHandle, ALVR_QUERY_VERSION_FUNCTION_NAME);
```

Call the query version function:

```
uint64_t versionNumber = 0;
fnQueryVersion(&versionNumber);
```

The query entry point is:

```
ALVR_RESULT (*ALVRQueryVersion_Fn)(uint64_t *pVersion);
```

Parameters

pVersion

The address of a pointer to a uint64_t that should be initialized. This number is made up of a *major*, *minor*, *release* and *build* component as defined in the *ALVR_FULL_VERSION* macro.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when *pVersion* is *nullptr*.

3.5 ALVRFactory

This factory creates and initializes objects implementing all LiquidVR SDK core interfaces.

CreateGPUAffinity

Initialize an instance of the *ALVRGPUAffinity* interface.

```
ALVR_RESULT CreateGPUAffinity(ALVRGPUAffinity **ppAffinity);
```

Parameters

ppAffinity

A pointer to a location which will receive a pointer of the *ALVRGPUAffinity* interface.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when *ppAffinity* is *nullptr*.

CreateALVRDeviceExD3D11

Create an instance of the *ALVRDeviceExD3D11* interface.

```
ALVR_RESULT CreateALVRDeviceExD3D11(ID3D11Device* pD3DDevice,
            void* pConfigDesc,
            ALVRDeviceExD3D11** ppDevice);
```

Parameters

pD3DDevice

A pointer to a D3D11 device for which the *ALVRDeviceExD3D11* interface is to be obtained.

pConfigDesc

A pointer to a structure with optional configuration data. Reserved for future extensions, currently ignored.

ppDevice

A pointer to a location which will receive a pointer of the *ALVRDeviceExD3D11* interface.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_NOT_INITIALIZED or *ALVR_FAIL* when a generic driver failure occurs. Check the driver installation when receiving this error.

CreateComputeContext

Create an instance of the *ALVRComputeContext* interface for a specific device.

```
ALVR_RESULT CreateComputeContext(ALVRDeviceEx* pDevice,
            unsigned int gpuIdx,
            CreateComputeContext* pDesc,
            ALVRComputeContext** ppContext);
```

Parameters

pDevice

A pointer to an *ALVRDeviceEx* interface representing a device for which the *ALVRComputeContext* interface is to be obtained

gpuIdx

An index of the GPU in multi-GPU configurations, which will be used for executing compute tasks within this context.

pDesc

A pointer to a structure with configuration data, defined as follows:

```
struct ALVRComputeContextDesc
{
    unsigned int flags; // ALVR_COMPUTE_FLAGS
};
```

where the *flags* field may contain one or more of the following values:

- *ALVR_COMPUTE_NONE* – no flags, use the regular Compute queue
- *ALVR_COMPUTE_HIGH_PRIORITY* – use the high priority Compute queue

ppContext

A pointer to a location which will receive a pointer of the *ALVRComputeContext* interface.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_NOT_INITIALIZED or *ALVR_FAIL* when a generic driver failure occurs. Check the driver installation when receiving this error.

CreateALVRExtensionVulkan

Create an instance of the *ALVRExtensionVulkan* interface for a specific Vulkan instance.

```
ALVR_RESULT CreateALVRExtensionVulkan (VkInstance vkInstance,
                                       void* pConfigDesc,
                                       ALVRExtensionVulkan** ppExt);
```

Parameters

vkInstance
A handle to a Vulkan instance.

pConfigDesc
Optional configuration parameters. Must be *nullptr*.

ppExt
A pointer to a location which will receive a pointer of the *ALVRExtensionVulkan* interface.

Return
ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_NOT_INITIALIZED or *ALVR_FAIL* when a generic driver failure occurs. Check the driver installation when receiving this error.

CreateMotionEstimator

Create an instance of the *ALVRMotionEstimator* interface for a specific device.

```
ALVR_RESULT CreateMotionEstimator(ALVRDeviceEx* pDevice,
            void* pDesc,
            ALVRMotionEstimator** ppMotionEstimator);
```

Parameters

pDevice
A pointer to an *ALVRDeviceEx* interface representing a device for which the *ALVRComputeContext* interface is to be obtained

pDesc
Optional configuration parameters. Must be *nullptr*.

ppMotionEstimator
A pointer to a location which will receive a pointer of the *ALVRMotionEstimator* interface.

Return
ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_NOT_INITIALIZED or *ALVR_FAIL* when a generic driver failure occurs. Check the driver installation when receiving this error.

D3D11CreateDeviceHP3D

Create a D3D11 device and device context using a high priority 3D queue, if available.

```
ALVR_RESULT ALVR_STD_CALL D3D11CreateDeviceHP3D(IDXGIAdapter* pAdapter,
                                    D3D_DRIVER_TYPE     DriverType,
                                    HMODULE             Software,
                                    UINT                Flags,
                                    const D3D_FEATURE_LEVEL* pFeatureLevels,
                                    UINT                FeatureLevels,
                                    UINT                SDKVersion,
                                    ID3D11Device**      ppDevice,
                                    D3D_FEATURE_LEVEL*  pFeatureLevel,
                                    ID3D11DeviceContext** ppImmediateContext);
```

Parameters

pAdapter

A pointer to the video adapter to use when creating a **device**. Pass *NULL* to use the default adapter, which is the first adapter that is enumerated by **IDXGIFactory1::EnumAdapters**.

DriverType

The **D3D_DRIVER_TYPE**, which represents the driver type to create.

Software

A handle to a DLL that implements a software rasterizer. If *DriverType* is *D3D_DRIVER_TYPE_SOFTWARE*, *Software* must not be *NULL*. Get the handle by calling **LoadLibrary**, **LoadLibraryEx** , or **GetModuleHandle**.

Flags

The runtime **layers** to enable (see **D3D11_CREATE_DEVICE_FLAG**); values can be bitwise OR'd together.

pFeatureLevels

A pointer to an array of **D3D_FEATURE_LEVEL**s, which determine the order of feature levels to attempt to create. If *pFeatureLevels* is set to *NULL*, this function uses the following array of feature levels:

```
{
    D3D_FEATURE_LEVEL_11_0,
    D3D_FEATURE_LEVEL_10_1,
    D3D_FEATURE_LEVEL_10_0,
    D3D_FEATURE_LEVEL_9_3,
    D3D_FEATURE_LEVEL_9_2,
    D3D_FEATURE_LEVEL_9_1,
};
```

FeatureLevels

The number of elements in *pFeatureLevels*.

SDKVersion

The SDK version; use *D3D11_SDK_VERSION*.

ppDevice

Returns the address of a pointer to an **ID3D11Device** object that represents the device created. If this parameter is *NULL*, no ID3D11Device will be returned.

FeatureLevel

If successful, returns the first **D3D_FEATURE_LEVEL** from the *pFeatureLevels* array which succeeded. Supply *NULL* as an input if you don't need to determine which feature level is supported.

ppImmediateContext

Returns the address of a pointer to an **ID3D11DeviceContext** object that represents the device context. If this parameter is *NULL*, no *ID3D11DeviceContext* will be returned.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_UNSUPPORTED when the hardware does not support high priority 3D queue

ALVR_FAIL when a generic driver failure occurs. Check the driver installation when receiving this error.

D3D11CreateDeviceAndSwapChainHP3D

Create a D3D11 device, device context and a swap chain using a high priority 3D queue, if available.

```
ALVR_RESULT ALVR_STD_CALL D3D11CreateDeviceAndSwapChainHP3D(
                                    IDXGIAdapter* pAdapter,
                                    D3D_DRIVER_TYPE     DriverType,
                                    HMODULE             Software,
                                    UINT                Flags,
                                    const D3D_FEATURE_LEVEL* pFeatureLevels,
                                    UINT                FeatureLevels,
                                    UINT                SDKVersion,
                                    const DXGI_SWAP_CHAIN_DESC* pSwapChainDesc,
                                    IDXGISwapChain** ppSwapChain,
                                    ID3D11Device**      ppDevice,
                                    D3D_FEATURE_LEVEL*  pFeatureLevel,
                                    ID3D11DeviceContext** ppImmediateContext);
```

Parameters

pAdapter

A pointer to the video adapter to use when creating a **device**. Pass *NULL* to use the default adapter, which is the first adapter that is enumerated by **IDXGIFactory1::EnumAdapters**.

DriverType

The **D3D_DRIVER_TYPE**, which represents the driver type to create.

Software

A handle to a DLL that implements a software rasterizer. If *DriverType* is *D3D_DRIVER_TYPE_SOFTWARE*, *Software* must not be *NULL*. Get the handle by calling **LoadLibrary**, **LoadLibraryEx** , or **GetModuleHandle**.

Flags

The runtime **layers** to enable (see **D3D11_CREATE_DEVICE_FLAG**); values can be bitwise OR'd together.

pFeatureLevels

A pointer to an array of **D3D_FEATURE_LEVEL**s, which determine the order of feature levels to attempt to create. If *pFeatureLevels* is set to *NULL*, this function uses the following array of feature levels:

```
{
    D3D_FEATURE_LEVEL_11_0,
    D3D_FEATURE_LEVEL_10_1,
    D3D_FEATURE_LEVEL_10_0,
    D3D_FEATURE_LEVEL_9_3,
    D3D_FEATURE_LEVEL_9_2,
    D3D_FEATURE_LEVEL_9_1,
};
```

FeatureLevels

The number of elements in *pFeatureLevels*.

SDKVersion

The SDK version; use *D3D11_SDK_VERSION*.

pSwapChainDesc

A pointer to a swap chain description (see **DXGI_SWAP_CHAIN_DESC**) that contains initialization parameters for the swap chain.

ppSwapChain

Returns the address of a pointer to the **IDXGISwapChain** object that represents the swap chain used for rendering.

ppDevice

Returns the address of a pointer to an **ID3D11Device** object that represents the device created. If this parameter is *NULL*, no ID3D11Device will be returned.

FeatureLevel

If successful, returns the first **D3D_FEATURE_LEVEL** from the *pFeatureLevels* array which succeeded. Supply *NULL* as an input if you don't need to determine which feature level is supported.

ppImmediateContext

Returns the address of a pointer to an **ID3D11DeviceContext** object that represents the device context. If this parameter is *NULL*, no *ID3D11DeviceContext* will be returned.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_UNSUPPORTED when the hardware does not support high priority 3D queue

ALVR_FAIL when a generic driver failure occurs. Check the driver installation when receiving this error.

3.6 ALVRPropertyStorage

Property storage implements a map of name-value pairs.

SetProperty

Assign a value to a property.

```
ALVR_RESULT SetProperty(const wchar_t* name, ALVRVariantStruct value);

template<typename _T>
ALVR_RESULT SetProperty(const wchar_t* name, const _T& value);
```

Parameters

name

Property name.

value

Property value.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when the name parameter is *nullptr*.

Remarks

Assigning a value to a property will add a new property to the map if one doesn't exist; otherwise change the value of an existing property.

GetProperty

Retrieve a value to a property.

```
ALVR_RESULT GetProperty(const wchar_t* name, ALVRVariantStruct* value) const;

template<typename _T>
ALVR_RESULT GetProperty(const wchar_t* name, _T* value) const;
```

Parameters

name

Property name.

value
Property value.

Return
ALVR_OK on success.

ALVR_INVALID_ARGUMENT when the *name* parameter is *nullptr* or when the property has not been set previously.

HasProperty

Check if a property exists in the storage.

```
bool HasProperty(const wchar_t* name) const;
```

Parameters

name
Property name

Return
true when the property exists in the storage.

false when the property does not exist in the storage.

GetPropertyCount

Get the number of properties in a property storage.

```
size_t GetPropertyCount() const;
```

Parameters

None

Return
The number of properties in the storage.

GetPropertyAt

Retrieve a value to a property at a specific location.

```
ALVR_RESULT GetPropertyAt(size_t index,
                          wchar_t* name,
                          size_t nameSize,
                          ALVRVariantStruct* value) const;
```

Parameters

index
Property index. Index must be in the range greater than or equal to 0 and less than the value returned by *GetPropertyCount()*.

name

A pointer to a buffer to store a property name. The size of the buffer is passed through the *nameSize* parameter.

nameSize

The size of the buffer to receive the property name in characters.

value

Property value.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when the *name* or *value* parameter is *nullptr* or when the property index is out of range.

3.7 ALVRDeviceEx

ALVRDeviceEx inherits from *ALVRPropertyStorage*. This is the base class for other device interfaces and currently does not define any methods.

3.8 ALVRDeviceExD3D11

ALVRDeviceExD3D11 inherits from *ALVRDeviceEx*.

CreateFence

Create a GPU fence. A GPU fence is a special synchronization object which allows the CPU to wait for an event triggered by the GPU.

```
ALVR_RESULT CreateFence(ALVRFence** ppFence);
```

Parameters

ppFence

A pointer to a location which will receive a pointer to the *ALVRFence* interface.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *ppFence* is *nullptr*

ALVR_FAIL on any other error

SubmitFence

Submit a GPU fence in the immediate context of D3D11 device.

```
ALVR_RESULT SubmitFence(unsigned int gpuIdx, ALVRFence* pFence);
```

Parameters

gpuIdx

An index of a GPU to submit a fence to.

pFence

A pointer to the *ALVRFence* interface to be submitted to the GPU.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *pFence* is *nullptr* or *gpuIdx* is out of range

ALVR_FAIL on any other error

CreateGpuSemaphore

Create a GPU semaphore. GPU semaphores are synchronization objects that allow one GPU to wait for events triggered by another GPU in multi-GPU configurations, or to synchronize between the queues in the same GPU.

```
ALVR_RESULT CreateGpuSemaphore(ALVRGpuSemaphore** ppSemaphore);
```

Parameters

ppSemaphore

A pointer to a location which will receive a pointer to the *ALVRGpuSemaphore* interface.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *ppSemaphore* is *nullptr*

ALVR_FAIL on any other error

QueueSemaphoreSignal

Queue a semaphore signal to a specific GPU queue in the immediate context of D3D11 device.

```
ALVR_RESULT QueueSemaphoreSignal(ALVR_GPU_ENGINE gpuEngine,
                                 unsigned int gpuIdx,
                                 ALVRGpuSemaphore* pSemaphore);
```

Parameters

gpuEngine

The type of a GPU engine (*ALVR_GPU_ENGINE_3D* or *ALVR_GPU_ENGINE_DMA*).

gpuIdx

GPU index in multi-GPU configurations.

pSemaphore

A pointer to the semaphore interface to signal.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

QueueSemaphoreWait

Queue a semaphore wait to a specific GPU queue in the immediate context of D3D11 device.

```
ALVR_RESULT QueueSemaphoreWait(ALVR_GPU_ENGINE gpuEngine,
                               unsigned int gpuIdx,
                               ALVRGpuSemaphore* pSemaphore);
```

Parameters

gpuEngine
The type of a GPU engine (*ALVR_GPU_ENGINE_3D* or *ALVR_GPU_ENGINE_DMA*).

gpuIdx
GPU index.

pSemaphore
A pointer to the semaphore interface to wait on.

Return
ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

CreateGpuTimeline

Create an instance of the *ALVRGpuTimeline* interface for a specific GPU.

```
ALVR_RESULT CreateGpuTimeline(unsigned int gpuIdx,
                              ALVRGpuTimeline** ppGpuTimeline);
```

Parameters

gpuIdx
GPU index

pSemaphore
A pointer to the location to receive a pointer to the *ALVRGpuTimeline* interface.

Return
ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

CreateLateLatchConstantBufferD3D11

Create an interface encapsulating a constant buffer for Late Latch implementation. This buffer may contain various parameters such as world, view or projection matrices used by shaders.

```
ALVR_RESULT CreateLateLatchConstantBufferD3D11(
            size_t updateSize,
            unsigned int numberOfUpdates,
            unsigned int bufferFlags,
            ALVRLateLatchConstantBufferDX11** ppBuffer);
```

Parameters

updateSize

The size of the data structure used per update,

numberOfUpdates

The number of update slots in the data buffer to be allocated; it should be greater or equal to the value statically defined in the shader.

bufferFlags

Can be either *ALVR_LATE_LATCH_NONE* or one or more of the following values:

ALVR_LATE_LATCH_SHARED_BUFFER – must be set when the buffer will be accessible via multiple APIs, for example, Direct3D and Asynchronous Compute.

ppBuffer

A pointer to the location to receive a pointer to *ALVRLateLatchConstantBufferDX11* interface.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the arguments are invalid.

3.9 ALVRFence

GPU Fences are objects used to synchronize CPU with GPU activities.

Wait

Sleep the CPU on a fence until a GPU fence is signaled.

```
ALVR_RESULT Wait(unsigned int timeout);
```

Parameters

timeout

Wait timeout in milliseconds.

Return

ALVR_OK on success.

ALVR_TIMEOUT when the fence has not been signaled before the *timeout* elapses.

ALVR_FAIL on failure.

3.10 ALVRSemaphore

GPU Semaphores are objects used to synchronize operations between different GPUs or between different queues of the same GPU.

GPU semaphores can be queued using the following methods:

- *ALVLDeviceExD3D11::QueueSemaphoreSignal()*
- *ALVRComputeContext::QueueSemaphoreSignal()*

GPU semaphores can wait using the following methods:

- *ALVLDeviceExD3D11::QueueSemaphoreWait()*
- *ALVRComputeContext::QueueSemaphoreWait()*

Semaphores must be queued before they can be waited for, *QueueSemaphoreWait()* would fail if the semaphore has not be queued yet. Consequently, *QueueSemaphoreWait()* cannot be called multiple times after a semaphore has been queued, the number of calls to *QueueSemaphoreWait()* must match the number of calls to *QueueSemaphoreSignal().*

The *ALVRSemaphore* interface doesn't have any methods and acts as a handle to address a semaphore.

3.11 ALVRGpuAffinity

ALVRGPUAffinity inherits from the *ALVRPropertyStorage* interface.

EnableGpuAffinity

Enable GPU Affinity mode for D3D11 device creation.

```
ALVR_RESULT EnableGpuAffinity(ALVR_GPU_AFFINITY_FLAGS flags);
```

Parameters

flags

Select options when enabling GPU Affinity by setting an enumeration defined as:

```
enum  ALVR_GPU_AFFINITY_FLAGS
{
    ALVR_GPU_AFFINITY_FLAGS_NONE = 0,
};
```

Return

ALVR_OK on success.

ALVR_FAIL on failure.

DisableGpuAffinity

Disable GPU affinity.

```
ALVR_RESULT DisableGpuAffinity();
```

Parameters

None

Return

ALVR_OK on success.

ALVR_FAIL on failure.

WrapDeviceD3D11

Intercept standard DX11 interfaces for *D3D11Device* and *D3D11DeviceContext* for use with LiquidVR and obtain a pointer to the *ALVRMultiGpuDeviceContext* interface.

```
ALVR_RESULT WrapDeviceD3D11(ID3D11Device* pDevice,
                    ID3D11Device** ppWrappedDevice,
                    ID3D11DeviceContext** ppWrappedContext,
                    ALVRMultiGpuDeviceContext** ppMultiGpuDeviceContext);
```

Parameters

pDevice

A pointer to an original *ID3D11Device* to be wrapped by this function.

ppWrappedDevice

The address of a pointer to a wrapped *ID3D11Device*.

ppWrappedContext

The address of a pointer to a wrapped *ID3D11DeviceContext*.

ppMultiGpuDeviceContext

The address of a pointer to a wrapped *ALVRMultiGpuDeviceContext*.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

3.12 ALVRMultiGpuDeviceContext

Defines an AMD LiquidVR custom multi-GPU device context that wraps an immediate *ID3D11Device* context.

GetGpuControlInfo

Query Multi-GPU information for the wrapped *ID3D11Device*.

```
void GetGpuControlInfo(ALVRGpuControlInfo* pInfo);
```

Parameters

pInfo

A pointer to the *ALVRGpuControlInfo* structure to receive the number of active GPUs in the system, a mask of active GPUs and a mask of GPUs with attached displays available for presentation.

```
struct ALVRGpuControlInfo
{
    unsigned int     numGpus; ///< Number of GPUs available for control
    unsigned int     maskAllGpus; ///< GPU Mask representing all active GPUs
    unsigned int     maskDisplayGpu; ///< GPU Mask representing the display GPU
};
```

Return

Void.

SetGpuRenderAffinity

Set the GPU affinity to send immediate context rendering commands to a one or more GPUs (e.g., for either left-eye only, right-eye only or both eyes).

```
void SetGpuRenderAffinity(UINT affinityMask);
```

Parameters

affinityMask

A mask for setting active GPUs.

Return

Void.

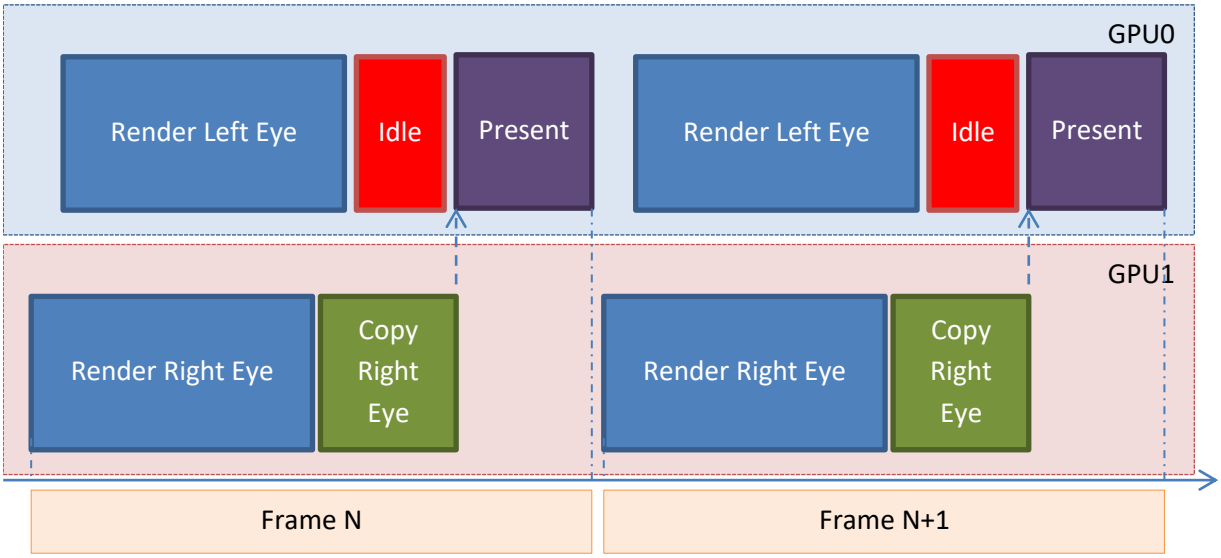
Remarks

SetGpuRenderAffinity can be used to implement two different rendering approaches: single submission and multiple submissions. The choice between the two approaches is driven by various performance considerations depending on the goal of reducing CPU load vs. maximizing rendering speed on the GPU.

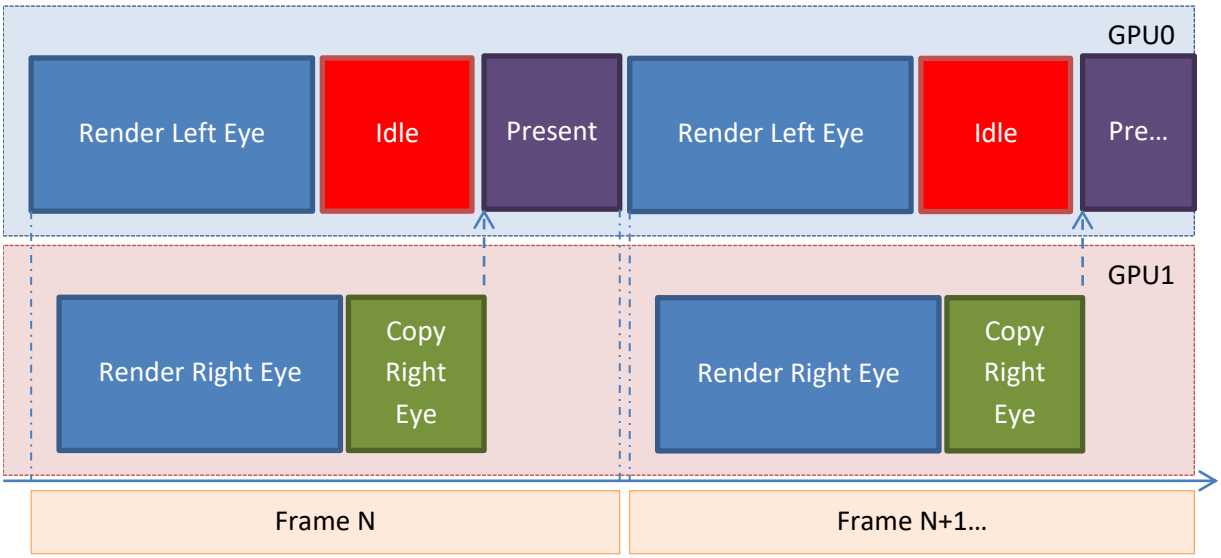
In a typical case of using multiple GPUs for rendering a stereoscopic scene, the image for one eye is rendered by one GPU, while the image for the other eye is rendered by another GPU. Both GPUs are running in the CrossFire™ mode with the display connected to the primary GPU. The image rendered on the secondary GPU eventually needs to be transferred to the primary GPU to be presented. Presentation cannot occur before both rendering tasks are completed and the image for the right eye is transferred from the secondary GPU to the primary GPU, resulting in some idle time on the primary GPU.

In the absolute majority of cases the amounts of time needed to render a frame for the left and the right eye are very similar. Since presentation on the primary GPU cannot start until the image rendered on the secondary GPU is transferred over to the primary GPU, and the image transfer is performed on the secondary (source) GPU, the secondary GPU has more work to do

before a frame can be presented. Thus, it is recommended to submit rendering tasks to the secondary GPU first, so that the idle time on the primary GPU could be minimized. In the multiple submissions mode the application can control which GPU a job is submitted to first. The following diagrams illustrate the difference in performance between scenarios of submitting a job to the secondary GPU vs the primary GPU first:



When the rendering task for one eye is submitted to the primary GPU first before the rendering task for the other eye is submitted to the secondary GPU, the idle time between rendering and presentation would increase, resulting in a lower frame rate:



When GPU tasks are submitted to both GPUs at the same, the software running on the CPU has no control over which GPU would start executing the submitted rendering task first, which may result in lower overall frame rate. The ability to control the order of execution on both GPUs can be gained by explicitly setting the GPU render affinity before submitting render tasks to each GPU, as shown below:

Single Submission Mode	Multiple Submissions Mode

`SetGpuRenderAffinity(0x02);`
`PassParametersToShader(RightEyeParams);`
`SetGpuRenderAffinity(0x01);`
`PassParametersToShader(LeftEyeParams);`
`SetGpuRenderAffinity(0xFFFFFFFF);`
`DrawFrame();`
	`SetGpuRenderAffinity(0x02);`
	`PassParametersToShader(RightEyeParams);`
	`DrawFrame();`
	`SetGpuRenderAffinity(0x01);`
	`PassParametersToShader(LeftEyeParams);`
	`DrawFrame();`

However, in the single submission mode the number of calls *to DrawFrame()*, which sets up the GPU to perform a rendering operation, is less by one for every frame compared to the multiple submissions mode. The amount of CPU time needed to set up the GPU is not negligible, therefore the multiple submissions mode would result in a higher CPU usage.

The choice between the two drawing modes is determined by whether the graphics performance is limited by CPU or GPU. When CPU is the bottleneck, the single submission mode would be preferable, while the multiple submissions mode would result in better frame rates when performance is GPU-bound.

MarkResourceAsInstanced

GPU resources can be either "mirrored" or "instanced". The views of mirrored resources by different GPUs are synchronized, an update of a resource on one GPU alters the view of this resource by other GPUs.

Instanced resources, on the other hand, are viewed differently by different GPUs. An update to an instanced resource on one GPU will change this resource for this GPU only. To synchronize the views of the same resource by different GPUs, the most recent content of the resource must be copied to other GPUs.

By default resources are created in the mirrored mode. Individual resources can be marked as instanced by using the *MarkResourceAsInstanced()* method.

```
void MarkResourceAsInstanced(ID3D11Resource* pResource);
```

Parameters

pResource

A pointer to a D3D11 resource.

Return

Void.

Remarks

This is only needed on resources where the application needs to send different data to each GPU using the *ID3D11DeviceContext::Map()* and *ID3D11DeviceContext::Unmap()* interfaces. It should be noted that once a resource is marked as "instanced", calling *ID3D11DeviceContext::Map()* while the GPU Affinity Mask is set to more than one GPU will result in undefined behavior.

TransferResource

Copy a resource from one GPU to another.

```
ALVR_RESULT TransferResource(ID3D11Resource*     pSrcResource,
                      ID3D11Resource*     pDstResource,
                      unsigned int        srcGpuIdx,
                      unsigned int        dstGpuIdx,
                      unsigned int        srcSubResourceIndex,
                      unsigned int        dstSubResourceIndex,
                      const D3D11_RECT*   pSrcRegion,
                      const D3D11_RECT*   pDstRegion);
```

Parameters

pSrcResource
A pointer to a D3D11 resource stored on the source GPU.

pDstResource
A pointer to a D3D11 resource stored on the destination GPU.

srcGpuIdx
Source GPU index. The master GPU is the one with a display attached (can be queried), and others are slaves.

dstGpuIdx
Destination GPU index. The master GPU is the one with a display attached (can be queried), and other are slaves.

srcSubResourceIndex
Source subresource index.

dstSubResourceIndex
Destination subresource index.

pSrcRegion
Define the region to read from the source resource.

pDstRegion
Define the region to write to in the destination resource.

Return
ALVR_OK on success

ALVR_INVALID_PARAMETER when any of the parameters are invalid

ALVR_FAIL on any other error

TransferResourceEx

Copy a resource from one GPU to another using a specific GPU engine.

```
ALVR_RESULT TransferResourceEx(ID3D11Resource*     pSrcResource,
                        ID3D11Resource*     pDstResource,
                        unsigned int        srcGpuIdx,
```

```
                        unsigned int        dstGpuIdx,
                        unsigned int        srcSubResourceIndex,
                        unsigned int        dstSubResourceIndex,
                        const D3D11_RECT*   pSrcRegion,
                        const D3D11_RECT*   pDstRegion,
                        ALVR_GPU_ENGINE     transferEngine,
                        bool                performSync);
```

Parameters

pSrcResource

A pointer to a D3D11 resource stored on the source GPU.

pDstResource

A pointer to a D3D11 resource stored on the destination GPU.

srcGpuIdx

Source GPU index. The master GPU is the one with a display attached (can be queried), and others are slaves.

dstGpuIdx

Destination GPU index. The master GPU is the one with a display attached (can be queried), and others are slaves.

srcSubResourceIndex

Source subresource index.

dstSubResourceIndex

Destination subresource index.

pSrcRegion

Define the region to read from the source resource. Supported only for transfers by the D3D engine. Must be set to *nullptr* when using the DMA engine for the transfer.

pDstRegion

Define the region to write to in the destination resource. Supported only for transfers by the D3D engine. Must be set to *nullptr* when using the DMA engine for the transfer.

transferEngine

Specify which engine to use to perform the transfer (*ALVR_GPU_ENGINE_3D* or *ALVR_GPU_ENGINE_DMA*).

performSync

Perform internal synchronization of 3D and DMA jobs across GPUs.

Return

ALVR_OK on success

ALVR_INVALID_PARAMETER when any of the parameters are invalid

ALVR_FAIL on any other error

Remarks

When the *performSync* parameter is set to *true*, internal engine synchronization is performed. The transfer is executed only when all previously queued operations on both the source and the destination GPUs have completed. This mode is recommended when the order of submission of GPU tasks is unknown. When the *performSync* parameter is set to *false*, no internal engine synchronization is performed.

When the order of GPU task submission is known, it is recommended to perform synchronization manually using GPU semaphores and set the *performSync* parameter to *false*.

Resource transfers with specified source or destination sub-regions (partial transfers) are only supported by the D3D engine. When using the DMA engine to perform the transfer between GPUs, the *pSrcRegion* and *pDstRegion* parameters must be set to *nullptr*. When an engine that does not support partial transfers is used and either of these parameters is not *nullptr*, *ALVR_INVALID_PARAMETER* error is returned.

3.13 ALVRLateLatchConstantBufferDX11

Defines interface for Late Data Latch using D3D11 API.

Update

Update data in a new slot in the data constant buffer and move the current slot index to the next available slot. Typically, the data for VR rendering contains world, view and projection matrices calculated based on the most recent user head positions and orientations.

```
ALVR_RESULT Update(const void* pData, size_t offset, size_t size);
```

Parameters

pData

A pointer to a memory buffer which contains information such as view, projection and world matrices and other parameters. The format of the buffer is defined in the vertex shader.

offset

An offset in bytes in the current slot of the Late Latch constant buffer where the data will be copied to. Note that the offset applies to destination only.

size

The size of data in bytes to be copied to the Late Latch constant buffer.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL when the update fails

Remarks

It is important to note that a single call to the *Update()* method will update a single Late Data Latch buffer slot. Once *Update()* returns, the current slot index is incremented and previous slots can no longer be updated. Specifying a non-zero offset leaves the memory at the beginning of the slot uninitialized, therefore caution should be exercised every time *Update()* is called with a non-zero offset. A non-zero offset should only be used in cases when a portion of a Late Data Latch buffer slot needs to be filled by GPU (to provide GPU generated constants to the shader).

QueueLatch

Queue the latch of the latest data slot index in the D3D11 immediate context. During rendering the shader would use this index to retrieve the corresponding data from the data constant buffer.

```
ALVR_RESULT QueueLatch(void);
```

Parameters

Return

ALVR_OK on success

ALVR_FAIL when the update fails

GetIndexD3D11

Retrieve a pointer to a D3D11 buffer which contains a latched index (stored as a 32-bit unsigned integer). Using the index, the shader knows which slot of the data constant buffer contains the latest latched data.

```
ID3D11Buffer* GetIndexD3D11(void);
```

Parameters

None

Return

A pointer to an *ID3D11Buffer* that contains a 32-bit index of the current data slot in the buffer returned by *GetDataD3D11()*.

Remarks

Note that the reference counter of the buffer object returned is unaffected by this call. *AddRef()* should be called explicitly when this pointer is saved and a matching call to *Release()* should be performed when the saved pointer is no longer needed.

GetDataD3D11

Retrieve a pointer to a D3D11 data constant buffer which contains an array of data slots updated with the *Update()* method. The latched slot is referenced by an index stored in the constant buffer returned by the *GetIndexD3D11()* method.

```
ID3D11Buffer* GetDataD3D11(void);
```

Parameters

None

Return

A pointer to an *ID3D11Buffer* containing an array of updated data slots.

Remarks

Note that the reference counter of the buffer object returned is unaffected by this call. *AddRef()* should be called explicitly when this pointer is saved and a matching call to *Release()* should be performed when the saved pointer is no longer needed.

GetIndex

Retrieve a pointer to a LiquidVR buffer object which contains a latched index (stored as a 32-bit unsigned integer). Using the index, the shader knows which slot of the data constant buffer contains the latest latched data.

```
ALVRBuffer* GetIndex(void);
```

Parameters

None

Return

A pointer to an *ALVRBuffer* that contains a 32-bit index of the current data slot in the buffer returned by *GetData()*.

Remarks

Note that the reference counter of the buffer object returned is unaffected by this call. *AddRef()* should be called explicitly when this pointer is saved and a matching call to *Release()* should be performed when the saved pointer is no longer needed.

GetData

Retrieve a pointer to a LiquidVR buffer object which contains an array of data slots updated with the *Update()* method. The latched slot is referenced by an index stored in the constant buffer returned by the *GetIndex()* method.

```
ALVRBuffer* GetData(void);
```

Parameters

None

Return

A pointer to an *ALVRBuffer* containing an array of updated data slots.

Remarks

Note that the reference counter of the buffer object returned is unaffected by this call. *AddRef()* should be called explicitly when this pointer is saved and a matching call to *Release()* should be performed when the saved pointer is no longer needed.

3.14 ALVRComputeContext

The *ALVRComputeContext* interface is responsible for providing access to the Asynchronous Compute functionality in LiquidVR. The *ALVRComputeContext* interface inherits from the *ALVRPropertyStorage* interface.

CreateComputeTask

Create a new Asynchronous Compute task

```
ALVR_RESULT CreateComputeTask(ALVR_SHADER_MODEL shaderModel,
                              unsigned int flags,
                              const void* pCode,
                              size_t codeSize,
                              ALVRComputeTask** ppTask);
```

Parameters

shaderModel

Shader model (currently *ALVR_SHADER_MODEL_D3D11* only)

flags

Compute task flags, reserved for future use, currently ignored.

pCode

A pointer to a compiled shader bytecode. For *ALVR_SHADER_MODEL_D3D11* shader model this is the data returned by the *D3DCompileFromFile()* function (it is retrieved with *ID3DBlob::GetBufferPointer()* method on a compiled blob returned by the *D3DCompileFromFile()* function).

codeSize

The size of the shader bytecode passed in *pCode*.

ppTask

A pointer to the *ALVRComputeTask* interface representing the newly created task.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

CreateBuffer

Create a buffer resource for Asynchronous Compute.

```
ALVR_RESULT CreateBuffer(const ALVRBufferDesc* pDesc,
                                 ALVRBuffer** ppBuffer);
```

Parameters

pDesc

A pointer to the *ALVRBufferDesc* structure containing buffer creation parameters.

ppBuffer

A pointer to the *ALVRBuffer* interface representing the newly created buffer.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

Remarks

The *ALVRBufferDesc* structure describes the buffer being created and is defined as follows:

```
struct ALVRBufferDesc
{
    unsigned int        bufferFlags;
    unsigned int        cpuAccessFlags;
    unsigned int        apiSupport;
    size_t              size;
    size_t              structureStride;
    ALVR_FORMAT         format;
};
```

bufferFlags

A combination of the following values describing how the buffer is used by the shader:

- *ALVR_BUFFER_SHADER_INPUT* – the buffer is used as input by the Asynchronous Compute shader
- *ALVR_BUFFER_SHADER_OUTPUT* – the buffer is used as output by the Asynchronous Compute shader
- *ALVR_BUFFER_CONSTANT* – the buffer data is constant and is not modifiable by the Asynchronous Compute shader

cpuAccessFlags

A combination of the following values describing how the buffer is used by the CPU:

- *ALVR_CPU_ACCESS_NONE* – the buffer is not accessible to the CPU

- *ALVR_CPU_ACCESS_READ* – the buffer can be accessed by the CPU for reading
- *ALVR_CPU_ACCESS_WRITE* – the buffer can be accessed by the CPU for writing

apiSupport

A combination of the following values describing how the buffer is accessed through different APIs:

- *ALVR_RESOURCE_API_ASYNC_COMPUTE* – the buffer is used by an Asynchronous Compute shader
- *ALVR_RESOURCE_API_D3D11* – the buffer is used for rendering through the Direct3D 11 API
- ALVR_RESOURCE_API_VULKAN – the buffer will be used for Vulkan interop. It is an error to request ALVR_RESOURCE_API_VULKAN and *ALVR_RESOURCE_API_D3D11* support at the same time.

size

Buffer size in bytes.

structureStride

Size of the data element contained in the buffer. A buffer is organized as an array of equal size structures with the number of elements being equal to *size/structureStride*.

format

The format of data contained in the buffer. When the buffer is untyped, the *format* field should be set to *ALVR_FORMAT_UNKNOWN*.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

PinBuffer

Make an externally allocated buffer in system memory available to the GPU as a buffer resource.

```
ALVR_RESULT PinBuffer(const ALVRPinBufferDesc* pDesc,
                                ALVRBuffer** ppBuffer);
```

Parameters

pDesc

A pointer to the *ALVRPinBufferDesc* structure containing system memory pinning parameters.

ppBuffer

A pointer to the *ALVRBuffer* interface representing the pinned buffer.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

Remarks

The *ALVRPinBufferDesc* structure describes the buffer being created and is defined as follows:

```
struct ALVRBufferDesc
{
    void*               buffer;
    unsigned int        bufferFlags;        // ALVR_BUFFER_FLAGS
    size_t              size;               // 4K aligned
    size_t              structureStride;
    ALVR_FORMAT         format;
};
```

buffer

A pointer to a buffer in system memory to be pinned. Note that the buffer must be page-aligned and should be allocated using the *VirtualAlloc* Win32 API function.

bufferFlags

A combination of the following values describing how the buffer is used by the shader:

- *ALVR_BUFFER_SHADER_INPUT* – the buffer is used as input by the Asynchronous Compute shader
- *ALVR_BUFFER_SHADER_OUTPUT* – the buffer is used as output by the Asynchronous Compute shader
- *ALVR_BUFFER_CONSTANT* – the buffer data is constant and is not modifiable by the Asynchronous Compute shader

size

Buffer size in bytes.

structureStride

Size of the data element contained in the buffer. A buffer is organized as an array of equal size structures with the number of elements being equal to *size/structureStride*.

format

The format of data contained in the buffer. When the buffer in untyped, the *format* field should be set to *ALVR_FORMAT_UNKNOWN*.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

CreateSampler

Create a sampler object for Asynchronous Compute.

```
ALVR_RESULT CreateSampler(const ALVRSamplerDesc* pDesc,
                          ALVRSampler** ppSampler);
```

Parameters

spDesc

Sampler descriptor. A sample descriptor is represented by a structure of the *ALVRSamplerDesc* type:

```
struct ALVRSamplerDesc
{
   ALVR_FILTER_MODE    filterMode;
   ALVR_ADDRESS_MODE   addressU;
   ALVR_ADDRESS_MODE   addressV;
   ALVR_ADDRESS_MODE   addressW;
   unsigned int        maxAnisotropy;
   float               mipLodBias;
   float               minLod;
   float               maxLod;
   ALVR_BORDER_COLOR   borderColorType;
};
```

The *filterMode* field can be set to either:

- *ALVR_FILTER_POINT* for point sampling for minification, magnification and mip-level sampling (similar to *D3D11_FILTER_MIN_MAG_MIP_POINT* in Direct3D 11)
- *ALVR_FILTER_LINEAR* for linear interpolation for minification, magnification and mip-level sampling (similar to *D3D11_FILTER_MIN_MAG_MIP_LINEAR* in Direct3D 11)
- *ALVR_FILTER_MAG_LINEAR_MIN_POINT_MIP_POINT* for point sampling for minification, linear interpolation for magnification, point sampling for mip-level sampling (similar to *D3D11_FILTER_MIN_POINT_MAG_LINEAR_MIP_POINT* in Direct3D 11)
- *ALVR_FILTER_MAG_POINT_MIN_LINEAR_MIP_POINT* for point sampling for magnification, linear interpolation for minification, point sampling for mip-level sampling (similar to *D3D11_FILTER_MIN_LINEAR_MAG_POINT_MIP_POINT* in Direct3D 11)
- *ALVR_FILTER_MAG_LINEAR_MIN_LINEAR_MIP_POINT* for linear interpolation for minification, linear interpolation for magnification, point sampling for mip-level sampling (similar to *D3D11_FILTER_MIN_LINEAR_MAG_LINEAR_MIP_POINT* in Direct3D 11)
- *ALVR_FILTER_MAG_POINT_MIN_POINT_MIP_LINEAR* for point sampling for minification, point sampling for magnification, linear interpolation for mip-level sampling (similar to *D3D11_FILTER_MIN_POINT_MAG_POINT_MIP_LINEAR* in Direct3D 11)

- *ALVR_FILTER_MAG_LINEAR_MIN_POINT_MIP_LINEAR* for point sampling for minification and linear interpolation for magnification, linear interpolation for mip-level sampling (similar to *D3D11_FILTER_MIN_POINT_MAG_LINEAR_MIP_LINEAR* in Direct3D 11)
- *ALVR_FILTER_MAG_POINT_MIN_LINEAR_MIP_LINEAR* for linear interpolation for minification and point sampling for magnification, linear interpolation for mip-level sampling (similar to *D3D11_FILTER_MIN_LINEAR_MAG_POINT_MIP_LINEAR* in Direct3D 11)
- *ALVR_FILTER_ANISOTROPIC* for anisotropic interpolation (similar to *D3D11_FILTER_ANISOTROPIC* in Direct3D 11)

The *addressU*, *addressV* and *addressW* members specify a method to resolve a U, V or W texture coordinate outside the 0 to 1 range and can be set to one of the following values:

- *ALVR_ADDRESS_WRAP* – repeat the texture at every integer texture coordinate value
- *ALVR_ADDRESS_MIRROR* – flip and repeat the texture at every integer texture coordinate value
- *ALVR_ADDRESS_CLAMP* – texture coordinates below 0 are set to the texture color at 0 and coordinates above 1 are set to the texture color at 1
- *ALVR_ADDRESS_MIRROR_ONCE* – flip the texture once
- *ALVR_ADDRESS_CLAMP_BORDER* - texture coordinates below 0 and above 1 are set to one of the following values:
    - *ALVR_BORDER_COLOR_WHITE* – opaque white
    - *ALVR_BORDER_COLOR_TRANSPARENT_BLACK* – transparent
    - *ALVR_BORDER_COLOR_OPAQUE_BLACK* – opaque black

maxAnisotropy specifies the maximum degree of anisotropy supported (nominator of the ratio, anisotropic filter only). Valid values are integers between 1 and 16.

mipLodBias represents the offset from the mipmap level specified in the shader for fetching. For example, if a texture should be sampled at mipmap level 3 and *mipLodBias* is 2, then the texture will be sampled at mipmap level 5.

minLod is the lower end of the mipmap range to clamp access to, where 0 is the largest and most detailed mipmap level and any level higher than that is less detailed.

maxLod is the upper end of the mipmap range to clamp access to, where 0 is the largest and most detailed mipmap level and any level higher than that is less detailed. This value must be greater than or equal to *minLod*.

borderColorType defines the color of the border when any of the *addressU*, *addressV* and *addressW* members are set to *ALVR_ADDRESS_CLAMP_BORDER* and can be one of the following values:

- *ALVR_BORDER_COLOR_WHITE* – opaque white
- *ALVR_BORDER_COLOR_TRANSPARENT_BLACK* – transparent
- *ALVR_BORDER_COLOR_OPAQUE_BLACK* – opaque black

ppSampler

A pointer to the *ALVRSampler* interface representing the newly created sampler.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

CreateSurface

Create a surface object (a.k.a. texture or image) for Asynchronous Compute.

```
ALVR_RESULT CreateSurface(const ALVRSurfaceDesc* pDesc,
                          ALVRSurface** ppSurface);
```

Parameters

spDesc

Surface descriptor. A surface descriptor is represented by a structure of the *ALVRSurfaceDesc* type:

```
struct ALVRSurfaceDesc
{
    ALVR_SURFACE_TYPE   type;
    ALVR_FORMAT         format;
    unsigned int        surfaceFlags;
    unsigned int        apiSupport;
    unsigned int        width;
    unsigned int        height;
    union
    {
        unsigned int    depth;
        unsigned int    sliceCount;
    };
    ALVR_FORMAT         shaderInputFormat;
    ALVR_FORMAT         shaderOutputFormat;
    unsigned int        mipCount;
};
```

type can be set to either *ALVR_SURFACE_1D*, *ALVR_SURFACE_2D* or *ALVR_SURFACE_3D* for single dimension, two-dimensional and three-dimensional surfaces respectively

format specifies the pixel format of the surface being created.

surfaceFlags is a combination of the following values:

- *ALVR_SURFACE_SHADER_INPUT* – indicates that the surface is used as Asynchronous Compute shader input
- *ALVR_SURFACE_SHADER_OUTPUT* – indicates that the surface is used as Asynchronous Compute shader output
- *ALVR_SURFACE_RENDER_TARGET* – indicates that the surface is used for 3D rendering outside of Asynchronous Compute API (can be combined with either *ALVR_SURFACE_SHADER_INPUT,* or *ALVR_SURFACE_SHADER_OUTPUT*, or both)

apiSupport indicates which APIs a surface can be used with and can be any combination of the following values:

- *ALVR_SURFACE_API_ASYNC_COMPUTE* –the surface is used with Asynchronous Compute shaders
- *ALVR_SURFACE_API_D3D11* –the surface is used with Direct3D 11 API
- *ALVR_RESOURCE_API_VULKAN* – the surface can be used for Vulkan interop. It is an error to request *ALVR_RESOURCE_API_VULKAN* and *ALVR_SURFACE_API_D3D11* support at the same time.

The *width*, *height* and *depth* members specify the size of the surface for each dimension

1D and 2D surfaces can be created as arrays of slices of equal size, with *width*, *height* defining the size of each slice. The number of slices is determined by the *sliceCount* member. Slices are conceptually similar to Direct3D 11 texture arrays. Only 1D and 2D surfaces can be arrays, a 3D surface cannot be an array.

mipCount defines the number of mipmap levels in a surface

shaderInputFormat and *shaderOutputFormat* optionally define how the surface data should be interpreted by a shader when the surface is bound to a shader as input or output. These shader format overrides must be the same bit depth as the *format*. *shaderOutputFormat* must be a format that the shader can write. When these field are not in use, they should be set to *ALVR_FORMAT_UNKNOWN*.

ppSurface

A pointer to the *ALVRSurface* interface representing the newly created surface.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

CreateChildSurface

Create a surface object which provides access to a subset of subresources of the parent surface object. The child surface object inherits the number of mipmap levels and array slices from the parent surface and just restricts access to a defined subset of these subresources.

```
ALVR_RESULT CreateChildSurface(ALVRSurface* pParentSurface,
                           const ALVRChildSurfaceDesc* pDesc,
                           ALVRSurface** ppSurface);
```

Parameters

pParentSurface

A pointer to the parent surface

spDesc

The Child surface descriptor. A child surface descriptor is represented by a structure of the *ALVRChildSurfaceDesc* type:

```
struct ALVRChildSurfaceDesc
{
    unsigned int startMip;
    unsigned int mipCount;
    unsigned int startSlice;
    unsigned int sliceCount;
    ALVR_FORMAT  shaderInputFormat;
    ALVR_FORMAT  shaderOutputFormat;
};
```

startMip is the first mipmap level to be accessed within the child surface.

mipCount is the number of consecutive mipmap levels of the parent surface to be accessed within the child surface.

startSlice is the first slice to be accessed within the child surface.

sliceCount is the number of consecutive slices of the parent surface to be accessed within in the child surface.

shaderInputFormat and *shaderOutputFormat* optionally define format overrides when the surface is bound to a shader as input or output. These shader format overwrites must be the same bit depth as the *format* of the parent surface. *shaderOutputFormat* must be a format that the shader can write. When these field are not in use, they should be set to *ALVR_FORMAT_UNKNOWN*.

ppSurface

A pointer to the *ALVRSurface* interface representing the newly created surface.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

CreateTimestamp

Create the *ALVRComputeTimestamp* object

```
ALVR_RESULT CreateTimestamp(ALVRComputeTimestamp** ppTimestamp);
```

Parameters

ppTimestamp

A pointer to a location to receive a pointer to the *ALVRComputeTimestamp* interface.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *ppTimestamp* is *nullptr*

ALVR_FAIL on any other error

QueueTask

Queue an Asynchronous Compute task to the Asynchronous Compute context.

```
ALVR_RESULT QueueTask(ALVRComputeTask* pTask,
                      const ALVRPoint3D* pOffset,
                      const ALVRSize3D* pSize);
```

Parameters

pTask

A pointer to an *ALVRComputeTask* object.

pOffset

Offsets used to calculate threadgroup indices in the shader. The *ALVRPoint3D* structure is defined as follows:

```
struct ALVRPoint3D
{
    unsigned int x;
    unsigned int y;
    unsigned int z;
};
```

For 2D tasks only *x* and *y* fields are used, for 1D tasks only the *x* field is used.

When *pOffset* is *nullptr*, it will be assumed that the threadgroup indices starts at zero value.

pSize

Dimensions of the task in threadgroups. The *ALVRSize3D* structure is defined as follows:

```
struct ALVRSize3D
{
    unsigned int width;
    unsigned int height;
    unsigned int depth;
};
```

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *ppTimestamp* is *nullptr*

ALVR_FAIL on any other error

Remarks

Note that queuing a task does not start it, but rather just adds it to the task queue. To execute all queued tasks call the *ALVRComputeContext::Flush()* method.

QueueTimestamp

Queue a GPU timestamp write request to the Asynchronous Compute context.

```
ALVR_RESULT QueueTimestamp(ALVRComputeTimestamp* pTimestamp);
```

Parameters

pTimestamp

A pointer to an *ALVRComputeTimestamp* object.

Return

ALVR_OK on success

ALVR_FAIL on any error

QueueSemaphoreSignal

Queue a GPU semaphore signal request to the Asynchronous Compute context.

```
ALVR_RESULT QueueSemaphoreSignal(ALVRGpuSemaphore* pSemaphore);
```

Parameters

pTimestamp

A pointer to an *ALVRGpuSemaphore* object.

Return

ALVR_OK on success

ALVR_FAIL on any error

QueueSemaphoreWait

Queue a GPU semaphore wait request to the Asynchronous Compute context.

```
ALVR_RESULT QueueSemaphoreWait(ALVRGpuSemaphore* pSemaphore);
```

Parameters

pTimestamp
A pointer to an *ALVRGpuSemaphore* object.

Return
ALVR_OK on success

ALVR_FAIL on any error

QueueCopyBufferToBuffer

Queue a request to copy a region in a buffer to another buffer using the Asynchronous Compute context.

```
ALVR_RESULT QueueCopyBufferToBuffer(ALVRBuffer* pSrc,
                                    size_t srcOffset,
                                    ALVRBuffer* pDst,
                                    size t dstOffset,
                                    size_t size);
```

Parameters

pSrc
A pointer to the source *ALVRBuffer* object.

srcOffset
The offset in bytes in the source buffer to copy data from.

pDst
A pointer to the destination *ALVRBuffer* object.

dstOffset
The offset in bytes in the destination buffer to copy data to.

size
The size in bytes of the buffer region to be copied.

Return
ALVR_OK on success

ALVR_INVALID_ARGUMENT when *pSrc* or *pDst* are *nullptr* or when *size* is 0

ALVR_FAIL on any other error

QueueCopyBufferToSurface

Queue a request to copy a buffer region to a surface using the Asynchronous Compute context.

```
ALVR_RESULT QueueCopyBufferToSurface(ALVRBuffer* pSrc,
                                     size_t srcOffset,
                                     ALVRSurface* pDst,
                                     const ALVRBox* pDstBox);
```

Parameters

pSrc

A pointer to the source *ALVRBuffer* object.

srcOffset

The offset in bytes in the source buffer to copy surface data from.

pDst

A pointer to the destination *ALVRSurface* object.

pDstBox

The destination surface region to copy data to. The *ALVRBox* structure is defined as follows:

```
struct ALVRBox
{
    unsigned int left;
    unsigned int top;
    unsigned int front;
    unsigned int right;
    unsigned int bottom;
    unsigned int back;
};
```

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *pSrc*, *pDst* or *pDstBox* are *nullptr* or when *size* is 0

ALVR_FAIL on any error

QueueCopySurfaceToSurface

Queue a request to copy a surface region to another surface using the Asynchronous Compute context.

```
ALVR_RESULT QueueCopySurfaceToSurface(ALVRSurface* pSrc,
                                      const ALVRBox* pSrcBox,
                                      ALVRSurface* pDst,
                                      const ALVRPoint3D* pDstOffset);
```

Parameters

pSrc

A pointer to the source *ALVRSurface* object.

pSrcBox

The source surface region to copy data from. When *pSrcBox* is *nullptr*, it is assumed that the entire source surface is being copied.

pDst

A pointer to the destination *ALVRSurface* object.

pDstOffset

The destination surface offset to the region where data is copied. The *ALVRPoint3D* structure is defined as follows:

```
struct ALVRPoint3D
{
    unsigned int x;
    unsigned int y;
    unsigned int z;
};
```

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *pSrc* or *pDst* are *nullptr* or when *size* is 0

ALVR_FAIL on any error

QueueCopySurfaceToBuffer

Queue a request to copy a surface region to a buffer using the Asynchronous Compute context.

```
ALVR_RESULT QueueCopySurfaceToBuffer(ALVRSurface* pSrc,
                                     const ALVRBox* pSrcBox,
                                     ALVRBuffer* pDst,
                                     size_t dstOffset);
```

Parameters

pSrc

A pointer to the source *ALVRSurface* object.

pSrcBox

The source surface region to copy data from. When *pSrcBox* is *nullptr*, it is assumed that the entire source surface is being copied.

pDst

A pointer to the destination *ALVRBuffer* object.

dstOffset

An offset in bytes in the destination buffer to copy data to.

When *pDstOffset* is *nullptr*, it is assumed that copied region starts at the beginning of the destination buffer.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *pSrc* or *pDst* are *nullptr* or when *size* is 0

ALVR_FAIL on any error

Flush

Execute all operations previously queued to the Asynchronous Compute context and optionally trigger a fence when the last operation is completed.

```
ALVR_RESULT Flush(ALVRFence* pFence);
```

Parameters

pFence

An optional fence to be triggered when the last operation queued to the Asynchronous Compute prior to flush is completed.

Return

ALVR_OK on success

ALVR_FAIL on any error

OpenSharedBuffer

Open a buffer created outside of the Asynchronous Compute context using a shared handle. The buffer can be shared between different processes, devices and different APIs, such as Direct3D 11 and LiquidVR.

```
ALVR_RESULT OpenSharedBuffer(const ALVROpenBufferDesc* pDesc,
                             ALVRBuffer** ppBuffer);
```

Parameters

pDesc

A pointer to the *ALVROpenBufferDesc* structure containing parameters for opening a shared buffer.

ppBuffer

A pointer to the *ALVRBuffer* interface representing the newly opened buffer.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

Remarks

The *OpenSharedBuffer* method allows sharing a buffer between Direct3D and LiquidVR, within a process or between multiple processes. For more information on shared resources please refer to the following MSDN article:

https://msdn.microsoft.com/en-us/library/windows/desktop/bb219800(v=vs.85).aspx#Sharing_Resources

The *ALVROpenBufferDesc* structure describes the opened buffer and is defined as follows:

```
struct ALVROpenBufferDesc
{
    HANDLE              sharedHandle;
    unsigned int        bufferFlags;
    size_t              structureStride;
    ALVR_FORMAT         format;
    unsigned int        openFlags;
};
```

sharedHandle

A shared resource handle obtained from D3D11 API.

bufferFlags

A combination of the following values describing how the buffer is used by the shader:

ALVR_BUFFER_SHADER_INPUT – the buffer is used as input by the Asynchronous Compute shader

ALVR_BUFFER_SHADER_OUTPUT – the buffer is used as output by the Asynchronous Compute shader

ALVR_BUFFER_CONSTANT – the buffer is constant and is not modifiable by the Asynchronous Compute shader

structureStride

Size of the data element contained in the buffer. A buffer is organized as an array of equal size structures with the number of elements being equal to *size/structureStride*.

format

The format of data contained in the buffer. When the buffer is untyped, the *format* field should be set to *ALVR_FORMAT_UNKNOWN*.

openFlags

Reserved. Must be set to 0.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

OpenSharedSurface

Open a surface object created outside of the Asynchronous Compute context using a shared resource handle. The surface can be shared between different processes, devices and different APIs, such as Direct3D 11 and LiquidVR.

```
ALVR_RESULT OpenSharedSurface(const ALVROpenSurfaceDesc* pDesc,
                              ALVRSurface** ppSurface);
```

Parameters

spDesc

Surface descriptor. A sample descriptor is represented by a structure of the *ALVROpenSurfaceDesc* type.

ppSurface

A pointer to the *ALVRSurface* interface representing the newly opened surface.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL on any other error

Remarks

The *OpenSharedSurface* method allows sharing a surface between Direct3D and LiquidVR, within a process or between multiple processes. For more information on shared resources please refer to the following MSDN article:

https://msdn.microsoft.com/en-us/library/windows/desktop/bb219800(v=vs.85).aspx#Sharing_Resources

The *ALVROpenSurfaceDesc* structure describes the opened surface and is defined as follows:

```
struct ALVROpenSurfaceDesc
{
    HANDLE              sharedHandle;
    ALVR_FORMAT         format;
    unsigned int        surfaceFlags;
    unsigned int        openFlags;
    ALVR_FORMAT         shaderInputFormat;
    ALVR_FORMAT         shaderOutputFormat;
    unsigned int        sliceCount;
    unsigned int        mipCount;
    unsigned int        sampleCount;
    unsigned int        type
};
```

sharedHandle

A texture handle obtained from APIs like *Direct3DDevice9::CreateTexture* when the *pSharedHandle* parameter is not *nullptr*.

format

Surface format of the opened surface, which must be the same bit-depth as the format of the original shared surface.

surfaceFlags

is a combination of the following values:

ALVR_SURFACE_SHADER_INPUT – indicates that the surface is used as Asynchronous Compute shader input

ALVR_SURFACE_SHADER_OUTPUT – indicates that the surface is used as Asynchronous Compute shader output

ALVR_SURFACE_RENDER_TARGET – indicates that the surface is used for 3D rendering outside of Asynchronous Compute API (can be combined with either *ALVR_SURFACE_SHADER_INPUT*, or *ALVR_SURFACE_SHADER_OUTPUT*, or both)

openFlags

Reserved. Must be set to 0.

shaderInputFormat

shaderOutputFormat

shaderInputFormat and *shaderOutputFormat* optionally define how the surface data should be interpreted by a shader when the surface is bound to a shader as input or output. These shader format overrides must be the same bit depth as the *format*. When these field are not in use, they should be set to *ALVR_FORMAT_UNKNOWN*.

sliceCount

The number of surface slices for surface arrays.

mipCount

The number of surface mipmap levels.

3.15 ALVRComputeTask

BindConstantBuffer

Bind a constant buffer to an Asynchronous Compute task.

```
ALVR_RESULT BindConstantBuffer(unsigned int slot, ALVRBuffer* pBuffer);
```

Parameters

slot

A zero-based index of a constant buffer slot.

pBuffer

A pointer to an *ALVRBuffer* object.

Return

ALVR_OK on success

ALVR_FAIL on any error

BindSampler

Bind a sampler to an Asynchronous Compute task.

```
ALVR_RESULT BindSampler(unsigned int slot, ALVRSampler* pBuffer);
```

Parameters

slot

A zero-based index of a sampler slot.

pSampler

A pointer to an *ALVRSampler* object.

Return

ALVR_OK on success

ALVR_FAIL on any error

BindInput

Bind a resource as input to an Asynchronous Compute task.

```
ALVR_RESULT BindInput(unsigned int slot, ALVRResource* pResource);
```

Parameters

slot

A zero-based index of an input resource slot.

pResource

A pointer to an *ALVRResource* object to be used as input by the shader.

Return

ALVR_OK on success

ALVR_FAIL on any error

BindOutput

Bind a resource as output to an Asynchronous Compute task.

```
ALVR_RESULT BindOutput(unsigned int slot, ALVRResource* pResource);
```

Parameters

slot

A zero-based index of an output resource slot.

pResource

A pointer to an *ALVRResource* object to be used as output by the shader.

Return

ALVR_OK on success

ALVR_FAIL on any error

CreateFence

Create a GPU fence. GPU fence is a special synchronization object which allows the CPU to wait for an event triggered by the GPU. This method is provided on the *ALVRComputeTask* class for applications that do not create a *ALVRDeviceExD3D11* object.

```
ALVR_RESULT CreateFence(ALVRFence** ppFence);
```

Parameters

ppFence
A pointer to a location which will receive a pointer to the *ALVRFence* interface.

Return
ALVR_OK on success

ALVR_INVALID_ARGUMENT when *ppFence* is *nullptr*

ALVR_FAIL on any other error

3.16 ALVRComputeTimestamp

GetValue

Get the value of an Asynchronous Compute timestamp once it is written by an operation queued to the Asynchronous Compute context with *QueueTimestamp*. Use a fence to ensure timestamps are available before retrieving them.

```
ALVR_RESULT GetValue(uint64_t* pValue);
```

Parameters

pValue
A pointer to receive a 64-bit GPU timestamp value.

Return
ALVR_OK on success

ALVR_FAIL on any error

3.17 ALVRBuffer

GetSize

Get size of a buffer.

```
size_t GetSize(void) const;
```

Parameters

None.

Return
Size of the buffer in bytes.

Map

Map a GPU buffer into a CPU address space and return a pointer to the buffer in system memory for CPU access.

```
ALVR_RESULT Map(void** pData);
```

Parameters

pData

Returned CPU pointer to mapped GPU buffer memory.

Return

ALVR_OK on success

ALVR_FAIL on any error

Remarks

A call to *ALVRBuffer::Map()* maps GPU memory to the CPU address space. The pointer to a buffer in system memory remains valid until *ALVRBuffer::Unmap()* is called. Calls to *ALVRBuffer::Map()* and *ALVRBuffer::Unmap()* are not reference-counted, i.e. subsequent calls to *ALVRBuffer::Map()* on an already mapped buffer will return the same pointer and a single call to *ALVRBuffer::Unmap()* would unmap the buffer regardless of how many times *ALVRBuffer::Map()* has been called.

Unmap

Unmap a GPU buffer previously mapped with *ALVRBuffer::Map()*.

```
ALVR_RESULT Unmap(void);
```

Parameters

None.

Return

ALVR_OK on success

ALVR_FAIL on any error

3.18 ALVRResourceD3D11

An encapsulation type for a Direct3D 11 resource, defined as follows:

```
struct ALVRResourceD3D11
{
    ID3D11Resource* pResource;
};
```

3.19 ALVRResource

The *ALVRResource* interface is a common interface to access ALVR resources.

GetApiResource

Retrieve native API-specific resource object.

```
ALVR_RESULT GetApiResource(ALVR_RENDER_API renderApi, void* pResource);
```

Parameters

renderApi

An ID of the rendering API to retrieve native resource object for. Can be one of the following values:

- *ALVR_RENDER_API_D3D11* for Direct3D 11
- *ALVR_RENDER_API_ASYNC_COMPUTE* for Asynchronous Compute
- *ALVR_RENDER_API_VULKAN* for Vulkan interop. It is an error to use this renderApi type if the resource has not been created with Vulkan support.

pResource

A pointer to a location to receive the requested resource. The type of this object is API dependent (passed in the *renderApi* parameter).

For Direct3D 11, it is a structure of type *ALVRResourceD3D11*:

```
struct ALVRResourceD3D11
{
    ID3D11Resource* pResource;
};
```

For Vulkan, it is a structure of type *ALVRResourceVulkan*:

```
enum ALVR_VULKAN_RESOURCE_TYPE
{
    ALVR_VULKAN_RESOURCE_BUFFER = 0,
    ALVR_VULKAN_RESOURCE_IMAGE = 1
};

struct ALVRResourceVulkan
{
    ALVR_VULKAN_RESOURCE_TYPE resourceType;
    union
    {
        VkBuffer buffer;
        VkImage  image;
    };
};
```

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when any of the parameters are invalid

ALVR_FAIL when the update fails

3.20 ALVRSurface

The *ALVRSurface* interface provides access to a surface object. *ALVRSurface* inherits from *ALVRResource*. Currently the *ALVRSurface* interface does not add any additional methods to the *ALVRResource* interface.

To create a LiquidVR surface, call the *ALVRComputeContext::CreateSurface()* method.

LiquidVR surface, specified at creation, can be 1D, 2D, 3D or CUBE as defined by the *ALVR_SURFACE_TYPE* enumeration as follows:

```
enum ALVR_SURFACE_TYPE
{
    ALVR_SURFACE_1D,
    ALVR_SURFACE_2D,
    ALVR_SURFACE_3D,
    ALVR_SURFACE_CUBE   = 3,
};
```

A surface's pixel format is defined by the *ALVR_FORMAT* enumeration defined as follows:

```
enum ALVR_FORMAT
{
    ALVR_FORMAT_UNKNOWN = 0,
    ALVR_FORMAT_R32G32B32A32_FLOAT = 2,
    ALVR_FORMAT_R32G32B32A32_UINT = 3,
    ALVR_FORMAT_R32G32B32A32_SINT = 4,
    ALVR_FORMAT_R16G16B16A16_FLOAT = 10,
    ALVR_FORMAT_R16G16B16A16_UNORM = 11,
    ALVR_FORMAT_R16G16B16A16_UINT = 12,
    ALVR_FORMAT_R16G16B16A16_SNORM = 13,
    ALVR_FORMAT_R16G16B16A16_SINT = 14,
    ALVR_FORMAT_R32G32_FLOAT = 16,
    ALVR_FORMAT_R32G32_UINT = 17,
    ALVR_FORMAT_R32G32_SINT = 18,
    ALVR_FORMAT_R10G10B10A2_UNORM = 24,
    ALVR_FORMAT_R10G10B10A2_UINT = 25,
    ALVR_FORMAT_R11G11B10_FLOAT = 26,
    ALVR_FORMAT_R8G8B8A8_UNORM = 28,
    ALVR_FORMAT_R8G8B8A8_UNORM_SRGB = 29,
    ALVR_FORMAT_R8G8B8A8_UINT = 30,
    ALVR_FORMAT_R8G8B8A8_SNORM = 31,
    ALVR_FORMAT_R8G8B8A8_SINT = 32,
    ALVR_FORMAT_R16G16_FLOAT = 34,
    ALVR_FORMAT_R16G16_UNORM = 35,
    ALVR_FORMAT_R16G16_UINT = 36,
    ALVR_FORMAT_R16G16_SNORM = 37,
    ALVR_FORMAT_R16G16_SINT = 38,
    ALVR_FORMAT_R32_FLOAT = 41,
    ALVR_FORMAT_R32_UINT = 42,
    ALVR_FORMAT_R32_SINT = 43,
    ALVR_FORMAT_R8G8_UNORM = 49,
    ALVR_FORMAT_R8G8_UINT = 50,
    ALVR_FORMAT_R8G8_SNORM = 51,
    ALVR_FORMAT_R8G8_SINT = 52,
    ALVR_FORMAT_R16_FLOAT = 54,
    ALVR_FORMAT_R16_UNORM = 56,
    ALVR_FORMAT_R16_UINT = 57,
    ALVR_FORMAT_R16_SNORM = 58,
    ALVR_FORMAT_R16_SINT = 59,
    ALVR_FORMAT_R8_UNORM = 61,
    ALVR_FORMAT_R8_UINT = 62,
    ALVR_FORMAT_R8_SNORM = 63,
    ALVR_FORMAT_R8_SINT = 64,
    ALVR_FORMAT_R9G9B9E5_SHAREDEXP = 67,
    ALVR_FORMAT_BC1_UNORM = 71,
    ALVR_FORMAT_BC1_UNORM_SRGB = 72,
    ALVR_FORMAT_BC2_UNORM = 74,
    ALVR_FORMAT_BC2_UNORM_SRGB = 75,
    ALVR_FORMAT_BC3_UNORM = 77,
    ALVR_FORMAT_BC3_UNORM_SRGB = 78,
```

```
    ALVR_FORMAT_BC4_UNORM = 80,
    ALVR_FORMAT_BC4_SNORM = 81,
    ALVR_FORMAT_BC5_UNORM = 83,
    ALVR_FORMAT_BC5_SNORM = 84,
    ALVR_FORMAT_B5G6R5_UNORM = 85,
    ALVR_FORMAT_B5G5R5A1_UNORM = 86,
    ALVR_FORMAT_B8G8R8A8_UNORM = 87,
    ALVR_FORMAT_B8G8R8X8_UNORM = 88,
    ALVR_FORMAT_B8G8R8A8_UNORM_SRGB = 91,
    ALVR_FORMAT_B8G8R8X8_UNORM_SRGB = 93,
    ALVR_FORMAT_BC6H_UF16 = 95,
    ALVR_FORMAT_BC6H_SF16 = 96,
    ALVR_FORMAT_BC7_UNORM = 98,
    ALVR_FORMAT_BC7_UNORM_SRGB = 99,
    ALVR_FORMAT_NV12 = 103,
    ALVR_FORMAT_FORCE_UINT = 0xffffffff
};
```

3.20.1 Accessing Surfaces of Multi-Plane Formats

Pixel formats stored as multiple planes, such as NV12, can have their planes accessed individually using Child Surfaces created using the *ALVRComputeContext::CreateChildSurface()* method. Each child surface represents a single plane of the parent surface.

Note that a call to *GetApiResource()* on a child surface would still return the same native resource as the parent object, however, when a child *ALVRSurface* object is bound to a shader, the shader would be given a pointer to the correct plane in the GPU memory.

Which plane a child surface is to be associated with is determined by the value of the *shaderInputFormat* or *shaderOutputFormat* fields of the *ALVRChildSurfaceDesc* structure passed to *ALVRComputeContext::CreateChildSurface().* The following mappings are supported:

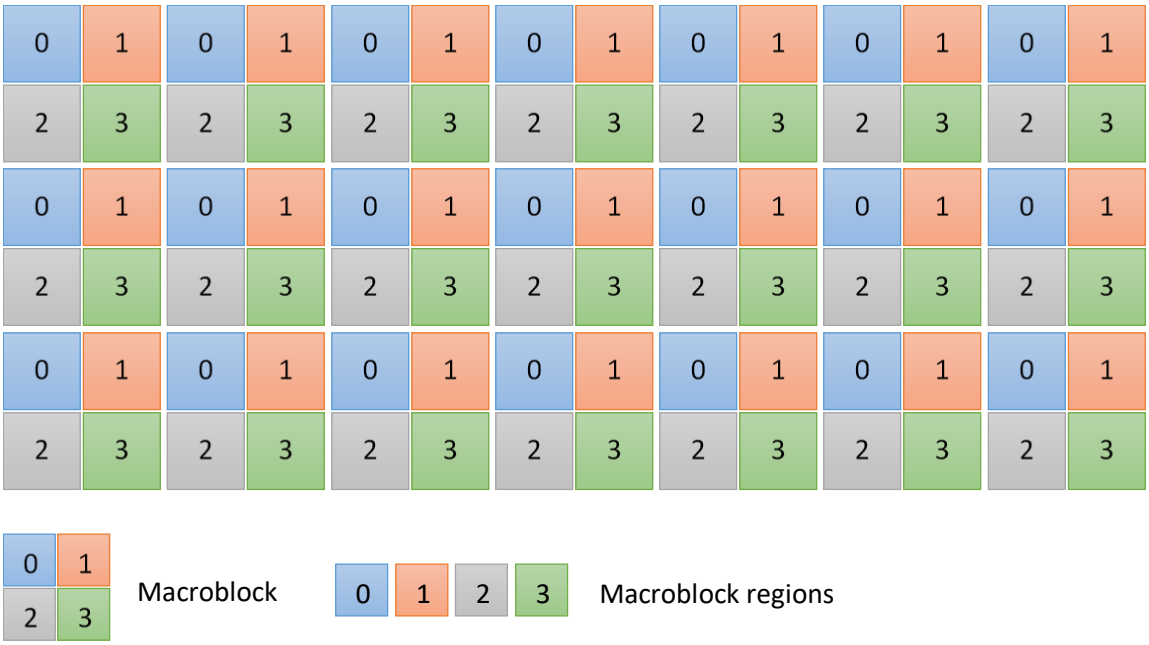
Surface Format	Child Surface Format	Mapped Resource
ALVR_FORMAT_NV12	ALVR_FORMAT_R8_UNORM, ALVR_FORMAT_R8_SNORM, ALVR_FORMAT_R8_UINT, ALVR_FORMAT_R8_SINT	Y plane, 8 bits per entry
	ALVR_FORMAT_R8G8_UNORM, ALVR_FORMAT_R8G8_SNORM, ALVR_FORMAT_R8G8_UINT, ALVR_FORMAT_R8G8_SINT	UV plane, 16 bits per entry

3.21 ALVRMotionEstimator

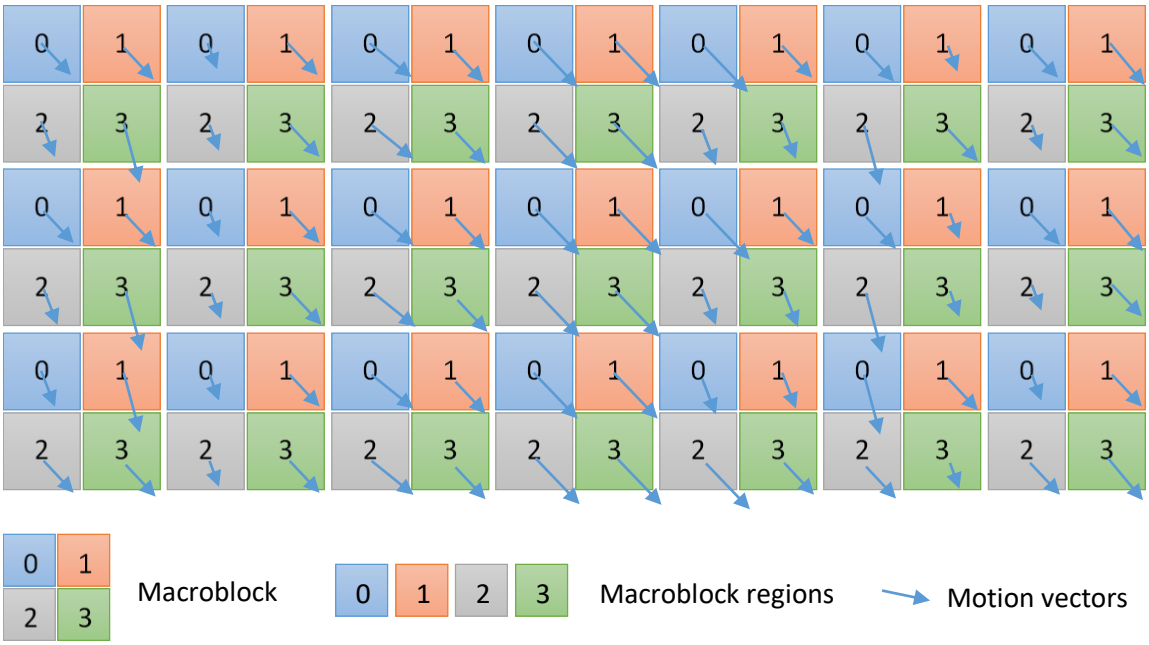
The *ALVRMotionEstimator* interface is used to generate motion vectors from two consecutive frames.

Note that motion estimation is currently supported on the R9 Fury™, RX480™, RX470™ and RX460™ families of products only.

Motion vectors are returned in a buffer located in the GPU memory. Motion vectors are calculated per a region of a macroblock and are represented by region's coordinates in fractions of a pixel. The size of the macroblock, the number of regions per macroblock and the motion vector precision are hardware-specific.



The diagram above represents a 7x3 macroblock image with each macroblock being split into four regions. Each region is associated with a single motion vector specifying the new absolute coordinates of the region relative to the previous frame.



Each motion vector is represented by a pair of integer values containing the *x* and *y* coordinates of the location the region is moving towards. The precision of motion vectors can be sub-pixel and is defined by the underlying hardware.

The buffer containing motion vectors contains an array of the following structures, with each element representing one region of a macroblock, ordered as shown in the above image:

```
struct ALVRMotionVector
{
    int16_t x;
    int16_t y;
    int16_t reserved[2];
};
```

Values stored in the *x* and *y* fields are in units specified in the *precision* field returned in the *ALVRMotionEstimatorDesc* structure.

GetDesc

Get motion estimator's capabilities.

```
ALVR_RESULT ALVR_STD_CALL GetDesc(ALVRMotionEstimatorDesc* pDesc);
```

Parameters

pDesc

A pointer to an *ALVRMotionEstimatorDesc* structure defined as follows:

```
struct ALVRMotionEstimatorDesc
{
    uint32_t maxWidthInPixels;
    uint32_t maxHeightInPixels;
    uint32_t mbWidth;
    uint32_t mbHeight;
    uint32_t regionWidth;
    uint32_t regionHeight;
    ALVRRational precision;
};
```

The *ALVRMotionEstimatorDesc* structure contains the following fields:

Field	Description
maxWidthInPixels	Max supported width of input surfaces
maxHeightInPixels	Max supported height of input surfaces
mbWidth	Macroblock width in pixels
mbHeight	Macroblock height in pixels
regionWidth	Region width
regionHeight	Region height
precision	Motion vector precision (numerator and denominator), in fractions of a pixel

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *pDesc* is *nullptr*.

ALVR_NOT_INITIALIZED when the motion estimator has failed to initialize.

Open

Open the motion estimator configuring it with specific parameters. The motion estimator cannot accept frames until it is opened.

```
ALVR_RESULT ALVR_STD_CALL Open(ALVRMotionEstimatorConfig* pConfig);
```

Parameters

pConfig

A pointer to an *ALVRMotionEstimatorConfig* structure defined as follows:

```
struct ALVRMotionEstimatorConfig
{
    uint32_t width;      //  width of input surfaces in pixels
    uint32_t height;     //  height of input surfaces in pixels
};
```

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *pConfig* is *nullptr*.

ALVR_NOT_INITIALIZED when the motion estimator has failed to initialize.

Close

Close the motion estimator. The motion estimator cannot be used again after it has been closed until it is reopened.

```
ALVR_RESULT ALVR_STD_CALL Close();
```

Parameters

None

Return

ALVR_OK on success

ALVR_NOT_INITIALIZED when the motion estimator has failed to initialize.

SubmitFrames

Submit frames for motion vector estimation.

```
ALVR_RESULT ALVR_STD_CALL SubmitFrames(ALVRSurface* curFrame,
ALVRSurface* prevFrame, ALVRBuffer* motionVectors,
const void* opt, int64_t* jobID);
```

Parameters

curFrame

A pointer to an *ALVRSurface* object containing the current frame

prevFrame

A pointer to an *ALVRSurface* object containing the previous frame

motionVectors

A pointer to an *ALVRBuffer* buffer to receive estimated motion vectors. The buffer must be kept alive and not reused until *ALVRMotionEstimator::QueryMotionVectors* is called to retrieve the result.

The buffer must be created with the *ALVR_RESOURCE_API_MOTION_ESTIMATOR* API enabled by setting the appropriate bit in the *apiSupport* field of the *ALVRBufferDesc* structure. The *ALVR_RESOURCE_API_MOTION_ESTIMATOR* API can be combined with the *ALVR_RENDER_API_D3D11* or *ALVR_RENDER_API_ASYNC_COMPUTE* APIs, but is incompatible with the *ALVR_RENDER_API_VULKAN* API.

opt

A pointer to the optional data to be passed to motion estimator. Currently ignored and should be set to *nullptr*.

jobID

An optional pointer to a 64-bit integer to receive a Job ID assigned to the motion estimator. When the motion estimator completes the job and results are retrieved using *ALVRMotionEstimator::QueryMotionVectors*, the latter call would return the same Job ID allowing to match the output to the input frames when *ALVRMotionEstimator::QueryMotionVectors* is called asynchronously.

This parameter can be set to *nullptr* when not needed.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *pConfig* is *nullptr*.

ALVR_NOT_INITIALIZED when the motion estimator has failed to initialize.

QueryMotionVectors

Retrieve the result of a previously queued motion estimation job. The resulting motion vectors are placed in the *ALVRBuffer* object provided to the corresponding *ALVRMotionEstimator::SubmitFrames* call.

```
ALVR_RESULT ALVR_STD_CALL QueryMotionVectors(int64_t* jobID);
```

Parameters

jobID

An optional pointer to a 64-bit integer to receive a Job ID assigned to the motion estimator. The job ID returned by this method matches the value returned by the corresponding *ALVRMotionEstimator::SubmitFrames* call.

This parameter can be set to *nullptr* when not needed.

Return

ALVR_OK on success

ALVR_INVALID_ARGUMENT when *pConfig* is *nullptr*.

ALVR_NOT_INITIALIZED when the motion estimator has failed to initialize.

3.22 ALVRExtensionVulkan

The *ALVRExtensionVulkan* interface provides the base functionality for interoperability between LiquidVR and Vulkan. This interface provides access to multi device information and allows a LiquidVR Vulkan device to be created. The LiquidVR Vulkan device or *ALVRDeviceExVulkan* interface is used for converting LiquidVR resources(buffers, surfaces, semaphores) to Vulkan handles.

The following example code demonstrates how to find a LiquidVR display from a Vulkan device handle:

```
ALVRVulkanMultiDeviceInfo multDeviceInfo = {};
res=pExtensionVk->GetMultiDeviceInfo(GetVkDevice(), &multDeviceInfo);
...
// Match the LUID
ALVRDisplayInfoEnumerator* pEnumerator = NULL;
res=testParams->m_pDisplayManager->EnumerateDisplays
(ALVR_DISPLAY_VISIBILITY_PUBLIC, &pEnumerator);

bool foundIt = false;
for (int index = 0;; index++)
{
   ALVRDisplayInfo *display = NULL;
   if (pEnumerator->Next(&display) != ALVR_OK)
   {
      break;
   }
   ALVRDisplayAdapterInfo adapterInfo = {};
   if (ALVR_OK == display->GetAdapterInfo(&adapterInfo))
   {
      LUID adapterLuid = adapterInfo.adapterLuid;
      if (adapterLuid.LowPart == multDeviceInfo.adapterLuid.LowPart &&
adapterLuid.HighPart == multDeviceInfo.adapterLuid.HighPart)
      {
          foundIt = true;
          break;
      }
   }
}
pEnumerator->Release();
```

GetMultiDeviceInfo

Returns an *ALVRVulkanMultiDeviceInfo* structure for a specific Vulkan device handle.

```
ALVR_RESULT GetMultiDeviceInfo (VkDevice vkDevice, ALVRVulkanMultiDeviceInfo*
pInfo);
```

Parameters

vkDevice

A handle to a Vulkan device.

pInfo

A pointer to a location which will receive a pointer of the *ALVRVulkanMultiDeviceInfo* defined as follows:

```
struct ALVRVulkanMultiDeviceInfo
{
    LUID                    adapterLuid;
    unsigned int            gpuIdx;
};
```

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_FAIL on any error.

CreateALVRDeviceExVulkan

Create an instance of the *ALVRDeviceExVulkan* interface for a specific Vulkan device handle. *ALVRDeviceExVulkan* inherits from *ALVRDeviceEx* and can be used as a device parameter in other LiquidVR methods.

```
ALVR_RESULT CreateALVRDeviceExVulkan (VkDevice vkDevice,
                                      void* pConfigDesc,
                                      ALVRDeviceExVulkan **ppDeviceEx);
```

Parameters

vkDevice

A handle to a Vulkan device.

pConfigDesc

Optional configuration parameters. Must be *nullptr*.

ppDeviceEx

A pointer to a location which will receive a pointer of the *ALVRDeviceExVulkan* interface.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_FAIL on any error.

3.23 ALVRDeviceExVulkan

This class provides the functionality which allows the conversion from LiquidVR to Vulkan objects. Interoperability between buffers, surfaces and semaphores is provided.

Important notes:

1. Fences can be created using the *ALVRComputeContext::CreateFence()* method. Initialize the compute context with a *ALVRDeviceExVulkan* device.

2. The Vulkan handles that are returned by the methods of this interface represent pointers and are created by an internal Vulkan extension of the AMD driver. This requires that the following validation layers be turned off in a Vulkan application:
    a. VK_LAYER_LUNARG_object_tracker
    b. VK_LAYER_GOOGLE_unique_objects

OpenSharedBuffer

Create a Vulkan buffer handle from a shared resource.

```
ALVR_RESULT OpenSharedBuffer(const ALVRVulkanOpenBufferDesc* pDesc,
                             VkBuffer* pBuffer);
```

Parameters

pDesc

A pointer to the *ALVRVulkanOpenBufferDesc* defined as follows:

```
struct ALVRVulkanOpenBufferDesc
{
    HANDLE                  sharedHandle;   // Shared resource handle
    unsigned int            flags;          // Reserved for now, should be 0.
    unsigned int            usage;
    uint32_t                queueFamilyIndexCount;
    const uint32_t*         pQueueFamilyIndices;
    ALVR_OPEN_SHARED_FLAGS  sharedFlags;
};
```

pBuffer

A pointer to a location that will receive the Vulkan buffer.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_FAIL on any error.

OpenSharedImage

Create a Vulkan image handle from a shared resource.

```
ALVR_RESULT OpenSharedImage(const ALVRVulkanOpenSurfaceDesc* pDesc,
                            VkImage* pImage);
```

Parameters

pDesc

A pointer to the *ALVRVulkanOpenSurfaceDesc* defined as follows:

```
struct ALVRVulkanOpenSurfaceDesc
{
    HANDLE sharedHandle;             // Shared resource handle
    unsigned int flags;  // Only VK_IMAGE_CREATE_MUTABLE_FORMAT_BIT and
                         // VK_IMAGE_CREATE_CUBE_COMPATIBLE_BIT supported
```

```
    int format; // Must be compatible with original resource format
    unsigned int usage;  // Must be compatible with original resource usage
    uint32_t queueFamilyIndexCount;
    const uint32_t* pQueueFamilyIndices;
    ALVR_OPEN_SHARED_FLAGS  sharedFlags;
};
```

pImage

A pointer to a location that will receive the Vulkan image.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_FAIL on any error.

OpenSharedSemaphore

Create a Vulkan semaphore handle from a LiquidVR semaphore.

```
ALVR_RESULT OpenLVRSemaphore(const ALVRVulkanOpenSemaphoreDesc* pDesc,
                             VkSemaphore* pSemaphore);
```

Parameters

pDesc

A pointer to the *ALVRVulkanOpenSemaphoreDesc* defined as follows:

```
enum ALVR_SEMAPHORE_SHARED_FLAGS
{
    ALVR_SEMAPHORE_SHARED_NONE = 0x00000000,
    ALVR_SEMAPHORE_SHARED_CROSS_PROCESS = 0x00000001,
};

struct ALVRVulkanOpenSemaphoreDesc
{
    ALVRGpuSemaphore*           pSemaphore;
    ALVR_SEMAPHORE_SHARED_FLAGS sharedFlags;
};
```

pSemaphore

A pointer to a location that will receive the Vulkan semaphore.

Return

ALVR_OK on success.

ALVR_INVALID_ARGUMENT when any of the parameters are invalid.

ALVR_FAIL on any error.