



oculus

Oculus Rift Developer Guide

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Contents

LibOVR Integration	4
Overview of the SDK	4
Initialization and Sensor Enumeration	5
Head Tracking and Sensors	7
Position Tracking	9
User Input Integration	11
Health and Safety Warning	11
Rendering to the Oculus Rift	12
Rendering to the Oculus Rift	12
Rendering Setup Outline	14
Texture Swap Chain Initialization	14
Frame Rendering	17
Frame Timing	19
Rendering on Different Threads	20
Layers	21
Asynchronous TimeWarp	25
Adaptive Queue Ahead	26
Performance Indicator	27
Advanced Rendering Configuration	29
Coping with Graphics API or Hardware RenderTarget Granularity	29
Forcing a Symmetrical Field of View	30
Improving Performance by Decreasing Pixel Density	32
Improving Performance by Decreasing Field of View	33
Improving Performance by Rendering in Mono	34
Protecting Content	34
VR Focus Management	36
Rift Audio	39
Oculus Touch Controllers	43
Hand Tracking	43
Button State	43
Button Touch State	45
Haptic Feedback	46
SDK Samples and Gamepad Usage	48
Oculus Debug Tool	49
Performance Head-Up Display	52
Pairing the Oculus Touch Controllers	59

LibOVR Integration

The Oculus SDK is designed to be as easy to integrate as possible. This guide outlines a basic Oculus integration with a C/C++ game engine or application.

We'll discuss initializing the LibOVR, HMD device enumeration, head tracking, frame timing, and rendering for the Rift.

Many of the code samples below are taken directly from the OculusRoomTiny demo source code (available in `Oculus/LibOVR/Samples/OculusRoomTiny`). OculusRoomTiny and OculusWorldDemo are great places to view sample integration code when in doubt about a particular system or feature.

Overview of the SDK

There are three major phases when using the SDK: setup, the game loop, and shutdown.

To add Oculus support to a new application, do the following:

1. Initialize LibOVR through `ovr_Initialize`.
2. Call `ovr_Create` and check the return value to see if it succeeded. You can periodically poll for the presence of an HMD with `ovr_GetHmdDesc(nullptr)`.
3. Integrate head-tracking into your application's view and movement code. This involves:
 - a. Obtaining predicted headset orientation for the frame through a combination of the `GetPredictedDisplayTime` and `ovr_GetTrackingState` calls.
 - b. Applying Rift orientation and position to the camera view, while combining it with other application controls.
 - c. Modifying movement and game play to consider head orientation.
4. Initialize rendering for the HMD.
 - a. Select rendering parameters such as resolution and field of view based on HMD capabilities.
 - See: `ovr_GetFovTextureSize` and `ovr_GetRenderDesc`.
 - b. Configure rendering by creating D3D/OpenGL-specific swap texture sets to present data to the headset.
 - See: `ovr_CreateTextureSwapChainDX` and `ovr_CreateTextureSwapChainGL`.
5. Modify application frame rendering to integrate HMD support and proper frame timing:
 - a. Make sure your engine supports rendering stereo views.
 - b. Add frame timing logic into the render loop to obtain correctly predicted eye render poses.
 - c. Render each eye's view to intermediate render targets.
 - d. Submit the rendered frame to the headset by calling `ovr_SubmitFrame`.
6. Customize UI screens to work well inside of the headset.
7. Destroy the created resources during shutdown.
 - See: `ovr_DestroyTextureSwapChain`, `ovr_Destroy`, and `ovr_Shutdown`.

A more complete summary of rendering details is provided in the [Rendering Setup Outline](#) on page 14 section.

Initialization and Sensor Enumeration

This example initializes LibOVR and requests information about the available HMD.

Review the following code:

```
// Include the OculusVR SDK
#include <OVR_CAPI.h>
void Application()
{
    ovrResult result = ovr_Initialize(nullptr);
    if (OVR_FAILURE(result))
        return;

    ovrSession session;
    ovrGraphicsLuid luid;
    result = ovr_Create(&session, &luid);
    if (OVR_FAILURE(result))
    {
        ovr_Shutdown();
        return;
    }

    ovrHmdDesc desc = ovr_GetHmdDesc(session);
    ovrSizei resolution = desc.Resolution;

    ovr_Destroy(session);
    ovr_Shutdown();
}
```

As you can see, `ovr_Initialize` is called before any other API functions and `ovr_Shutdown` is called to shut down the library before you exit the program. In between these function calls, you are free to create HMD objects, access tracking state, and perform application rendering.

In this example, `ovr_Create(&session, &luid)` creates the HMD. Use the LUID returned by `ovr_Create()` to select the IDXGIAdapter on which your ID3D11Device or ID3D12Device is created. Finally, `ovr_Destroy` must be called to clear the HMD before shutting down the library.

You can use `ovr_GetHmdDesc()` to get a description of the HMD.

If no Rift is plugged in, `ovr_Create(&session, &luid)` returns a failed `ovrResult` unless a virtual HMD is enabled through RiftConfigUtil. Although the virtual HMD will not provide any sensor input, it can be useful for debugging Rift-compatible rendering code and for general development without a physical device.

The description of an HMD (`ovrHmdDesc`) handle can be retrieved by calling `ovr_GetHmdDesc(session)`. The following table describes the fields:

Field	Type	Description
Type	<code>ovrHmdType</code>	Type of the HMD, such as <code>ovr_DK2</code> or <code>ovr_DK2</code> .
ProductName	<code>char[]</code>	Name of the product as a string.
Manufacturer	<code>char[]</code>	Name of the manufacturer.
VendorId	<code>short</code>	Vendor ID reported by the headset USB device.
ProductId	<code>short</code>	Product ID reported by the headset USB device.

Field	Type	Description
SerialNumber	char[]	Serial number string reported by the headset USB device.
FirmwareMajor	short	The major version of the sensor firmware.
FirmwareMinor	short	The minor version of the sensor firmware.
AvailableHmdCaps	unsigned int	Capability bits described by ovrHmdCaps which the HMD currently supports.
DefaultHmdCaps	unsigned int	Default capability bits described by ovrHmdCaps for the current HMD.
AvailableTrackingCaps	unsigned int	Capability bits described by ovrTrackingCaps which the HMD currently supports.
DefaultTrackingCaps	unsigned int	Default capability bits described by ovrTrackingCaps for the current HMD.
DefaultEyeFov	ovrFovPort[]	Recommended optical field of view for each eye.
MaxEyeFov	ovrFovPort[]	Maximum optical field of view that can be practically rendered for each eye.
Resolution	ovrSizei	Resolution of the full HMD screen (both eyes) in pixels.
DisplayRefreshRate	float	Nominal refresh rate of the HMD in cycles per second at the time of HMD creation.

The description of a sensor (`ovrTrackerDesc`) handle can be retrieved by calling `ovr_GetTrackerDesc(sensor)`. The following table describes the fields:

Field	Type	Description
FrustumHfovInRadians	float	The horizontal FOV of the position sensor frustum.
FrustumVfovInRadians	float	The vertical FOV of the position sensor frustum.
FrustumNearZInMeters	float	The distance from the position sensor to the near frustum bounds.
FrustumFarZInMeters	float	The distance from the position sensor to the far frustum bounds.

Head Tracking and Sensors

The Oculus Rift hardware contains a number of micro-electrical-mechanical (MEMS) sensors including a gyroscope, accelerometer, and magnetometer.

There is also a sensor to track headset position. The information from each of these sensors is combined through the sensor fusion process to determine the motion of the user's head in the real world and synchronize the user's view in real-time.

Once the ovrSession is created, you can poll sensor fusion for head position and orientation by calling `ovr_GetTrackingState`. These calls are demonstrated by the following code:

```
// Query the HMD for ts current tracking state.  
ovrTrackingState ts = ovr_GetTrackingState(session, ovr_GetTimeInSeconds(), ovrTrue);  
  
if (ts.StatusFlags & (ovrStatus_OrientationTracked | ovrStatus_PositionTracked))  
{  
    ovrPosef pose = ts.HeadPose.ThePose;  
    ...  
}
```

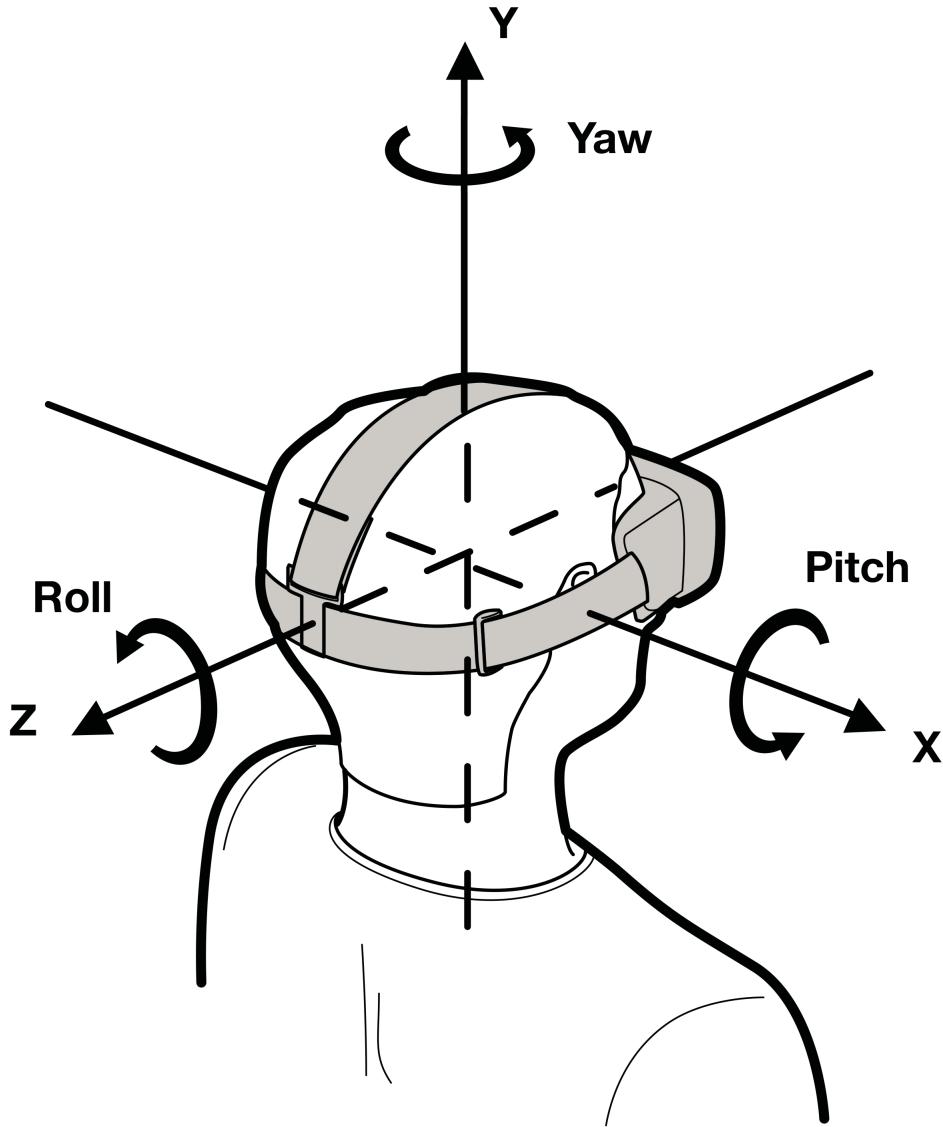
This example initializes the sensors with orientation, yaw correction, and position tracking capabilities. If the sensor is not available during the time of the call, but is plugged in later, the sensor is automatically enabled by the SDK.

After the sensors are initialized, the sensor state is obtained by calling `ovr_GetTrackingState`. This state includes the predicted head pose and the current tracking state of the HMD as described by `StatusFlags`. This state can change at runtime based on the available devices and user behavior. For example, the `ovrStatus_PositionTracked` flag is only reported when `HeadPose` includes the absolute positional tracking data from the sensor.

The reported `ovrPoseStatef` includes full six degrees of freedom (6DoF) head tracking data including orientation, position, and their first and second derivatives. The pose value is reported for a specified absolute point in time using prediction, typically corresponding to the time in the future that this frame's image will be displayed on screen. To facilitate prediction, `ovr_GetTrackingState` takes absolute time, in seconds, as a second argument. The current value of absolute time can be obtained by calling `ovr_GetTimeInSeconds`. If the time passed into `ovr_GetTrackingState` is the current time or earlier, the tracking state returned will be based on the latest sensor readings with no prediction. In a production application, however, you should use the real-time computed value returned by `GetPredictedDisplayTime`. Prediction is covered in more detail in the section on Frame Timing.

As already discussed, the reported pose includes a 3D position vector and an orientation quaternion. The orientation is reported as a rotation in a right-handed coordinate system, as illustrated in the following figure.

Figure 1: Rift Coordinate System



The x-z plane is aligned with the ground regardless of camera orientation.

As seen from the diagram, the coordinate system uses the following axis definitions:

- Y is positive in the up direction.
- X is positive to the right.
- Z is positive heading backwards.

Rotation is maintained as a unit quaternion, but can also be reported in yaw-pitch-roll form. Positive rotation is counter-clockwise (CCW, direction of the rotation arrows in the diagram) when looking in the negative direction of each axis, and the component rotations are:

- Pitch is rotation around X, positive when pitching up.
- Yaw is rotation around Y, positive when turning left.
- Roll is rotation around Z, positive when tilting to the left in the XY plane.

The simplest way to extract yaw-pitch-roll from `ovrPose` is to use the C++ OVR Math helper classes that are included with the library. The following example uses direct conversion to assign `ovrPosef` to the equivalent C++ `Posef` class. You can then use the `Quatf::GetEulerAngles<>` to extract the Euler angles in the desired axis rotation order.

All simple C math types provided by OVR such as `ovrVector3f` and `ovrQuatf` have corresponding C++ types that provide constructors and operators for convenience. These types can be used interchangeably.

If an application uses a left-handed coordinate system, it can use the `ovrPosef_FlipHandedness` function to switch any right-handed `ovrPosef` provided by `ovr_GetTrackingState`, `ovr_GetEyePoses`, or `ovr_CalcEyePoses` functions to be left-handed. Be aware that the `RenderPose` and `QuadPoseCenter` requested for the `ovrLayers` must still use the right-handed coordinate system.

Position Tracking

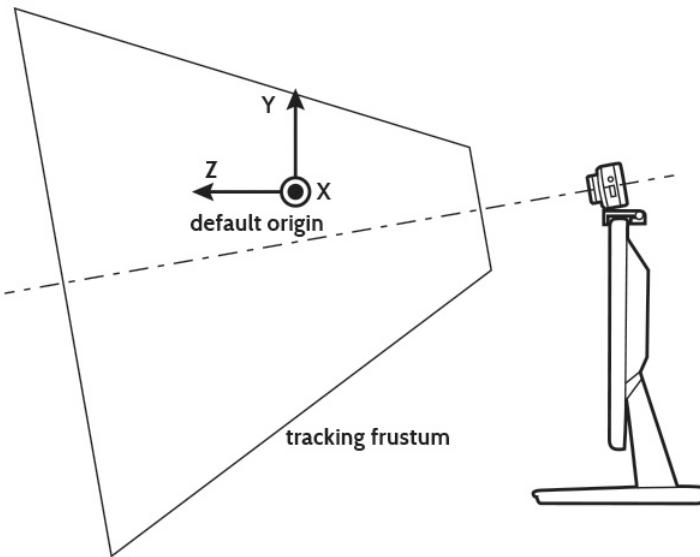
The frustum is defined by the horizontal and vertical FOV, and the distance to the front and back frustum planes.

Approximate values for these parameters can be accessed through the `ovrTrackerDesc` struct as follows:

```
ovrSession session;
ovrGraphicsLuid luid;
if(OVR_SUCCESS(ovr_Create(&session, &luid)))
{
    // Extract tracking frustum parameters.
    float frustumHorizontalFOV = session->CameraFrustumHfovInRadians;
    ...
}
```

The following figure shows the tracking sensor and a representation of the resulting tracking frustum.

Figure 2: Tracking Sensor and Tracking Frustum



The relevant parameters and typical values are listed below:

Field	Type	Typical Value
<code>FrustumHfovInRadians</code>	float	1.292 radians (74 degrees)

Field	Type	Typical Value
FrustumVFoVInRadians	float	0.942 radians (54 degrees)
FrustumNearZInMeters	float	0.4m
FrustumFarZInMeters	float	2.5m

These parameters are provided to enable application developers to provide a visual representation of the tracking frustum. The previous figure also shows the default tracking origin and associated coordinate system.

 Note: Although the sensor axis (and hence the tracking frustum) are shown tilted downwards slightly, the tracking coordinate system is always oriented horizontally such that the axes are parallel to the ground.

By default, the tracking origin is located one meter away from the sensor in the direction of the optical axis but with the same height as the sensor. The default origin orientation is level with the ground with the negative axis pointing towards the sensor. In other words, a headset yaw angle of zero corresponds to the user looking towards the sensor.

 Note: This can be modified using the API call `ovr_RecenterTrackingOrigin` which resets the tracking origin to the headset's current location, and sets the yaw origin to the current headset yaw value.

 Note: The tracking origin is set on a per application basis; switching focus between different VR apps also switches the tracking origin.

The head pose is returned by calling `ovr_GetTrackingState`. The returned `ovrTrackingState` struct contains several items relevant to position tracking:

- HeadPose—includes both head position and orientation.
- Pose—the pose of the sensor relative to the tracking origin.
- CalibratedOrigin—the pose of the origin previously calibrated by the user and stored in the profile reported in the new recentered tracking origin space. This value can change when the application calls `ovr_RecenterTrackingOrigin`, though it refers to the same location in real-world space. Otherwise it will remain as an identity pose. Different tracking origin types will report different CalibrateOrigin poses, as the calibration origin refers to a fixed position in real-world space but the two tracking origin types refer to different y levels.

The `StatusFlags` variable contains the following status bits relating to position tracking:

- `ovrStatus_PositionTracked`—flag that is set only when the headset is being actively tracked.

There are several conditions that may cause position tracking to be interrupted and for the flag to become zero:

- The headset moved wholly or partially outside the tracking frustum.
- The headset adopts an orientation that is not easily trackable with the current hardware (for example facing directly away from the sensor).
- The exterior of the headset is partially or fully occluded from the sensor's point of view (for example by hair or hands).
- The velocity of the headset exceeds the expected range.

Following an interruption, assuming the conditions above are no longer present, tracking normally resumes quickly and the `ovrStatus_PositionTracked` flag is set.

If you want to get the pose and leveled pose of a sensor, call `ovr_GetTrackingState`. The returned `ovrTrackerPose` struct contains the following:

- Pose—the pose of the sensor relative to the tracking origin.

- `LeveledPose`— the pose of the sensor relative to the tracking origin but with roll and pitch zeroed out. You can use this as a reference point to render real-world objects in the correct place.

User Input Integration

To provide the most comfortable, intuitive, and usable interface for the player, head tracking should be integrated with an existing control scheme for most applications.

For example, in a first person shooter (FPS) game, the player generally moves forward, backward, left, and right using the left joystick, and looks left, right, up, and down using the right joystick. When using the Rift, the player can now look left, right, up, and down, using their head. However, players should not be required to frequently turn their heads 180 degrees since this creates a bad user experience. Generally, they need a way to reorient themselves so that they are always comfortable (the same way in which we turn our bodies if we want to look behind ourselves for more than a brief glance).

To summarize, developers should carefully consider their control schemes and how to integrate head-tracking when designing applications for VR. The `OculusRoomTiny` application provides a source code sample that shows how to integrate Oculus head tracking with the aforementioned standard FPS control scheme.

For more information about good and bad practices, refer to the *Oculus Best Practices Guide*.

Health and Safety Warning

All applications that use the Oculus Rift periodically display a health and safety warning.

This warning appears for a short amount of time when the user wears the Rift; it can be dismissed by pressing a key or gazing at the acknowledgement. After the screen is dismissed, it shouldn't display for at least 30 minutes.

Rendering to the Oculus Rift

The Oculus Rift requires split-screen stereo with distortion correction for each eye to cancel lens-related distortion.

Figure 3: OculusWorldDemo Stereo Rendering



Correcting for distortion can be challenging, with distortion parameters varying for different lens types and individual eye relief. To make development easier, Oculus SDK handles distortion correction automatically within the Oculus Compositor process; it also takes care of latency-reducing timewarp and presents frames to the headset.

With Oculus SDK doing a lot of the work, the main job of the application is to perform simulation and render stereo world based on the tracking pose. Stereo views can be rendered into either one or two individual textures and are submitted to the compositor by calling `ovr_SubmitFrame`. We cover this process in detail in this section.

Rendering to the Oculus Rift

The Oculus Rift requires the scene to be rendered in split-screen stereo with half of the screen used for each eye.

When using the Rift, the left eye sees the left half of the screen, and the right eye sees the right half. Although varying from person-to-person, human eye pupils are approximately 65 mm apart. This is known as interpupillary distance (IPD). The in-application cameras should be configured with the same separation.



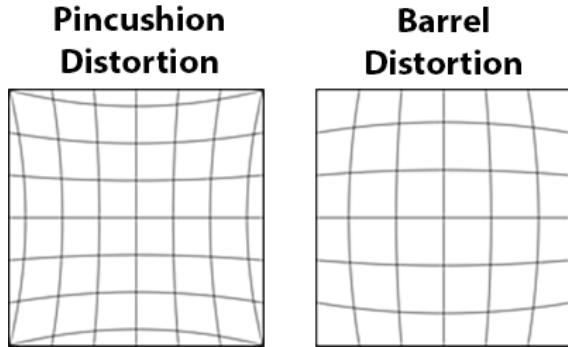
Note:

This is a translation of the camera, not a rotation, and it is this translation (and the parallax effect that goes with it) that causes the stereoscopic effect. This means that your application will need to render the entire scene twice, once with the left virtual camera, and once with the right.

The reprojection stereo rendering technique, which relies on left and right views being generated from a single fully rendered view, is usually not viable with an HMD because of significant artifacts at object edges.

The lenses in the Rift magnify the image to provide a very wide field of view (FOV) that enhances immersion. However, this process distorts the image significantly. If the engine were to display the original images on the Rift, then the user would observe them with pincushion distortion.

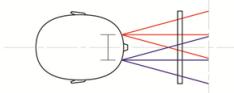
Figure 4: Pincushion and Barrel Distortion



To counteract this distortion, the SDK applies post-processing to the rendered views with an equal and opposite barrel distortion so that the two cancel each other out, resulting in an undistorted view for each eye. Furthermore, the SDK also corrects chromatic aberration, which is a color separation effect at the edges caused by the lens. Although the exact distortion parameters depend on the lens characteristics and eye position relative to the lens, the Oculus SDK takes care of all necessary calculations when generating the distortion mesh.

When rendering for the Rift, projection axes should be parallel to each other as illustrated in the following figure, and the left and right views are completely independent of one another. This means that camera setup is very similar to that used for normal non-stereo rendering, except that the cameras are shifted sideways to adjust for each eye location.

Figure 5: HMD Eye View Cones



In practice, the projections in the Rift are often slightly off-center because our noses get in the way! But the point remains, the left and right eye views in the Rift are entirely separate from each other, unlike stereo views generated by a television or a cinema screen. This means you should be very careful if trying to use methods developed for those media because they do not usually apply in VR.

The two virtual cameras in the scene should be positioned so that they are pointing in the same direction (determined by the orientation of the HMD in the real world), and such that the distance between them is the same as the distance between the eyes, or interpupillary distance (IPD). This is typically done by adding the `ovrEyeRenderDesc::HmdToEyeOffset` translation vector to the translation component of the view matrix.

Although the Rift's lenses are approximately the right distance apart for most users, they may not exactly match the user's IPD. However, because of the way the optics are designed, each eye will still see the correct view. It is important that the software makes the distance between the virtual cameras match the user's IPD as found in their profile (set in the configuration utility), and not the distance between the Rift's lenses.

Rendering Setup Outline

The Oculus SDK makes use of a compositor process to present frames and handle distortion.

To target the Rift, you render the scene into one or two render textures, passing these textures into the API. The Oculus runtime handles distortion rendering, GPU synchronization, frame timing, and frame presentation to the HMD.

The following are the steps for SDK rendering:

1. Initialize:

- a. Initialize Oculus SDK and create an `ovrSession` object for the headset as was described earlier.
- b. Compute the desired FOV and texture sizes based on `ovrHmdDesc` data.
- c. Allocate `ovrTextureSwapChain` objects, used to represent eye buffers, in an API-specific way: call `ovr_CreateTextureSwapChainDX` for either Direct3D 11 or 12 or `ovr_CreateTextureSwapChainGL` for OpenGL.

2. Set up frame handling:

- a. Use `ovr_GetTrackingState` and `ovr_CalcEyePoses` to compute eye poses needed for view rendering based on frame timing information.
- b. Perform rendering for each eye in an engine-specific way, rendering into the current texture within the texture set. Current texture is retrieved using `ovr_GetTextureSwapChainCurrentIndex()` and `ovr_GetTextureSwapChainBufferDX()` or `ovr_GetTextureSwapChainBufferGL()`. After rendering to the texture is complete, the application must call `ovr_CommitTextureSwapChain`.
- c. Call `ovr_SubmitFrame`, passing swap texture set(s) from the previous step within a `ovrLayerEyeFov` structure. Although a single layer is required to submit a frame, you can use multiple layers and layer types for advanced rendering. `ovr_SubmitFrame` passes layer textures to the compositor which handles distortion, timewarp, and GPU synchronization before presenting it to the headset.

3. Shutdown:

- a. Call `ovr_DestroyTextureSwapChain` to destroy swap texture buffers. Call `ovr_DestroyMirrorTexture` to destroy a mirror texture. To destroy the `ovrSession` object, call `ovr_Destroy`.

Texture Swap Chain Initialization

This section describes rendering initialization, including creation of texture swap chains.

Initially, you determine the rendering FOV and allocate the required `ovrTextureSwapChain`. The following code shows how the required texture size can be computed:

```
// Configure Stereo settings.
Sizei recommendedTex0Size = ovr_GetFovTextureSize(session, ovrEye_Left,
                                                    session->DefaultEyeFov[0], 1.0f);
Sizei recommendedTex1Size = ovr_GetFovTextureSize(session, ovrEye_Right,
                                                    session->DefaultEyeFov[1], 1.0f);
Sizei bufferSize;
bufferSize.w = recommendedTex0Size.w + recommendedTex1Size.w;
bufferSize.h = max ( recommendedTex0Size.h, recommendedTex1Size.h );
```

Render texture size is determined based on the FOV and the desired pixel density at the center of the eye. Although both the FOV and pixel density values can be modified to improve performance, this example uses the recommended FOV (obtained from `session->DefaultEyeFov`). The function `ovr_GetFovTextureSize` computes the desired texture size for each eye based on these parameters.

The Oculus API allows the application to use either one shared texture or two separate textures for eye rendering. This example uses a single shared texture for simplicity, making it large enough to fit both eye renderings. Once texture size is known, the application can call `ovr_CreateTextureSwapChainGL` or `ovr_CreateTextureSwapChainDX` to allocate the texture swap chains in an API-specific way. Here's how a texture swap chain can be created and accessed under OpenGL:

```
ovrTextureSwapChain textureSwapChain = 0;

ovrTextureSwapChainDesc desc = {};
desc.Type = ovrTexture_2D;
desc.ArraySize = 1;
desc.Format = OVR_FORMAT_R8G8B8A8_UNORM_SRGB;
desc.Width = bufferSize.w;
desc.Height = bufferSize.h;
desc.MipLevels = 1;
desc.SampleCount = 1;
desc.StaticImage = ovrFalse;

if (ovr_CreateTextureSwapChainGL(session, &desc, &textureSwapChain) == ovrSuccess)
{
    // Sample texture access:
    int texId;
    ovr_GetTextureSwapChainBufferGL(session, textureSwapChain, 0, &texId);
    glBindTexture(GL_TEXTURE_2D, texId);
    ...
}
```

Here's a similar example of texture swap chain creation and access using Direct3D 11:

```
ovrTextureSwapChain textureSwapChain = 0;
std::vector<ID3D11RenderTargetView*> texRtv;

ovrTextureSwapChainDesc desc = {};
desc.Type = ovrTexture_2D;
desc.Format = OVR_FORMAT_R8G8B8A8_UNORM_SRGB;
desc.ArraySize = 1;
desc.Width = bufferSize.w;
desc.Height = bufferSize.h;
desc.MipLevels = 1;
desc.SampleCount = 1;
desc.StaticImage = ovrFalse;
desc.MiscFlags = ovrTextureMisc_None;
desc.BindFlags = ovrTextureBind_DX_RenderTarget;

if (ovr_CreateTextureSwapChainDX(session, DIRECTX.Device, &desc, &textureSwapChain) == ovrSuccess)
{
    int count = 0;
    ovr_GetTextureSwapChainLength(session, textureSwapChain, &count);
    texRtv.resize(textureCount);
    for (int i = 0; i < count; ++i)
    {
        ID3D11Texture2D* texture = nullptr;
        ovr_GetTextureSwapChainBufferDX(session, textureSwapChain, i, IID_PPV_ARGS(&texture));
        DIRECTX.Device->CreateRenderTargetView(texture, nullptr, &texRtv[i]);
        texture->Release();
    }
}
```

Here's sample code from the provided OculusRoomTiny sample running in Direct3D 12:

```
ovrTextureSwapChain TexChain;
std::vector<D3D12_CPU_DESCRIPTOR_HANDLE> texRtv;
std::vector<ID3D12Resource*> TexResource;

ovrTextureSwapChainDesc desc = {};
desc.Type = ovrTexture_2D;
desc.ArraySize = 1;
desc.Format = OVR_FORMAT_R8G8B8A8_UNORM_SRGB;
desc.Width = sizeW;
desc.Height = sizeH;
```

```

desc.MipLevels = 1;
desc.SampleCount = 1;
desc.MiscFlags = ovrTextureMisc_DX_Typeless;
desc.StaticImage = ovrFalse;
desc.BindFlags = ovrTextureBind_DX_RenderTarget;

// DIRECTX.CommandQueue is the ID3D12CommandQueue used to render the eye textures by the app
ovrResult result = ovr_CreateTextureSwapChainDX(session, DIRECTX.CommandQueue, &desc, &TexChain);
if (!OVR_SUCCESS(result))
    return false;

int textureCount = 0;
ovr_GetTextureSwapChainLength(Session, TexChain, &textureCount);
texRtv.resize(textureCount);
TexResource.resize(textureCount);
for (int i = 0; i < textureCount; ++i)
{
    result = ovr_GetTextureSwapChainBufferDX(Session, TexChain, i, IID_PPV_ARGS(&TexResource[i]));
    if (!OVR_SUCCESS(result))
        return false;

    D3D12_RENDER_TARGET_VIEW_DESC rtvd = {};
    rtvd.Format = DXGI_FORMAT_R8G8B8A8_UNORM;
    rtvd.ViewDimension = D3D12_RTV_DIMENSION_TEXTURE2D;
    texRtv[i] = DIRECTX.RtvHandleProvider.AllocCpuHandle(); // Gives new D3D12_CPU_DESCRIPTOR_HANDLE
    DIRECTX.Device->CreateRenderTargetView(TexResource[i], &rtvd, texRtv[i]);
}

```

 Note: For Direct3D 12, when calling `ovr_CreateTextureSwapChainDX`, the caller provides a `ID3D12CommandQueue` instead of a `ID3D12Device` to the SDK. It is the caller's responsibility to make sure that this `ID3D12CommandQueue` instance is where all VR eye-texture rendering is executed. Or, it can be used as a "join-node" fence to wait for the command lists executed by other command queues rendering the VR eye textures.

Once these textures and render targets are successfully created, you can use them to perform eye-texture rendering. The Frame Rendering section describes viewport setup in more detail.

The Oculus compositor provides sRGB-correct rendering, which results in more photorealistic visuals, better MSAA, and energy-conserving texture sampling, which are very important for VR applications. As shown above, applications are expected to create sRGB texture swap chains. Proper treatment of sRGB rendering is a complex subject and, although this section provides an overview, extensive information is outside the scope of this document.

There are several steps to ensuring a real-time rendered application achieves sRGB-correct shading and different ways to achieve it. For example, most GPUs provide hardware acceleration to improve gamma-correct shading for sRGB-specific input and output surfaces, while some applications use GPU shader math for more customized control. For the Oculus SDK, when an application passes in sRGB-space texture swap chains, the compositor relies on the GPU's sampler to do the sRGB-to-linear conversion.

All color textures fed into a GPU shader should be marked appropriately with the sRGB-correct format, such as `OVR_FORMAT_R8G8B8A8_UNORM_SRGB`. This is also recommended for applications that provide static textures as quad-layer textures to the Oculus compositor. Failure to do so will cause the texture to look much brighter than expected.

For D3D 11 and 12, the texture format provided in `desc` for `ovr_CreateTextureSwapChainDX` is used by the distortion compositor for the `ShaderResourceView` when reading the contents of the texture. As a result, the application should request texture swap chain formats that are in sRGB-space (e.g. `OVR_FORMAT_R8G8B8A8_UNORM_SRGB`).

If your application is configured to render into a linear-format texture (e.g. `OVR_FORMAT_R8G8B8A8_UNORM`) and handles the linear-to-gamma conversion using HLSL code, or does not care about any gamma-correction, then:

- Request an sRGB format (e.g. `OVR_FORMAT_R8G8B8A8_UNORM_SRGB`) texture swap chain.
- Specify the `ovrTextureMisc_DX_Typeless` flag in the `desc`.
- Create a linear-format `RenderTargetView` (e.g. `DXGI_FORMAT_R8G8B8A8_UNORM`)

 Note: The `ovrTextureMisc_DX_Typeless` flag for depth buffer formats (e.g. `OVR_FORMAT_D32`) is ignored as they are always converted to be typeless.

For OpenGL, the `format` parameter of `ovr_CreateTextureSwapChainGL` is used by the distortion compositor when reading the contents of the texture. As a result, the application should request texture swap chain formats preferably in sRGB-space (e.g. `OVR_FORMAT_R8G8B8A8_UNORM_SRGB`). Furthermore, your application should call `glEnable(GL_FRAMEBUFFER_SRGB)` before rendering into these textures.

Even though it is not recommended, if your application is configured to treat the texture as a linear format (e.g. `GL_RGBA`) and performs linear-to-gamma conversion in GLSL or does not care about gamma-correction, then:

- Request an sRGB format (e.g. `OVR_FORMAT_R8G8B8A8_UNORM_SRGB`) texture swap chain.
- Do not call `glEnable(GL_FRAMEBUFFER_SRGB)` when rendering into the texture.

The provided code sample demonstrates how to use the provided `ovrTextureMisc_DX_Typeless` flag in D3D11:

```
ovrTextureSwapChainDesc desc = {};
desc.Type = ovrTexture_2D;
desc.ArraySize = 1;
desc.Format = OVR_FORMAT_R8G8B8A8_UNORM_SRGB;
desc.Width = sizeW;
desc.Height = sizeH;
desc.MipLevels = 1;
desc.SampleCount = 1;
desc.MiscFlags = ovrTextureMisc_DX_Typeless;
desc.BindFlags = ovrTextureBind_DX_RenderTarget;
desc.StaticImage = ovrFalse;

ovrResult result = ovr_CreateTextureSwapChainDX(session, DIRECTX.Device, &desc,
&textureSwapChain);

if(!OVR_SUCCESS(result))
    return;

int count = 0;
ovr_GetTextureSwapChainLength(session, textureSwapChain, &count);
for (int i = 0; i < count; ++i)
{
    ID3D11Texture2D* texture = nullptr;
    ovr_GetTextureSwapChainBufferDX(session, textureSwapChain, i, IID_PPV_ARGS(&texture));
    D3D11_RENDER_TARGET_VIEW_DESC rtvd = {};
    rtvd.Format = DXGI_FORMAT_R8G8B8A8_UNORM;
    rtvd.ViewDimension = D3D11_RT_V_DIMENSION_TEXTURE2D;
    DIRECTX.Device->CreateRenderTargetView(texture, &rtvd, &texRtv[i]);
    texture->Release();
}
```

In addition to sRGB, these concepts also apply to the mirror texture creation. For more information, refer to the function documentation provided for `ovr_CreateMirrorTextureDX` and `ovr_CreateMirrorTextureGL` for D3D and OpenGL, respectively.

Frame Rendering

Frame rendering typically involves several steps: obtaining predicted eye poses based on the headset tracking pose, rendering the view for each eye and, finally, submitting eye textures to the compositor through `ovr_SubmitFrame`. After the frame is submitted, the Oculus compositor handles distortion and presents it on the Rift.

Before rendering frames it is helpful to initialize some data structures that can be shared across frames. As an example, we query eye descriptors and initialize the layer structure outside of the rendering loop:

```
// Initialize VR structures, filling out description.
```

```

ovrEyeRenderDesc eyeRenderDesc[2];
ovrVector3f hmdToEyeViewOffset[2];
ovrHmdDesc hmdDesc = ovr_GetHmdDesc(session);
eyeRenderDesc[0] = ovr_GetRenderDesc(session, ovrEye_Left, hmdDesc.DefaultEyeFov[0]);
eyeRenderDesc[1] = ovr_GetRenderDesc(session, ovrEye_Right, hmdDesc.DefaultEyeFov[1]);
hmdToEyeViewOffset[0] = eyeRenderDesc[0].HmdToEyeOffset;
hmdToEyeViewOffset[1] = eyeRenderDesc[1].HmdToEyeOffset;

// Initialize our single full screen Fov layer.
ovrLayerEyeFov layer;
layer.Header.Type      = ovrLayerType_EyeFov;
layer.Header.Flags    = 0;
layer.ColorTexture[0] = textureSwapChain;
layer.ColorTexture[1] = textureSwapChain;
layer.Fov[0]           = eyeRenderDesc[0].Fov;
layer.Fov[1]           = eyeRenderDesc[1].Fov;
layer.Viewport[0]       = Recti(0, 0, bufferSize.w / 2, bufferSize.h);
layer.Viewport[1]       = Recti(bufferSize.w / 2, 0, bufferSize.w / 2, bufferSize.h);
// ld.RenderPose and ld.SensorSampleTime are updated later per frame.

```

This code example first gets rendering descriptors for each eye, given the chosen FOV. The returned `ovrEyeRenderDesc` structure contains useful values for rendering, including the `HmdToEyeOffset` for each eye. Eye view offsets are used later to adjust for eye separation.

The code also initializes the `ovrLayerEyeFov` structure for a full screen layer. Starting with Oculus SDK 0.6, frame submission uses layers to composite multiple view images or texture quads on top of each other. This example uses a single layer to present a VR scene. For this purpose, we use `ovrLayerEyeFov`, which describes a dual-eye layer that covers the entire eye field of view. Since we are using the same texture set for both eyes, we initialize both eye color textures to `pTextureSet` and configure viewports to draw to the left and right sides of this shared texture, respectively.

 Note: Although it is often enough to initialize viewports once in the beginning, specifying them as a part of the layer structure that is submitted every frame allows applications to change render target size dynamically, if desired. This is useful for optimizing rendering performance.

After setup completes, the application can run the rendering loop. First, we need to get the eye poses to render the left and right views.

```

// Get both eye poses simultaneously, with IPD offset already included.
double displayMidpointSeconds = GetPredictedDisplayTime(session, 0);
ovrTrackingState hmdState = ovr_GetTrackingState(session, displayMidpointSeconds, ovrTrue);
ovr_CalcEyePoses(hmdState.HeadPose.ThePose, hmdToEyeViewOffset, layer.RenderPose);

```

In VR, rendered eye views depend on the headset position and orientation in the physical space, tracked with the help of internal IMU and external sensors. Prediction is used to compensate for the latency in the system, giving the best estimate for where the headset will be when the frame is displayed on the headset. In the Oculus SDK, this tracked, predicted pose is reported by `ovr_GetTrackingState`.

To do accurate prediction, `ovr_GetTrackingState` needs to know when the current frame will actually be displayed. The code above calls `GetPredictedDisplayTime` to obtain `displayMidpointSeconds` for the current frame, using it to compute the best predicted tracking state. The head pose from the tracking state is then passed to `ovr_CalcEyePoses` to calculate correct view poses for each eye. These poses are stored directly into the `layer.RenderPose[2]` array. With eye poses ready, we can proceed onto the actual frame rendering.

```

if (isVisible)
{
    // Get next available index of the texture swap chain
    int currentIndex = 0;
    ovr_GetTextureSwapChainCurrentIndex(session, textureSwapChain, &currentIndex);

    // Clear and set up render-target.
    DIRECTX.SetAndClearRenderTarget(pTexRtv[currentIndex], pEyeDepthBuffer);

    // Render Scene to Eye Buffers
    for (int eye = 0; eye < 2; eye++)

```

```

{
    // Get view and projection matrices for the Rift camera
    Vector3f pos = originPos + originRot.Transform(layer.RenderPose[eye].Position);
    Matrix4f rot = originRot * Matrix4f(layer.RenderPose[eye].Orientation);

    Vector3f finalUp      = rot.Transform(Vector3f(0, 1, 0));
    Vector3f finalForward = rot.Transform(Vector3f(0, 0, -1));
    Matrix4f view         = Matrix4f::LookAtRH(pos, pos + finalForward, finalUp);

    Matrix4f proj = ovrMatrix4f_Projection(layer.Fov[eye], 0.2f, 1000.0f, 0);
    // Render the scene for this eye.
    DIRECTX.SetViewport(layer.Viewport[eye]);
    roomScene.Render(proj * view, 1, 1, 1, 1, true);
}

// Commit the changes to the texture swap chain
ovrCommitTextureSwapChain(session, textureSwapChain);
}

// Submit frame with one layer we have.
ovrLayerHeader* layers = &layer.Header;
ovrResult result = ovrSubmitFrame(session, 0, nullptr, &layers, 1);
isVisible = (result == ovrSuccess);

```

This code takes a number of steps to render the scene:

- It applies the texture as a render target and clears it for rendering. In this case, the same texture is used for both eyes.
- The code then computes view and projection matrices and sets viewport scene rendering for each eye. In this example, view calculation combines the original pose (`originPos` and `originRot` values) with the new pose computed based on the tracking state and stored in the layer. These original values can be modified by input to move the player within the 3D world.
- After texture rendering is complete, we call `ovrSubmitFrame` to pass frame data to the compositor. From this point, the compositor takes over by accessing texture data through shared memory, distorting it, and presenting it on the Rift.

`ovrSubmitFrame` returns once the submitted frame is queued up and the runtime is available to accept a new frame. When successful, its return value is either `ovrSuccess` or `ovrSuccess_NotVisible`.

`ovrSuccess_NotVisible` is returned if the frame wasn't actually displayed, which can happen when VR application loses focus. Our sample code handles this case by updating the `isVisible` flag, checked by the rendering logic. While frames are not visible, rendering should be paused to eliminate unnecessary GPU load.

If you receive `ovrError_DisplayLost`, the device was removed and the session is invalid. Release the shared resources (`ovrDestroyTextureSwapChain`), destroy the session (`ovrDestroy`), recreate it (`ovrCreate`), and create new resources (`ovrCreateTextureSwapChainXXX`). The application's existing private graphics resources do not need to be recreated unless the new `ovrCreate` call returns a different `GraphicsLuid`.

Frame Timing

The Oculus SDK reports frame timing information through the `ovrGetPredictedDisplayTime` function, relying on the application-provided frame index to ensure correct timing is reported across different threads.

Accurate frame and sensor timing are required for accurate head motion prediction, which is essential for a good VR experience. Prediction requires knowing exactly when in the future the current frame will appear on the screen. If we know both sensor and display scanout times, we can predict the future head pose and improve image stability. Computing these values incorrectly can lead to under or over-prediction, degrading perceived latency, and potentially causing overshoot "wobbles".

To ensure accurate timing, the Oculus SDK uses absolute system time, stored as a double, to represent sensor and frame timing values. The current absolute time is returned by `ovrGetTimeInSeconds`. Current time

should rarely be used, however, since simulation and motion prediction will produce better results when relying on the timing values returned by `ovr_GetPredictedDisplayTime`. This function has the following signature:

```
ovr_GetPredictedDisplayTime(ovrSession session, long long frameIndex);
```

The `frameIndex` argument specifies which application frame we are rendering. Applications that make use of multi-threaded rendering must keep an internal frame index and manually increment it, passing it across threads along with frame data to ensure correct timing and prediction. The same `frameIndex` value must be passed to `ovr_SubmitFrame` as was used to obtain timing for the frame. The details of multi-threaded timing are covered in the next section, [Rendering on Different Threads](#) on page 20.

A special `frameIndex` value of 0 can be used in both functions to request that the SDK keep track of frame indices automatically. However, this only works when all frame timing requests and render submission is done on the same thread.

Rendering on Different Threads

In some engines, render processing is distributed across more than one thread.

For example, one thread may perform culling and render setup for each object in the scene (we'll call this the "main" thread), while a second thread makes the actual D3D or OpenGL API calls (we'll call this the "render" thread). Both of these threads may need accurate estimates of frame display time, so as to compute best possible predictions of head pose.

The asynchronous nature of this approach makes this challenging: while the render thread is rendering a frame, the main thread might be processing the next frame. This parallel frame processing may be out of sync by exactly one frame or a fraction of a frame, depending on game engine design. If we used the default global state to access frame timing, the result of `GetPredictedDisplayTime` could either be off by one frame depending which thread the function is called from, or worse, could be randomly incorrect depending on how threads are scheduled. To address this issue, previous section introduced the concept of `frameIndex` that is tracked by the application and passed across threads along with frame data.

For multi-threaded rendering result to be correct, the following must be true: (a) pose prediction, computed based on frame timing, must be consistent for the same frame regardless of which thread it is accessed from; and (b) eye poses that were actually used for rendering must be passed into `ovr_SubmitFrame`, along with the frame index.

Here is a summary of steps you can take to ensure this is the case:

1. The main thread needs to assign a frame index to the current frame being processed for rendering. It would increment this index each frame and pass it to `GetPredictedDisplayTime` to obtain the correct timing for pose prediction.
2. The main thread should call the thread safe function `ovr_GetTrackingState` with the predicted time value. It can also call `ovr_CalcEyePoses` if necessary for rendering setup.
3. Main thread needs to pass the current frame index and eye poses to the render thread, along with any rendering commands or frame data it needs.
4. When the rendering commands executed on the render thread, developers need to make sure these things hold:
 - a. The actual poses used for frame rendering are stored into the `RenderPose` for the layer.
 - b. The same value of `frameIndex` as was used on the main thread is passed into `ovr_SubmitFrame`.

The following code illustrates this in more detail:

```
void MainThreadProcessing()
{
    frameIndex++;
    // Ask the API for the times when this frame is expected to be displayed.
```

```

double frameTiming = GetPredictedDisplayTime(session, frameIndex);

// Get the corresponding predicted pose state.
ovrTrackingState state = ovr_GetTrackingState(session, frameTiming, ovrTrue);
ovrPosef eyePoses[2];
ovr_CalcEyePoses(state.HeadPose.ThePose, hmdToEyeViewOffset, eyePoses);

SetFrameHMDData(frameIndex, eyePoses);

// Do render pre-processing for this frame.
...
}

void RenderThreadProcessing()
{
    int frameIndex;
    ovrPosef eyePoses[2];

    GetFrameHMDData(&frameIndex, eyePoses);
    layer.RenderPose[0] = eyePoses[0];
    layer.RenderPose[1] = eyePoses[1];

    // Execute actual rendering to eye textures.
    ...

    // Submit frame with one layer we have.
    ovrLayerHeader* layers = &layer.Header;
    ovrResult result = ovr_SubmitFrame(session, frameIndex, nullptr, &layers, 1);
}

```

The Oculus SDK also supports Direct3D 12, which allows submitting rendering work to the GPU from multiple CPU threads. When the application calls `ovr_CreateTextureSwapChainDX`, the Oculus SDK caches off the `ID3D12CommandQueue` provided by the caller for future usage. As the application calls `ovr_SubmitFrame`, the SDK drops a fence on the cached `ID3D12CommandQueue` to know exactly when a given set of eye-textures are ready for the SDK compositor.

For a given application, using a single `ID3D12CommandQueue` on a single thread is the easiest. But, it might also split the CPU rendering workload for each eye-texture pair or push non-eye-texture rendering work, such as shadows, reflection maps, and so on, onto different command queues. If the application populates and executes command lists from multiple threads, it will also have to make sure that the `ID3D12CommandQueue` provided to the SDK is the single join-node for the eye-texture rendering work executed through different command queues.

Layers

Similar to the way a monitor view can be composed of multiple windows, the display on the headset can be composed of multiple layers. Typically at least one of these layers will be a view rendered from the user's virtual eyeballs, but other layers may be HUD layers, information panels, text labels attached to items in the world, aiming reticles, and so on.

Each layer can have a different resolution, can use a different texture format, can use a different field of view or size, and might be in mono or stereo. The application can also be configured to not update a layer's texture if the information in it has not changed. For example, it might not update if the text in an information panel has not changed since last frame or if the layer is a picture-in-picture view of a video stream with a low framerate. Applications can supply mipmapped textures to a layer and, together with a high-quality distortion mode, this is very effective at improving the readability of text panels.

Every frame, all active layers are composited from back to front using pre-multiplied alpha blending. Layer 0 is the furthest layer, layer 1 is on top of it, and so on; there is no depth-buffer intersection testing of layers, even if a depth-buffer is supplied.

A powerful feature of layers is that each can be a different resolution. This allows an application to scale to lower performance systems by dropping resolution on the main eye-buffer render that shows the virtual world, but keeping essential information, such as text or a map, in a different layer at a higher resolution.

There are several layer types available:

EyeFov	The standard "eye buffer" familiar from previous SDKs, which is typically a stereo view of a virtual scene rendered from the position of the user's eyes. Although eye buffers can be mono, this can cause discomfort. Previous SDKs had an implicit field of view (FOV) and viewport; these are now supplied explicitly and the application can change them every frame, if desired.
Quad	A monoscopic image that is displayed as a rectangle at a given pose and size in the virtual world. This is useful for heads-up-displays, text information, object labels and so on. By default the pose is specified relative to the user's real-world space and the quad will remain fixed in space rather than moving with the user's head or body motion. For head-locked quads, use the <code>ovrLayerFlag_HeadLocked</code> flag as described below.
EyeMatrix	The EyeMatrix layer type is similar to the EyeFov layer type and is provided to assist compatibility with Gear VR applications. For more information, refer to the Mobile SDK documentation.
Disabled	Ignored by the compositor, disabled layers do not cost performance. We recommend that applications perform basic frustum-culling and disable layers that are out of view. However, there is no need for the application to repack the list of active layers tightly together when turning one layer off; disabling it and leaving it in the list is sufficient. Equivalently, the pointer to the layer in the list can be set to null.

Each layer style has a corresponding member of the `ovrLayerType` enum, and an associated structure holding the data required to display that layer. For example, the EyeFov layer is type number `ovrLayerType_EyeFov` and is described by the data in the structure `ovrLayerEyeFov`. These structures share a similar set of parameters, though not all layer types require all parameters:

Parameter	Type	Description
<code>Header.Type</code>	enum <code>ovrLayerType</code>	Must be set by all layers to specify what type they are.
<code>Header.Flags</code>	A bitfield of <code>ovrLayerFlags</code>	See below for more information.
<code>ColorTexture</code>	<code>TextureSwapChain</code>	Provides color and translucency data for the layer. Layers are blended over one another using premultiplied alpha. This allows them to express either lerp-style blending, additive blending, or a combination of the two. Layer textures must be RGBA or BGRA formats and might have mipmaps, but cannot be arrays, cubes, or have MSAA. If the application desires to do MSAA rendering, then it must resolve the intermediate MSAA color texture into the layer's non-MSAA <code>ColorTexture</code> .
<code>Viewport</code>	<code>ovrRecti</code>	The rectangle of the texture that is actually used, specified in 0-1 texture "UV" coordinate space (not pixels). In theory, texture data outside this region is not visible in the layer. However, the usual caveats about texture sampling apply, especially with mipmapped textures. It is good practice to leave a border of <code>RGBA(0,0,0,0)</code> pixels around the displayed region to avoid "bleeding," especially between two eye buffers packed side by side into the same texture. The size of the border depends on the exact usage case, but around 8 pixels seems to work well in most cases.
<code>Fov</code>	<code>ovrFovPort</code>	The field of view used to render the scene in an Eye layer type. Note this does not control the HMD's display, it

Parameter	Type	Description
		simply tells the compositor what FOV was used to render the texture data in the layer - the compositor will then adjust appropriately to whatever the actual user's FOV is. Applications may change FOV dynamically for special effects. Reducing FOV may also help with performance on slower machines, though typically it is more effective to reduce resolution before reducing FOV.
RenderPose	ovrPosef	The camera pose the application used to render the scene in an Eye layer type. This is typically predicted by the SDK and application using the <code>ovr_GetTrackingState</code> and <code>ovr_CalcEyePoses</code> functions. The difference between this pose and the actual pose of the eye at display time is used by the compositor to apply timewarp to the layer.
SensorSampleTime	double	The absolute time when the application sampled the tracking state. The typical way to acquire this value is to have an <code>ovr_GetTimeInSeconds</code> call right next to the <code>ovr_GetTrackingState</code> call. The SDK uses this value to report the application's motion-to-photon latency in the Performance HUD. If the application has more than one <code>ovrLayerType_EyeFov</code> layer submitted at any given frame, the SDK scrubs through those layers and selects the timing with the lowest latency. In a given frame, if no <code>ovrLayerType_EyeFov</code> layers are submitted, the SDK will use the point in time when <code>ovr_GetTrackingState</code> was called with the <code>latencyMarker</code> set to <code>ovrTrue</code> as the substitute application motion-to-photon latency time.
QuadPoseCenter	ovrPosef	Specifies the orientation and position of the center point of a Quad layer type. The supplied direction is the vector perpendicular to the quad. The position is in real-world meters (not the application's virtual world, the actual world the user is in) and is relative to the "zero" position set by <code>ovr_RecenterTrackingOrigin</code> unless the <code>ovrLayerFlag_HeadLocked</code> flag is used.
QuadSize	ovrVector2f	Specifies the width and height of a Quad layer type. As with position, this is in real-world meters.

Layers that take stereo information (all those except Quad layer types) take two sets of most parameters, and these can be used in three different ways:

- Stereo data, separate textures—the app supplies a different `ovrTextureSwapChain` for the left and right eyes, and a viewport for each.
- Stereo data, shared texture—the app supplies the same `ovrTextureSwapChain` for both left and right eyes, but a different viewport for each. This allows the application to render both left and right views to the same texture buffer. Remember to add a small buffer between the two views to prevent "bleeding", as discussed above.
- Mono data—the app supplies the same `ovrTextureSwapChain` for both left and right eyes, and the same viewport for each.

Texture and viewport sizes may be different for the left and right eyes, and each can even have different fields of view. However beware of causing stereo disparity and discomfort in your users.

The `Header.Flags` field available for all layers is a logical-or of the following:

- `ovrLayerFlag_HighQuality`—enables 4x anisotropic sampling in the compositor for this layer. This can provide a significant increase in legibility, especially when used with a texture containing mipmaps; this is recommended for high-frequency images such as text or diagrams and when used with the Quad layer types. For Eye layer types, it will also increase visual fidelity towards the periphery, or when feeding in textures that have more than the 1:1 recommended pixel density. For best results, when creating mipmaps for the textures associated to the particular layer, make sure the texture sizes are a power of 2. However, the application does not need to render to the whole texture; a viewport that renders to the recommended size in the texture will provide the best performance-to-quality ratios.
- `ovrLayerFlag_TextureOriginAtBottomLeft`—the origin of a layer's texture is assumed to be at the top-left corner. However, some engines (particularly those using OpenGL) prefer to use the bottom-left corner as the origin, and they should use this flag.
- `ovrLayerFlag_HeadLocked`—Most layer types have their pose orientation and position specified relative to the "zero position" defined by calling `ovr_RecenterTrackingOrigin`. However the app may wish to specify a layer's pose relative to the user's face. When the user moves their head, the layer follows. This is useful for reticles used in gaze-based aiming or selection. This flag may be used for all layer types, though it has no effect when used on the Direct type.

At the end of each frame, after rendering to whichever `ovrTextureSwapChain` the application wants to update and calling `ovr_CommitTextureSwapChain`, the data for each layer is put into the relevant `ovrLayerEyeFov` / `ovrLayerQuad` / `ovrLayerDirect` structure. The application then creates a list of pointers to those layer structures, specifically to the `Header` field which is guaranteed to be the first member of each structure. Then the application builds a `ovrViewScaleDesc` struct with the required data, and calls the `ovr_SubmitFrame` function.

```
// Create eye layer.
ovrLayerEyeFov eyeLayer;
eyeLayer.Header.Type      = ovrLayerType_EyeFov;
eyeLayer.Header.Flags    = 0;
for ( int eye = 0; eye < 2; eye++ )
{
    eyeLayer.ColorTexture[eye] = EyeBufferSet[eye];
    eyeLayer.Viewport[eye]     = EyeViewport[eye];
    eyeLayer.Fov[eye]          = EyeFov[eye];
    eyeLayer.RenderPose[eye]   = EyePose[eye];
}

// Create HUD layer, fixed to the player's torso
ovrLayerQuad hudLayer;
hudLayer.Header.Type      = ovrLayerType_Quad;
hudLayer.Header.Flags    = ovrLayerFlag_HighQuality;
hudLayer.ColorTexture    = TheHudTextureSwapChain;
// 50cm in front and 20cm down from the player's nose,
// fixed relative to their torso.
hudLayer.QuadPoseCenter.Position.x = 0.00f;
hudLayer.QuadPoseCenter.Position.y = -0.20f;
hudLayer.QuadPoseCenter.Position.z = -0.50f;
hudLayer.QuadPoseCenter.Orientation.x = 0;
hudLayer.QuadPoseCenter.Orientation.y = 0;
hudLayer.QuadPoseCenter.Orientation.z = 0;
hudLayer.QuadPoseCenter.Orientation.w = 1;
// HUD is 50cm wide, 30cm tall.
hudLayer.QuadSize.x = 0.50f;
hudLayer.QuadSize.y = 0.30f;
// Display all of the HUD texture.
hudLayer.Viewport.Pos.x = 0.0f;
hudLayer.Viewport.Pos.y = 0.0f;
hudLayer.Viewport.Size.w = 1.0f;
hudLayer.Viewport.Size.h = 1.0f;

// The list of layers.
ovrLayerHeader *layerList[2];
layerList[0] = &eyeLayer.Header;
layerList[1] = &hudLayer.Header;

// Set up positional data.
ovrViewScaleDesc viewScaleDesc;
viewScaleDesc.HmdSpaceToWorldScaleInMeters = 1.0f;
viewScaleDesc.HmdToEyeViewOffset[0] = HmdToEyeOffset[0];
viewScaleDesc.HmdToEyeViewOffset[1] = HmdToEyeOffset[1];
```

```
ovrResult result = ovr_SubmitFrame(Session, 0, &viewScaleDesc, layerList, 2);
```

The compositor performs timewarp, distortion, and chromatic aberration correction on each layer separately before blending them together. The traditional method of rendering a quad to the eye buffer involves two filtering steps (once to the eye buffer, then once during distortion). Using layers, there is only a single filtering step between the layer image and the final framebuffer. This can provide a substantial improvement in text quality, especially when combined with mipmaps and the `ovrLayerFlag_HighQuality` flag.

One current disadvantage of layers is that no post-processing can be performed on the final composited image, such as soft-focus effects, light-bloom effects, or the Z intersection of layer data. Some of these effects can be performed on the contents of the layer with similar visual results.

Calling `ovr_SubmitFrame` queues the layers for display, and transfers control of the committed textures inside the `ovrTextureSwapChains` to the compositor. It is important to understand that these textures are being shared (rather than copied) between the application and the compositor threads, and that composition does not necessarily happen at the time `ovr_SubmitFrame` is called, so care must be taken. To continue rendering into a texture swap chain the application should always get the next available index with `ovr_GetTextureSwapChainCurrentIndex` before rendering into it. For example:

```
// Create two TextureSwapChains to illustrate.
ovrTextureSwapChain eyeTextureSwapChain;
ovr_CreateTextureSwapChainDX (... &eyeTextureSwapChain );
ovrTextureSwapChain hudTextureSwapChain;
ovr_CreateTextureSwapChainDX (... &hudTextureSwapChain );

// Set up two layers.
ovrLayerEyeFov eyeLayer;
ovrLayerEyeFov hudLayer;
eyeLayer.Header.Type = ovrLayerType_EyeFov;
eyeLayer...etc... // set up the rest of the data.
hudLayer.Header.Type = ovrLayerType_Quad;
hudLayer...etc... // set up the rest of the data.

// the list of layers
ovrLayerHeader *layerList[2];
layerList[0] = &eyeLayer.Header;
layerList[1] = &hudLayer.Header;

// Each frame...
int currentIndex = 0;
ovr_GetTextureSwapChainCurrentIndex(... eyeTextureSwapChain, &currentIndex);
// Render into it. It is recommended the app use ovr_GetTextureSwapChainBufferDX for each index on
// texture chain creation to cache
// textures or create matching render target views. Each frame, the currentIndex value returned can
// be used to index directly into that.
ovr_CommitTextureSwapChain(... eyeTextureSwapChain);

ovr_GetTextureSwapChainCurrentIndex(... hudTextureSwapChain, &currentIndex);
// Render into it. It is recommended the app use ovr_GetTextureSwapChainBufferDX for each index on
// texture chain creation to cache
// textures or create matching render target views. Each frame, the currentIndex value returned can
// be used to index directly into that.
ovr_CommitTextureSwapChain(... hudTextureSwapChain);

eyeLayer.ColorTexture[0] = eyeTextureSwapChain;
eyeLayer.ColorTexture[1] = eyeTextureSwapChain;
hudLayer.ColorTexture = hudTextureSwapChain;
ovr_SubmitFrame(Hmd, 0, nullptr, layerList, 2);
```

Asynchronous TimeWarp

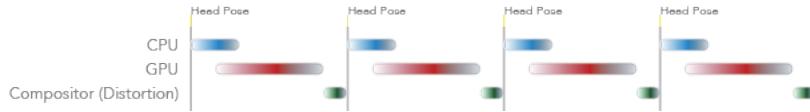
Asynchronous TimeWarp (ATW) is a technique for reducing latency and judder in VR applications and experiences.

In a basic VR game loop, the following occurs:

1. The software requests your head position.
2. The CPU processes the scene for each eye.
3. The GPU renders the scenes.
4. The Oculus Compositor applies distortion and displays the scenes on the headset.

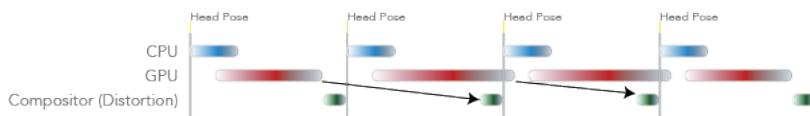
The following shows a basic example of a game loop:

Figure 6: Basic Game Loop



When frame rate is maintained, the experience feels real and is enjoyable. When it doesn't happen in time, the previous frame is shown which can be disorienting. The following graphic shows an example of judder during the basic game loop:

Figure 7: Basic Game Loop with Judder



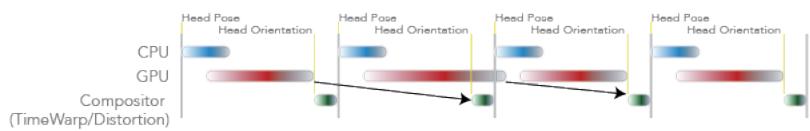
When you move your head and the world doesn't keep up, this can be jarring and break immersion.

ATW is a technique that shifts the rendered image slightly to adjust for changes in head movement. Although the image is modified, your head does not move much, so the change is slight.

Additionally, to smooth issues with the user's computer, game design or the operating system, ATW can help fix "potholes" or moments when the frame rate unexpectedly drops.

The following graphic shows an example of frame drops when ATW is applied:

Figure 8: Game Loop with ATW



At the refresh interval, the Compositor applies TimeWarp to the last rendered frame. As a result, a TimeWarped frame will always be shown to the user, regardless of frame rate. If the frame rate is very bad, flicker will be noticeable at the periphery of the display. But, the image will still be stable.

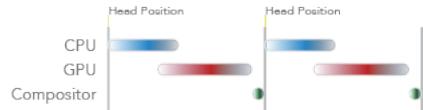
ATW is automatically applied by the Oculus Compositor; you do not need to enable or tune it. However, although ATW reduces latency, make sure that your application or experience makes frame rate.

Adaptive Queue Ahead

To improve CPU and GPU parallelism and increase the amount of time that the GPU has to process a frame, the SDK automatically applies queue ahead up to 1 frame.

Without queue ahead, the CPU begins processing the next frame immediately after the previous frame displays. After the CPU finishes, the GPU processes the frame, the compositor applies distortion, and the frame is displayed to the user. The following graphic shows CPU and GPU utilization without queue ahead:

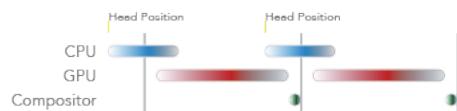
Figure 9: CPU and GPU Utilization without Queue Ahead



If the GPU cannot process the frame in time for display, the previous frame displays. This results in judder.

With queue ahead, the CPU can start earlier; this provides the GPU more time to process the frame. The following graphic shows CPU and GPU utilization with queue ahead:

Figure 10: CPU and GPU Utilization with Queue Ahead

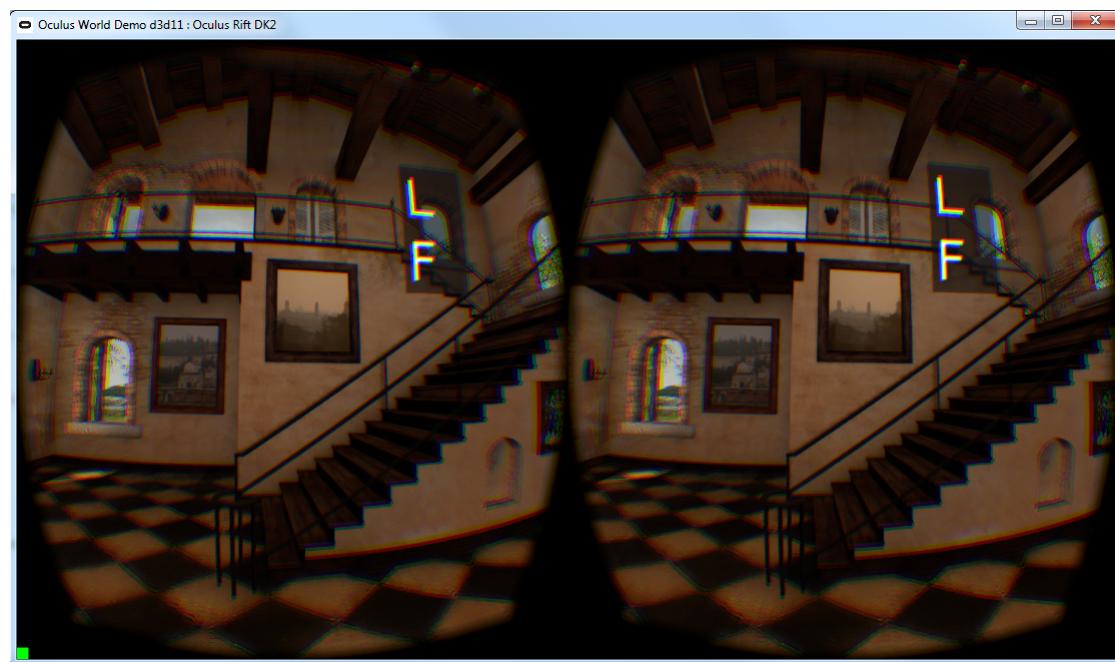


Performance Indicator

Asynchronous TimeWarp (ATW) can mask latency and judder issues that would normally be apparent. To help you identify when your application or experience isn't performing and to test your game or experience before submitting it, Oculus provides performance indicators.

When enabled, a letter code appears in the upper right of the headset whenever the application is experiencing a performance issue. The following figure shows an example of a performance indicator with L and F displayed:

Figure 11: Performance Indicator



To enable the performance indicator, set the following registry key:

```
HKLM\SOFTWARE\Oculus VR, LLC\LibOVR  
FrameDropHDEnabled (DWORD)  
  
Enable = 1  
Disable = 0
```

The performance indicator can return the following codes:

- L—a latency issue is occurring; more than one frame of queue ahead is being applied.
- F—the application is not maintaining frame rate.
- C—the compositor is not maintaining frame rate. Possible causes include:
 - Programs, such as anti-virus software, are overloading the CPU.
 - The CPU cannot handle the number of threads.
 - The CPU or GPU does not meet the recommended specification.
 - Certain patterns of GPU usage, such as heavy usage of shaders and tessellation, are affecting frame rate.
 - There is an issue with the GPU driver.
 - There is an unknown hardware issue.
- U—an unknown error occurred.

Each warning lasts one frame. So, if L stays visible, the application is having continuous latency issues.

Advanced Rendering Configuration

By default, the SDK generates configuration values that optimize for rendering quality.

It also provides a degree of flexibility. For example, you can make changes when creating render target textures.

This section discusses changes you can make when choosing between rendering quality and performance, or if the engine you are using imposes constraints.

Coping with Graphics API or Hardware Rendertarget Granularity

The SDK is designed with the assumption that you want to use your video memory as carefully as possible and that you can create exactly the right render target size for your needs.

However, real video cards and real graphics APIs have size limitations (all have a maximum size; some also have a minimum size). They might also have granularity restrictions, for example, only being able to create render targets that are a multiple of 32 pixels in size or having a limit on possible aspect ratios. As an application developer, you can also impose extra restrictions to avoid using too much graphics memory.

In addition to the above, the size of the actual render target surface in memory might not necessarily be the same size as the portion that is rendered to. The latter may be slightly smaller. However, since it is specified as a viewport, it typically does not have any granularity restrictions. When you bind the render target as a texture, however, it is the full surface that is used, and so the UV coordinates must be corrected for the difference between the size of the rendering and the size of the surface it is on. The API will do this for you, but you need to tell it the relevant information.

The following code shows a two-stage approach for settings render target resolution. The code first calls `ovr_GetFovTextureSize` to compute the ideal size of the render target. Next, the graphics library is called to create a render target of the desired resolution. In general, due to idiosyncrasies of the platform and hardware, the resulting texture size might be different from that requested.

```
// Get recommended left and right eye render target sizes.
Sizei recommendedTex0Size = ovr_GetFovTextureSize(session, ovrEye_Left,
    session->DefaultEyeFov[0], pixelsPerDisplayPixel);
Sizei recommendedTex1Size = ovr_GetFovTextureSize(session, ovrEye_Right,
    session->DefaultEyeFov[1], pixelsPerDisplayPixel);

// Determine dimensions to fit into a single render target.
Sizei renderTargetSize;
renderTargetSize.w = recommendedTex0Size.w + recommendedTex1Size.w;
renderTargetSize.h = max ( recommendedTex0Size.h, recommendedTex1Size.h );

// Create texture.
pRendertargetTexture = pRender->CreateTexture(renderTargetSize.w, renderTargetSize.h);

// The actual RT size may be different due to HW limits.
renderTargetSize.w = pRendertargetTexture->GetWidth();
renderTargetSize.h = pRendertargetTexture->GetHeight();

// Initialize eye rendering information.
// The viewport sizes are re-computed in case RenderTargetSize changed due to HW limitations.
ovrFovPort eyeFov[2] = { session->DefaultEyeFov[0], session->DefaultEyeFov[1] };

EyeRenderViewport[0].Pos = Vector2i(0,0);
EyeRenderViewport[0].Size = Sizei(renderTargetSize.w / 2, renderTargetSize.h);
EyeRenderViewport[1].Pos = Vector2i((renderTargetSize.w + 1) / 2, 0);
EyeRenderViewport[1].Size = EyeRenderViewport[0].Size;
```

This data is passed into `ovr_SubmitFrame` as part of the layer description.

You are free to choose the render target texture size and left and right eye viewports as you like, provided that you specify these values when calling `ovr_SubmitFrame` using the `ovrTexture`. However, using `ovr_GetFovTextureSize` will ensure that you allocate the optimum size for the particular HMD in use. The following sections describe how to modify the default configurations to make quality and performance trade-offs. You should also note that the API supports using different render targets for each eye if that is required by your engine (although using a single render target is likely to perform better since it will reduce context switches). `OculusWorldDemo` allows you to toggle between using a single combined render target versus separate ones for each eye, by navigating to the settings menu (press the Tab key) and selecting the Share RenderTarget option.

Forcing a Symmetrical Field of View

Typically the API will return an FOV for each eye that is not symmetrical, meaning the left edge is not the same distance from the center as the right edge.

This is because humans, as well as the Rift, have a wider FOV when looking outwards. When you look inwards, your nose is in the way. We are also better at looking down than we are at looking up. For similar reasons, the Rift's view is not symmetrical. It is controlled by the shape of the lens, various bits of plastic, and the edges of the screen. The exact details depend on the shape of your face, your IPD, and where precisely you place the Rift on your face; all of this is set up in the configuration tool and stored in the user profile. All of this means that almost nobody has all four edges of their FOV set to the same angle, so the frustum produced will be off-center. In addition, most people will not have the same fields of view for both their eyes. They will be close, but rarely identical.

As an example, on our first generation DK1 headset, the author's left eye has the following FOV:

- 53.6 degrees up
- 58.9 degrees down
- 50.3 degrees inwards (towards the nose)
- 58.7 degrees outwards (away from the nose)

In the code and documentation, these are referred to as 'half angles' because traditionally a FOV is expressed as the total edge-to-edge angle. In this example, the total horizontal FOV is $50.3+58.7 = 109.0$ degrees, and the total vertical FOV is $53.6+58.9 = 112.5$ degrees.

The recommended and maximum fields of view can be accessed from the HMD as shown below:

```
ovrFovPort defaultLeftFOV = session->DefaultEyeFov[ovrEye_Left];
ovrFovPort maxLeftFOV = session->MaxEyeFov[ovrEye_Left];
```

`DefaultEyeFov` refers to the recommended FOV values based on the current user's profile settings (IPD, eye relief etc). `MaxEyeFov` refers to the maximum FOV that the headset can possibly display, regardless of profile settings.

The default values provide a good user experience with no unnecessary additional GPU load. If your application does not consume significant GPU resources, you might want to use the maximum FOV settings to reduce reliance on the accuracy of the profile settings. You might provide a slider in the application control panel that enables users to choose interpolated FOV settings between the default and the maximum. But, if your application is heavy on GPU usage, you might want to reduce the FOV below the default values as described in [Improving Performance by Decreasing Field of View](#) on page 33.

The FOV angles for up, down, left, and right (expressed as the tangents of the half-angles), is the most convenient form to set up culling or portal boundaries in your graphics engine. The FOV values are also used to determine the projection matrix used during left and right eye scene rendering. We provide an API utility function `ovrMatrix4f_Projection` for this purpose:

```
ovrFovPort fov;
// Determine fov.
...
ovrMatrix4f projMatrix = ovrMatrix4f_Projection(fov, znear, zfar, 0);
```

It is common for the top and bottom edges of the FOV to not be the same as the left and right edges when viewing a PC monitor. This is commonly called the ‘aspect ratio’ of the display, and very few displays are square. However, some graphics engines do not support off-center frustums. To be compatible with these engines, you will need to modify the FOV values reported by the `ovrHmdDesc` struct. In general, it is better to grow the edges than to shrink them. This will put a little more strain on the graphics engine, but will give the user the full immersive experience, even if they won’t be able to see some of the pixels being rendered.

Some graphics engines require that you express symmetrical horizontal and vertical fields of view, and some need an even less direct method such as a horizontal FOV and an aspect ratio. Some also object to having frequent changes of FOV, and may insist that both eyes be set to the same. The following is a an example of code for handling this restrictive case:

```
ovrFovPort fovLeft = session->DefaultEyeFov[ovrEye_Left];
ovrFovPort fovRight = session->DefaultEyeFov[ovrEye_Right];

ovrFovPort fovMax = FovPort::Max(fovLeft, fovRight);
float combinedTanHalfFovHorizontal = max ( fovMax.LeftTan, fovMax.RightTan );
float combinedTanHalfFovVertical = max ( fovMax.UpTan, fovMax.DownTan );

ovrFovPort fovBoth;
fovBoth.LeftTan = fovBoth.RightTan = combinedTanHalfFovHorizontal;
fovBoth.UpTan = fovBoth.DownTan = combinedTanHalfFovVertical;

// Create render target.
Sizei recommendedTex0Size = ovr_GetFovTextureSize(session, ovrEye_Left,
                                                fovBoth, pixelsPerDisplayPixel);
Sizei recommendedTex1Size = ovr_GetFovTextureSize(session, ovrEye_Right,
                                                fovBoth, pixelsPerDisplayPixel);

...

// Initialize rendering info.
ovrFovPort eyeFov[2];
eyeFov[0]           = fovBoth;
eyeFov[1]           = fovBoth;

...

// Compute the parameters to feed to the rendering engine.
// In this case we are assuming it wants a horizontal FOV and an aspect ratio.
float horizontalFullFovInRadians = 2.0f * atanf ( combinedTanHalfFovHorizontal );
float aspectRatio = combinedTanHalfFovHorizontal / combinedTanHalfFovVertical;

GraphicsEngineSetFovAndAspect ( horizontalFullFovInRadians, aspectRatio );
...
```

 Note: You will need to determine FOV before creating the render targets, since FOV affects the size of the recommended render target required for a given quality.

Improving Performance by Decreasing Pixel Density

The DK1 has a resolution of 1280x800 pixels, split between the two eyes. However, because of the wide FOV of the Rift and the way perspective projection works, the size of the intermediate render target required to match the native resolution in the center of the display is significantly higher.

For example, to achieve a 1:1 pixel mapping in the center of the screen for the author's field-of-view settings on a DK1 requires a much larger render target that is 2000x1056 pixels in size.

Even if modern graphics cards can render this resolution at the required 60Hz, future HMDs might have significantly higher resolutions. For virtual reality, dropping below 60Hz provides a terrible user experience; it is always better to decrease the resolution to maintain framerate. This is similar to a user having a high resolution 2560x1600 monitor. Very few 3D applications can run at this native resolution at full speed, so most allow the user to select a lower resolution to which the monitor upscales to the fill the screen.

You can use the same strategy on the HMD. That is, run it at a lower video resolution and let the hardware upscale for you. However, this introduces two steps of filtering: one by the distortion processing and one by the video upscaler. Unfortunately, this double filtering introduces significant artifacts. It is usually more effective to leave the video mode at the native resolution, but limit the size of the intermediate render target. This gives a similar increase in performance, but preserves more detail.

One way to resolve this is to allow the user to adjust the resolution through a resolution selector. However, the actual resolution of the render target depends on the user's configuration, rather than a standard hardware setting. This means that the 'native' resolution is different for different people. Additionally, presenting resolutions higher than the physical hardware resolution might confuse some users. They might not understand that selecting 1280x800 is a significant drop in quality, even though this is the resolution reported by the hardware.

A better option is to modify the `pixelsPerDisplayPixel` value that is passed to the `ovr_GetFovTextureSize` function. This could also be based on a slider presented in the applications render settings. This determines the relative size of render target pixels as they map to pixels at the center of the display surface. For example, a value of 0.5 would reduce the render target size from 2000x1056 to 1000x528 pixels, which might allow mid-range PC graphics cards to maintain 60Hz.

```
float pixelsPerDisplayPixel = GetPixelsPerDisplayFromApplicationSettings();
Sizei recommendedTexSize = ovr_GetFovTextureSize(session, ovrEye_Left, fovLeft,
                                                pixelsPerDisplayPixel);
```

Although you can set the parameter to a value larger than 1.0 to produce a higher-resolution intermediate render target, Oculus hasn't observed any useful increase in quality and it has a high performance cost.

OculusWorldDemo allows you to experiment with changing the render target pixel density. Navigate to the settings menu (press the Tab key) and select Pixel Density. Press the up and down arrow keys to adjust the pixel density at the center of the eye projection. A value of 1.0 sets the render target pixel density to the display surface 1:1 at this point on the display. A value of 0.5 means sets the density of the render target pixels to half of the display surface. Additionally, you can select Dynamic Res Scaling which will cause the pixel density to automatically adjust between 0 to 1.

Improving Performance by Decreasing Field of View

In addition to reducing the number of pixels in the intermediate render target, you can increase performance by decreasing the FOV that the pixels are stretched across.

Depending on the reduction, this can result in tunnel vision which decreases the sense of immersion. Nevertheless, reducing the FOV increases performance in two ways. The most obvious is fillrate. For a fixed pixel density on the retina, a lower FOV has fewer pixels. Because of the properties of projective math, the outermost edges of the FOV are the most expensive in terms of numbers of pixels. The second reason is that there are fewer objects visible in each frame which implies less animation, fewer state changes, and fewer draw calls.

Reducing the FOV set by the player is a very painful choice to make. One of the key experiences of virtual reality is being immersed in the simulated world, and a large part of that is the wide FOV. Losing that aspect is not a thing we would ever recommend happily. However, if you have already sacrificed as much resolution as you can, and the application is still not running at 60Hz on the user's machine, this is an option of last resort.

We recommend giving players a Maximum FOV slider that defines the four edges of each eye's FOV.

```

ovrFovPort defaultFovLeft = session->DefaultEyeFov[ovrEye_Left];
ovrFovPort defaultFovRight = session->DefaultEyeFov[ovrEye_Right];

float maxFovAngle = ...get value from game settings panel...
float maxTanHalfFovAngle = tanf ( DegreeToRad ( 0.5f * maxFovAngle ) );

ovrFovPort newFovLeft = FovPort::Min(defaultFovLeft, FovPort(maxTanHalfFovAngle));
ovrFovPort newFovRight = FovPort::Min(defaultFovRight, FovPort(maxTanHalfFovAngle));

// Create render target.
Sizei recommendedTex0Size = ovr_GetFovTextureSize(session, ovrEye_Left newFovLeft,
    pixelsPerDisplayPixel);
Sizei recommendedTex1Size = ovr_GetFovTextureSize(session, ovrEye_Right, newFovRight,
    pixelsPerDisplayPixel);

...

// Initialize rendering info.
ovrFovPort eyeFov[2];
eyeFov[0]           = newFovLeft;
eyeFov[1]           = newFovRight;

...

// Determine projection matrices.
ovrMatrix4f projMatrixLeft = ovrMatrix4f_Projection(newFovLeft, znear, zfar, 0);
ovrMatrix4f projMatrixRight = ovrMatrix4f_Projection(newFovRight, znear, zfar, 0);

```

It might be interesting to experiment with non-square fields of view. For example, clamping the up and down ranges significantly (e.g. 70 degrees FOV) while retaining the full horizontal FOV for a 'Cinemascope' feel.

OculusWorldDemo allows you to experiment with reducing the FOV below the defaults. Navigate to the settings menu (press the Tab key) and select the "Max FOV" value. Pressing the up and down arrows to change the maximum angle in degrees.

Improving Performance by Rendering in Mono

A significant cost of stereo rendering is rendering two views, one for each eye.

For some applications, the stereoscopic aspect may not be particularly important and a monocular view might be acceptable in return for some performance. In other cases, some users may get eye strain from a stereo view and wish to switch to a monocular one. However, they still wish to wear the HMD as it gives them a high FOV and head-tracking.

OculusWorldDemo allows the user to toggle mono render mode by pressing the F7 key.

To render in mono, your code should have the following changes:

- Set the FOV to the maximum symmetrical FOV based on both eyes.
- Call `ovhHmd_GetFovTextureSize` with this FOV to determine the recommended render target size.
- Configure both eyes to use the same render target and the same viewport when calling `ovr_SubmitFrame`.
- Render the scene once to the shared render target.

This merges the FOV of the left and right eyes into a single intermediate render. This render is still distorted twice, once per eye, because the lenses are not exactly in front of the user's eyes. However, this is still a significant performance increase.

Setting a virtual IPD to zero means that everything will seem gigantic and infinitely far away, and of course the user will lose much of the sense of depth in the scene.

 Note: It is important to scale virtual IPD and virtual head motion together so, if the virtual IPD is set to zero, all virtual head motion due to neck movement is also be eliminated. Sadly, this loses much of the depth cues due to parallax. But, if the head motion and IPD do not agree, it can cause significant disorientation and discomfort. Experiment with caution!

Protecting Content

There are some cases where you only want the content to display on the headset. The protected content feature is designed to prevent any mirroring of the compositor.

To use the protected content feature, configure your application to create one or more `ovrTextureSwapChain` objects with the `ovrTextureMisc_ProtectedContent` flag specified. Any submission which references a protected swap chain is considered a protected frame; any protected frames are composited and displayed in the HMD, but are not replicated to mirrors or available to the capture buffer API.

If the HMD is not HDCP compliant, the texture swap chain creation API will fail with `ovrError_ContentProtectionNotAvailable`. If the textures can be created (HDCP-compliant HMD), but the link is broken later, the next `ovrSubmitFrame` call that references protected texture swap chains will fail with the `ovrError_ContentProtectionNotAvailable` error. Configure your application to respond according to your requirements. For example, you might submit that next frame without protected swap chains, but at a lower quality that doesn't require protection. Or, you might stop playback and display an error or warning to the user.

 Note: Because the mirror window is in the control of the application, if your application does not use the mirror texture, it is up to your application to render something to the preview window. Make sure your application does not display protected content. Since the surfaces are not known to be protected by the OS, they will be displayed normally inside the application that created them.

To enable protected content, specify the

```
ovrTextureMisc_ProtectedContent
```

flag similarly to the following:

```
ovrTextureSwapChainDesc desc = {};
desc.Type = ovrTexture_2D;
desc.ArraySize = 1;
desc.Format = OVR_FORMAT_R8G8B8A8_UNORM_SRGB;
desc.Width = sizeW;
desc.Height = sizeH;
desc.MipLevels = 1;
desc.SampleCount = 1;
desc.MiscFlags = ovrTextureMisc_DX_Typeless | ovrTextureMisc_ProtectedContent;
desc.BindFlags = ovrTextureBind_DX_RenderTarget;
desc.StaticImage = ovrFalse;

ovrResult result = ovr_CreateTextureSwapChainDX(session, Device, &desc, &TextureChain);
```

VR Focus Management

When you submit your application to Oculus, you provide the application and metadata necessary to list it in the Oculus Store and launch it from Oculus Home.

Once launched from Oculus Home, you need to write a loop that polls for session status. `ovr_GetSessionStatus` returns a struct with the following booleans:

- `ShouldQuit`—True if the application should initiate shutdown.
- `HmdPresent`—True if an HMD is present.
- `DisplayLost`—True if the HMD was unplugged or the display driver was manually disabled or encountered a TDR.
- `HmdMounted`—True if the HMD is on the user's head.
- `IsVisible`—True if the game or experience has VR focus and is visible in the HMD.
- `ShouldRecenter`—True if the application should call `ovr_RecenterTrackingOrigin`. This is triggered when the user initiates recentering through the Universal Menu.

Managing When a User Quits

If `ShouldQuit` is true, save the application state and shut down or shut down without saving the application state. The user will automatically return to Oculus Home.

Depending on the type of application, you can prompt the user to start where he or she left off the next time it is opened (e.g., a multi-level game) or you can just start from the beginning of the experience (e.g., a passive video). If this is a multiplayer game, you might want to quit locally without ending the game.

Managing When a User Requests Recentering

If `ShouldRecenter` is true, the application should call `ovr_RecenterTrackingOrigin` and be prepared for future tracking positions to be based on a different origin.

Some applications may have reason to ignore the request or to implement it via an internal mechanism other than via `ovr_RecenterTrackingOrigin`. In such cases the application can call `ovr_ClearShouldRecenterFlag` to cause the recenter request to be cleared.

Managing an Unplugged Headset

If `DisplayLost` is true:

1. Pause the application, including audio.
2. Display a prompt on the monitor that says that the headset was unplugged.
3. Destroy any `TextureSwapChains` or mirror textures.
4. Call `ovrDestroy`.
5. Poll `ovrSessionStatus::HmdPresent` until true.
6. Call `ovrCreate` to recreate the session.
7. Recreate any `TextureSwapChains` or mirror textures.
8. Resume the application.

If `ovrDetect` doesn't return as true after a specified amount of time, act as though `ShouldQuit` returned true. If the user takes no action after a specified amount of time, choose a default action (save the session or close without saving) and close the application.

 Note: For multiplayer games, you might want to follow the same process without pausing the game.

Managing an Unavailable Headset

When a user removes the headset or if your application does have VR focus, `HmdMounted` or `IsVisible` returns false. Pause the application until they return true.

When your application loses VR focus, it automatically stops receiving input. If your application does not use the Oculus input API, it will need to ignore any received input.

 Note: For multiplayer games, you might want the game to continue without pausing.

Managing Loss of Windows Focus

When your application loses Windows focus, the Oculus Remote, Xbox controller, and Touch controllers will continue to work normally. However, the application will lose control of the mouse and keyboard.

If your application loses Windows focus and maintains VR focus (`IsVisible`), continue to process input and allow the application to run normally. If the keyboard or mouse is needed to continue, prompt the user to remove the headset and use Alt-Tab to regain Windows focus.

Code Sample

```
bool shouldQuit = false;

void RunApplication()
{
    ovrResult result = ovr_Initialize();

    if (OVR_SUCCESS(result))
    {
        ovrSession session;
        ovrGraphicsLuid luid;
        result = ovr_Create(&session, &luid);

        if (OVR_SUCCESS(result))
        {
            ovrSessionStatus ss;

            <create graphics device with luid>
            <create render target via ovr_CreateTextureSwapChain>

            while (!shouldQuit)
            {
                <get next frame pose, e.g. via ovr_GetEyePoses>
                <render frame>

                result = ovr_SubmitFrame(...);

                if (result == ovrSuccess_NotVisible)
                {
                    <turn off audio output>
                    do { // Wait until we regain visibility or should quit
                        <sleep>
                        result = ovr_GetSessionStatus(session, &ss);
                        if (ss.ShouldQuit)
                            shouldQuit = true;
                    } while (OVR_SUCCESS(result) && !ss.IsVisible && !shouldQuit);
                    <possibly re-enable audio>
                }
                else if (result == ovrError_DisplayLost)
                {
                    // We can either immediately quit or do the following:
                    <destroy render target and graphics device>
                    ovr_Destroy(session);
                }
            }
        }
    }
}
```

```
        do { // Spin while trying to recreate session.
            result = ovr_Create(&session, &luid);
        } while (OVR_FAILURE(result) && !shouldQuit);

        if (OVR_SUCCESS(result))
        {
            <recreate graphics device with luid>
            <recreate render target via ovr_CreateTextureSwapChain>
        }
    }
    else if (OVR_FAILURE(result))
    {
        shouldQuit = true;
    }

    ovr_GetSessionStatus(session, &ss);
    if (ss.ShouldQuit)
        shouldQuit = true;
    if (ss.ShouldRecenter)
    {
        ovr_RecenterTrackingOrigin(session); // or ovr_ClearShouldRecenterFlag(session)
        to ignore the request.
        <do anything else needed to handle this>
    }
}

<destroy render target via ovr_DestroyTextureSwapChain>
<destroy graphics device>

    ovr_Destroy(session);
}

    ovr_Shutdown();
}
}
```

Rift Audio

When setting up audio for the Rift, you need to determine whether the Rift headphones are active and pause the audio when your app doesn't have focus.

The user can enable the Rift headphones and microphone in the Oculus App or use the default Windows audio devices. Configuration is made in the Oculus app in Settings -> Devices -> Headset. The following screenshot shows the Rift headphones disabled and the microphone enabled:

Figure 12: Audio Configuration

This is pre-release alpha software - it is intended only for developers. Do not distribute.

Account

Privacy

Devices

Rift headset

- Connected

General

Debug

Serial #

WMHE100S50014L

Firmware Version

410 / 9a4861262f

Audio Output

Use the headset's earbuds

Audio Input

Use the headset's microphone

Forget Device

The headphone setting is handled automatically by the function `ovr_GetAudioDeviceOutGuid` (located in `OVR_CAPI_Audio.h`), which returns the GUID for the device to target when playing audio. Similarly, use `ovr_GetAudioDeviceInGuid` to identify the microphone device used for input.

FMOD

If you detect that the Rift headphones are enabled, use code similar to the following for FMOD:

```

ERRCHECK(FMOD::System_Create(&sys));
GUIDguid;
ovr_GetAudioDeviceOutGuid(&guid);

intdriverCount=0;
sys->getNumDrivers(&driverCount);

intdriver=0;
while(driver<driverCount)
{
    charname[256]={0};
    FMOD_GUIDfmodGuid={0};
    sys->getDriverInfo(driver,name,256,&fmodGuid,nullptr,nullptr,nullptr);

    if(guid.Data1==fmodGuid.Data1&&
       guid.Data2==fmodGuid.Data2&&
       guid.Data3==fmodGuid.Data3&&
       memcmp(guid.Data4,fmodGuid.Data4,8)==0)
    {
        break;
    }

    ++driver;
}

if(driver<driverCount)
{
    sys->setDriver(driver);
}
else
{
// error rift not connected
}

```

Wwise

If you detect that the Rift headphones are enabled, use code similar to the following for Wwise:

```

AkInitSettings initSettings;
AkPlatformInitSettings platformInitSettings;
AK::SoundEngine::GetDefaultInitSettings( initSettings );
AK::SoundEngine::GetDefaultPlatformInitSettings( platformInitSettings );

// Configure initSettings and platformInitSettings...

WCHAR outStr[128];
if (OVR_SUCCESS.ovr_GetAudioDeviceOutGuidStr(outStr))
{
    initSettings.eMainOutputType = AkAudioAPI::AkAPI_Wasapi;
    platformInitSettings.idAudioDevice = AK::GetDeviceIDFromName(outStr);
}

```

Unity 5

Audio input and output automatically use the Rift microphone and headphones unless configured to use the Windows default audio device by the user in the Oculus app. Events `OVRManager.AudioOutChanged` and `AudioInChanged` occur when audio devices change, making audio playback impossible without a restart.

Unity 5 and Wwise

To configure Wwise to use to configured audio device in Unity 5, pass the user-configured audio device name/GUID (set in the Oculus app) into the function `AkSoundEngine.GetDeviceIDFromName()`, located in `AkInitializer.cs`.

To get the audio device GUID from libOVR, you must include the Oculus Utilities unitypackage, which exposes that string through the class `OVRManager`.

The following function should be called before `AkSoundEngine.Init(...)`:

```
void SetRiftAudioDevice(AkPlatformInitSettings settings)
{
    string audioDevice = OVRManager.audioOutId;
    uint audioOutId = AkSoundEngine.GetDeviceIDFromName (audioDevice);
    settings.idAudioDevice = audioOutId;
}
```

Pass `AkPlatformInitSettings` into the function above and use it to initialize the Ak sound engine.

 Note: `OVRManager.audioOutId` will be deprecated in the future. This minor change should not impact the integration.

VR Audio Output in Oculus Store > Settings > Devices > Rift Headset may be used to configure which input mic to use within the Ak sound engine. The GUID for this is exposed through `OVRManager.audioInId`.

Unity 4

Audio input and output automatically use the Rift microphone and headphones, unless configured to use the Windows default audio device by the user in the Oculus app.

The Rift's microphone is not used by default when calling `Microphone.Start(null, ...)`. Find the entry in `Microphone.devices` that contains the word Rift and use it.

UE4 and Wwise

For general information on how to install and use the Wwise Unreal Integration, see Unreal's documentation on the Installation Github site: <https://github.com/audiokinetic/WwiseUE4Integration>

 Note: To access this documentation, you will need to associate your Github account with Epic Games.
For instructions on how to do so, see: <https://www.unrealengine.com/ue4-on-github>

To use Wwise with Unreal with Oculus SDK 1.x, you must apply the appropriate Oculus `Wwise_redirection_focus` patch from the private Audiokinetic Github repo. This patch allows applications to pause playback when losing VR focus, and to redirect audio to the Rift instead of the Windows default audio device. For detailed instructions, please see Audiokinetic's Unreal Integration documentation.

UE4 and FMOD

For an illustration of how to target the Oculus Rift headphones using FMOD in UE4, see the FMOD section above.

VR Sound Level Best Practices

Audio is an important part of the virtual reality experience, and it is important that all VR apps provide a comfortable listening level for users. Developers should target a reasonable sound level that is consistent between different experiences. To achieve this, Oculus recommends the following best practices.

First, target -18 LUFS during final mix, using tools such as Avid's Pro Limited Plugin, Nugen's VisLM, Klangfreund LUFS Meter, Audacity VuMeter, or similar loudness measurement tools.

Second, measure your experience against the audio levels in published Oculus experiences, especially the ambient audio in Home and the Dreamdeck experience. Set overall system volume so that Dreamdeck and Home sound comfortable, and then adjust your experience's mix to this volume.

Finally, mix your application using the Rift headphones. This ensures that the sounds you're creating and mixing have a frequency content appropriate for the headphones most Oculus users will use.

By adhering to these guidelines, we can guarantee that our Oculus VR users will have a pleasant audio experience.

Oculus Touch Controllers

The Oculus SDK provides APIs that return the position and state for each Oculus Touch controller.

This data is exposed through two locations:

- `ovrTrackingState::HandPoses[2]`—returns the pose and tracking state for each Oculus Touch controller.
- `ovrInputState`—structure returned by `ovr_GetInputState` that contains the Oculus Touch button, joystick, trigger, and capacitive touch sensor state.

The controller hand pose data is separated from the input state because it comes from a different system and is reported at separate points in time. Controller poses are returned by the constellation tracking system and are predicted simultaneously with the headset, based on the absolute time passed into `GetTrackingState`. Having both hand and headset data reported together provides a consistent snapshot of the system state.

Hand Tracking

The constellation sensor used to track the head position of the Oculus Rift also tracks the hand poses of the Oculus Touch controllers.

For installations that have the Oculus Rift and Oculus Touch controllers, there will be at least two constellation sensors to improve tracking accuracy and help with occlusion issues.

The SDK uses the same `ovrPoseStatef` struct as the headset, which includes six degrees of freedom (6DoF) and tracking data (orientation, position, and their first and second derivatives).

Here's an example of how to get tracking input:

```
ovrTrackingState trackState = ovr_GetTrackingState(session, displayMidpointSeconds, ovrTrue);
ovrPosef      handPoses[2];
ovrInputState  inputState;
```

In this code sample, we call `ovr_GetTrackingState` to get predicted poses. Hand controller poses are reported in the same coordinate frame as the headset and can be used for rendering hands or objects in the 3D world. An example of this is provided in the Oculus World Demo.

Button State

The input button state is reported based on the HID interrupts arriving to the computer and can be polled by calling `ovr_GetInputState`.

The following example shows how input can be used in addition to hand poses:

```
double displayMidpointSeconds = ovr_GetPredictedDisplayTime(session, frameIndex);
ovrTrackingState trackState = ovr_GetTrackingState(session, displayMidpointSeconds, ovrTrue);
ovrPosef      handPoses[2];
ovrInputState  inputState;

// Grab hand poses useful for rendering hand or controller representation
handPoses[ovrHand_Left]  = trackState.HandPoses[ovrHand_Left].ThePose;
handPoses[ovrHand_Right] = trackState.HandPoses[ovrHand_Right].ThePose;

if (OVR_SUCCESS(ovr_GetInputState(session, ovrControllerType_Touch, &inputState)))
{
```

```

if (inputState.Buttons & ovrButton_A)
{
    // Handle A button being pressed
}
if (inputState.HandTrigger[ovrHand_Left] > 0.5f)
{
    // Handle hand grip...
}
}

```

The ovrInputState struct includes the following fields:

Field	Type	Description
TimeInSeconds	double	System time when the controller state was last updated.
ConnectionState	unsigned int	Described by ovrControllerType. Indicates which controller types are present; you can check the ovrControllerType_LTouch bit, for example, to verify that the left touch controller is connected. Options include: <ul style="list-style-type: none"> • ovrControllerType_LTouch (0x01) • ovrControllerType_RTouch (0x02) • ovrControllerType_Touch (0x03)
Buttons	unsigned int	Button state described by ovrButtons. A corresponding bit is set if the button is pressed.
Touches	unsigned int	Touch values for buttons and sensors as indexed by ovrTouch. A corresponding bit is set if users finger is touching the button or is in a gesture state detectable by the controller.
IndexTrigger[2]	float	Left and right finger trigger values (ovrHand_Left and ovrHand_Right), in the range 0.0 to 1.0f. A value of 1.0 means that the trigger is fully depressed.
HandTrigger[2]	float	Left and right hand trigger values (ovrHand_Left and ovrHand_Right), in the range 0.0 to 1.0f. Hand trigger is often used to grab items. A value of 1.0 means that the trigger is fully depressed.
Thumbstick[2]	ovrVector2f	Horizontal and vertical thumbstick axis values (ovrHand_Left and ovrHand_Right), in the range -1.0f to 1.0f. The API automatically applies the dead zone, so

Field	Type	Description
		developers don't need to handle it explicitly.

The ovrInputState structure includes the current state of buttons, thumb sticks, triggers and touch sensors on the controller. You can check whether a button is pressed by checking against one of the button constants, as was done for ovrButton_A in the above example. The following is a list of binary buttons available on touch controllers:

Button Constant	Description
ovrButton_A	A button on the right Touch controller.
ovrButton_B	B button on the right Touch controller.
ovrButton_RThumb	Thumb stick button on the right Touch controller.
ovrButton_RShoulder	Shoulder button on the right Touch controller.
ovrButton_X	X button on the left Touch controller.
ovrButton_Y	Y button on the left Touch controller.
ovrButton_LThumb	Thumb stick button on the left Touch controller.
ovrButton_LShoulder	Shoulder button on the left Touch controller.
ovrButton_Enter	Enter button on the left Touch controller. This is equivalent to the Start button on the Xbox controller.

Button Touch State

In addition to buttons, Touch controllers can detect whether user fingers are touching some buttons or are in certain positions.

These states are reported as bits in the Touches field, and can be checked through one of the following constants:

ovrTouch_A	User in touching A button on the right controller.
ovrTouch_B	User in touching B button on the right controller.
ovrTouch_RThumb	User has a finger on the thumb stick of the right controller.
ovrTouch_RThumbRest	User has a finger on the textured thumb rest of the right controller.
ovrTouch_RIndexTrigger	User in touching the index finger trigger on the right controller.
ovrTouch_X	User in touching X button on the left controller.
ovrTouch_Y	User in touching Y button on the left controller.
ovrTouch_LThumb	User has a finger on the thumb stick of the left controller.
ovrTouch_LThumbRest	User has a finger on the textured thumb rest of the left controller.

ovrTouch_LIndexTrigger	User is touching the index finger trigger on the left controller.
ovrTouch_RIndexPointing	Users right index finger is pointing forward past the trigger.
ovrTouch_RThumbUp	Users right thumb is up and away from buttons on the controller, a gesture that can be interpreted as right thumbs up.
ovrTouch_LIndexPointing	Users left index finger is pointing forward past the trigger.
ovrTouch_LThumbUp	Users left thumb is up and away from buttons on the controller, a gesture that can be interpreted as left thumbs up.

Haptic Feedback

In addition to reporting input state, Oculus touch controllers can provide haptic feedback through vibration.

The SDK supports two types of haptics: buffered and non-buffered. Buffered haptics are designed to change rapidly (every 3.125ms) and work well for subtle effects. Non-buffered haptics are designed for simple effects that don't change often (every 33ms).

 Note: The buffered and non-buffered functions should not be used together, as they will result in unpredictable haptic feedback.

Buffer-Based Haptics

Running at 320Hz, each sample is 3.125 milliseconds. Because these samples are added to a buffer that holds 256 samples, the buffer can hold up to 800 milliseconds of samples.

To check the status of the buffer, call `ovr_GetControllerVibrationState`:

```
ovr_GetControllerVibrationState(ovrSession session, ovrControllerType controllerType,
                               ovrHapticsPlaybackState* outState);
```

To submit to the buffer, call `ovr_SubmitControllerVibration`:

```
ovr_SubmitControllerVibration(ovrSession session, ovrControllerType controllerType, const
                               ovrHapticsBuffer* buffer);
```

The following code sample shows basic haptic submission as part of a game loop:

```
uint8_t amplitude = (uint8_t)round(handTrigger[t] * 255) + 9;

result = ovr_GetControllerVibrationState(Session, touchController[t], &state);
if (result != ovrSuccess || state.SamplesQueued >= kLowLatencyBufferSizeInSamples)
{
    DefaultChannel.LogErrorF("%s Haptics skipped. Queue size %d", kTouchStr[t],
                           state.SamplesQueued);
    continue;
}

for (int32_t i = 0; i < kLowLatencyBufferSizeInSamples; ++i)
    samples.push_back(amplitude);

if (samples.size() > 0)
```

```
ovrHapticsBuffer buffer;
buffer.SubmitMode = ovrHapticsBufferSubmit_Enqueue;
buffer.SamplesCount = (uint32_t)samples.size();
buffer.Samples = samples.data();
result = ovr_SubmitControllerVibration(Session, touchController[t], &buffer);
if (result != ovrSuccess)
{
    // Something bad happened
    DefaultChannel.LogErrorF("%s: Haptics submit failed %d", kTouchStr[t], result);
}
```

Non-Buffered Haptics

Vibration can be enabled by calling `ovr_SetControllerVibration`:

```
ovr_SetControllerVibration( Hmd, ovrControllerType_LTouch, freq, trigger);
```

Vibration is enabled by specifying frequency and amplitude. Frequency can take on values of 0.0f, 0.5f, and 1.0f, while amplitude ranges from 0.0f to 1.0f. Set amplitude and frequency to 0.0f to disable vibration.

SDK Samples and Gamepad Usage

Some of the Oculus SDK samples use gamepad controllers to enable movement around the virtual world.

This section describes the devices that are currently supported and setup instructions.

Xbox 360 Wired Controller for Windows

To set up the controller:

- Plug the device into a USB port. Windows should recognize the controller and install any necessary drivers automatically.

Logitech F710 Wireless Gamepad

To set up the gamepad for Windows:

1. Put the controller into 'XInput' mode by moving the switch on the front of the controller to the 'X' position.
2. Press a button on the controller so that the green LED next to the 'Mode' button begins to flash.
3. Plug the USB receiver into the PC while the LED is flashing.
4. Windows should recognize the controller and install any necessary drivers automatically.

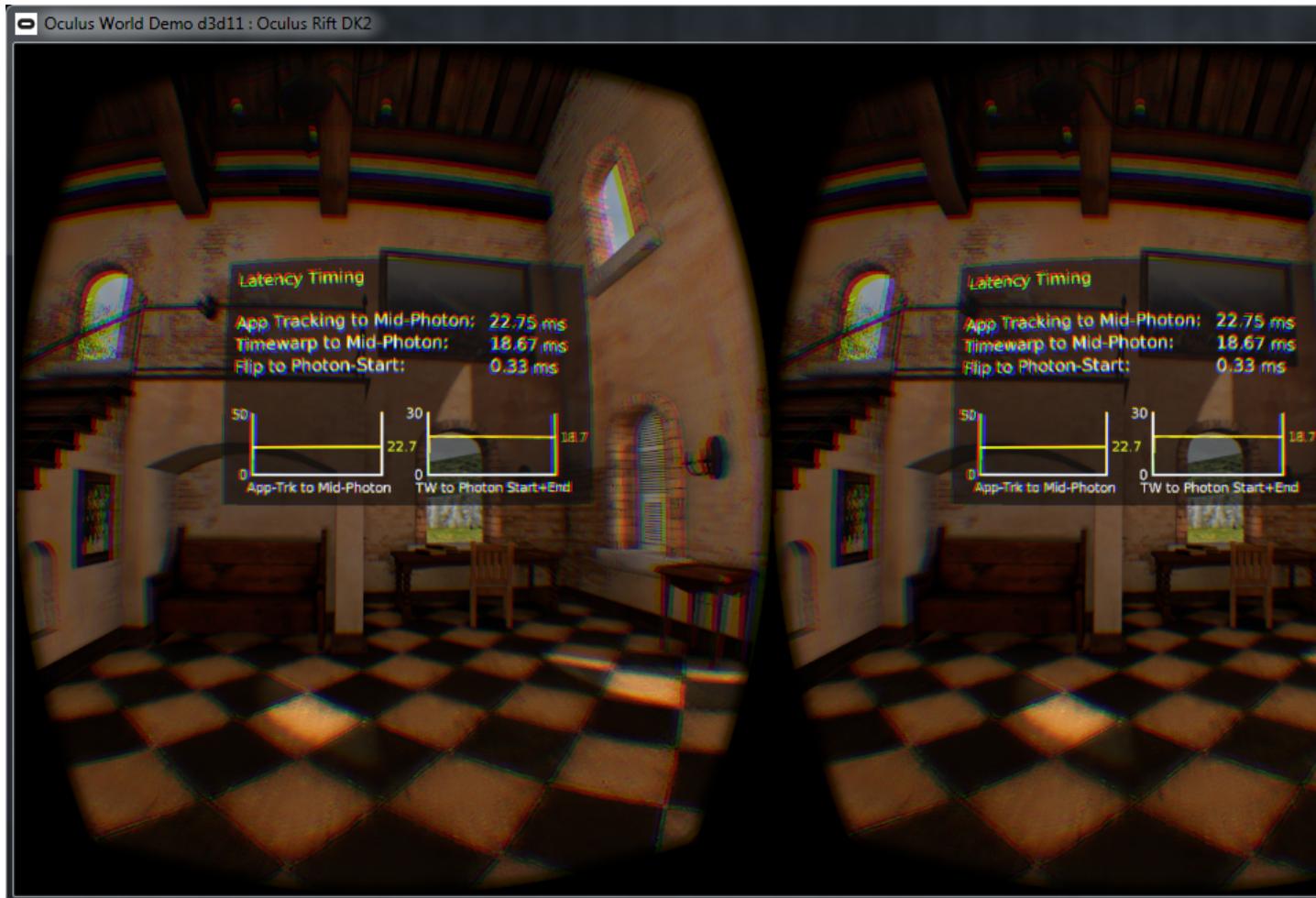
Oculus Debug Tool

The Oculus Debug Tool enables you to view performance or debugging information within your game or experience.

To use the tool:

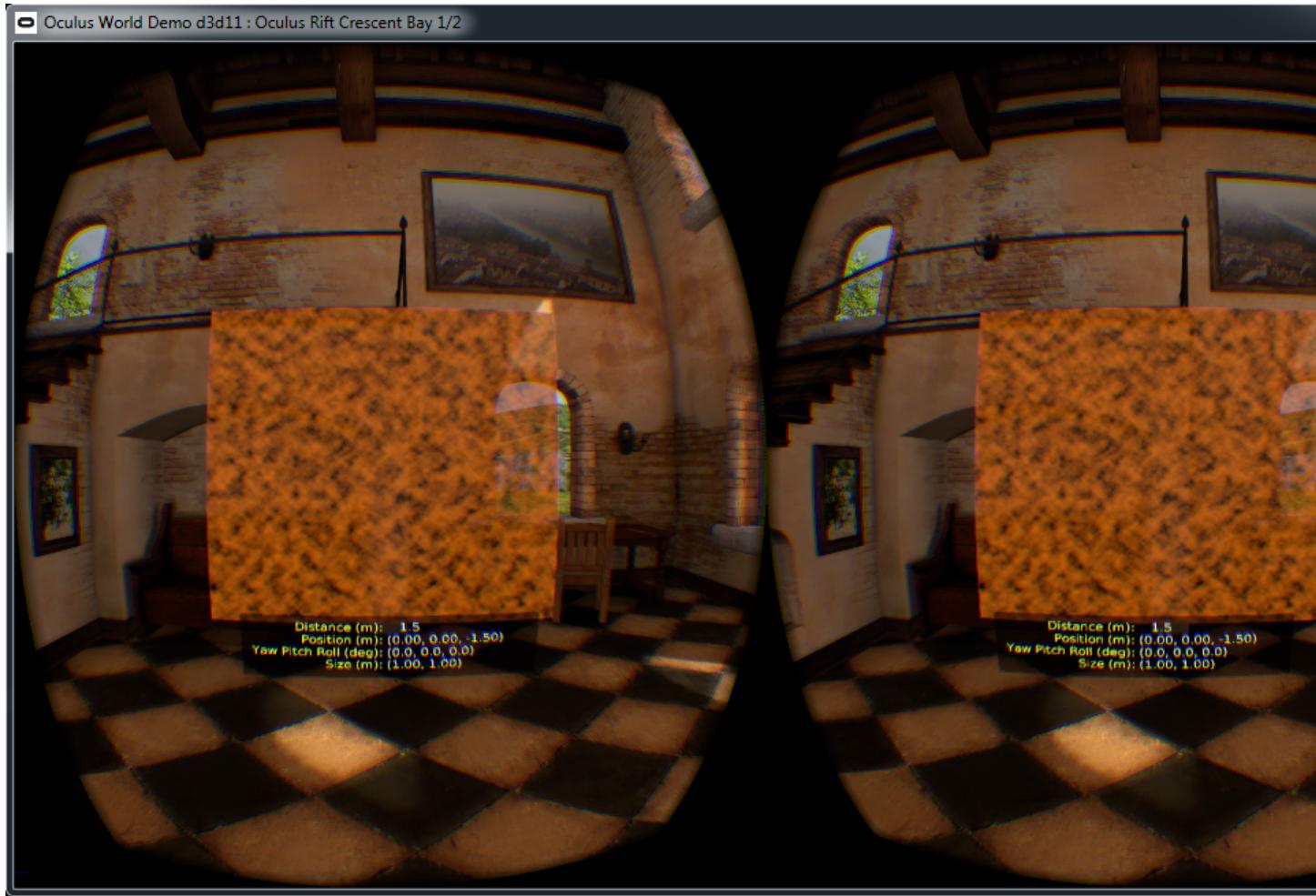
1. Go to Tools directory of the Oculus SDK.
2. Double-click `OculusDebugTool.exe`. The Oculus Debug Tool opens.
3. Select the Visible HUD to view. Options include: None (no HUD is displayed), Performance HUD, Stereo Debug HUD, or Layer HUD.
4. If you selected Performance HUD, select which Performance HUD you want to view. Options include: Latency Timing, Render Timing, Performance Headroom, and Version Information. For more information, see [Performance Head-Up Display](#) on page 52.

The following is an example of the Performance HUD:



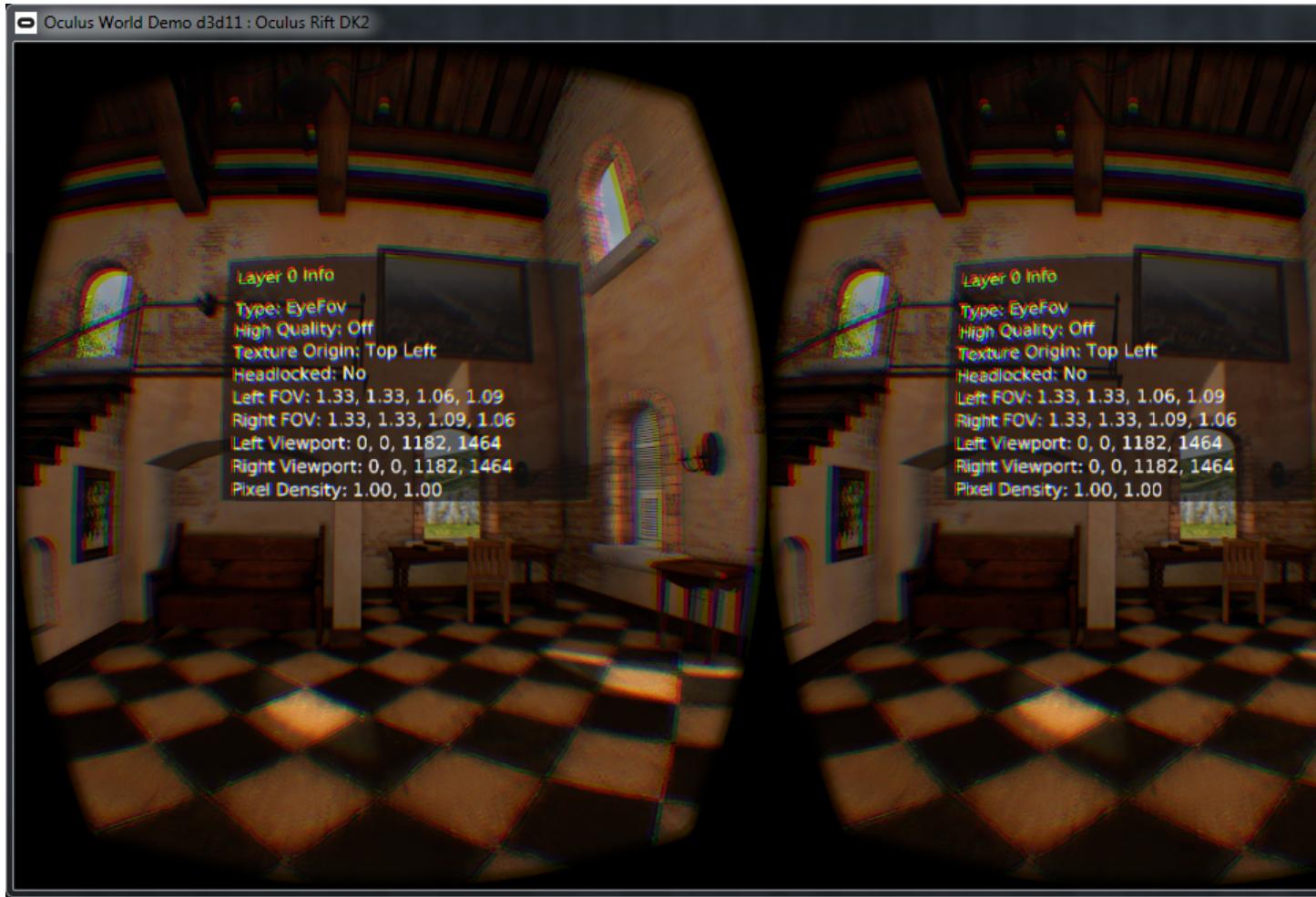
5. If you selected Stereo Debug HUD, configure the mode, size, position, and color from the Stereo Debug HUD options.

The following is an example of the Stereo Debug HUD:



6. If you selected Layer HUD, select the layer for which to show information or select the Show All check box.

The following is an example of the Layer HUD:



7. Put on the headset and view the results.

Performance Head-Up Display

The Performance Head-Up Display (HUD) enables you or your users to view performance information for applications built with the SDK.

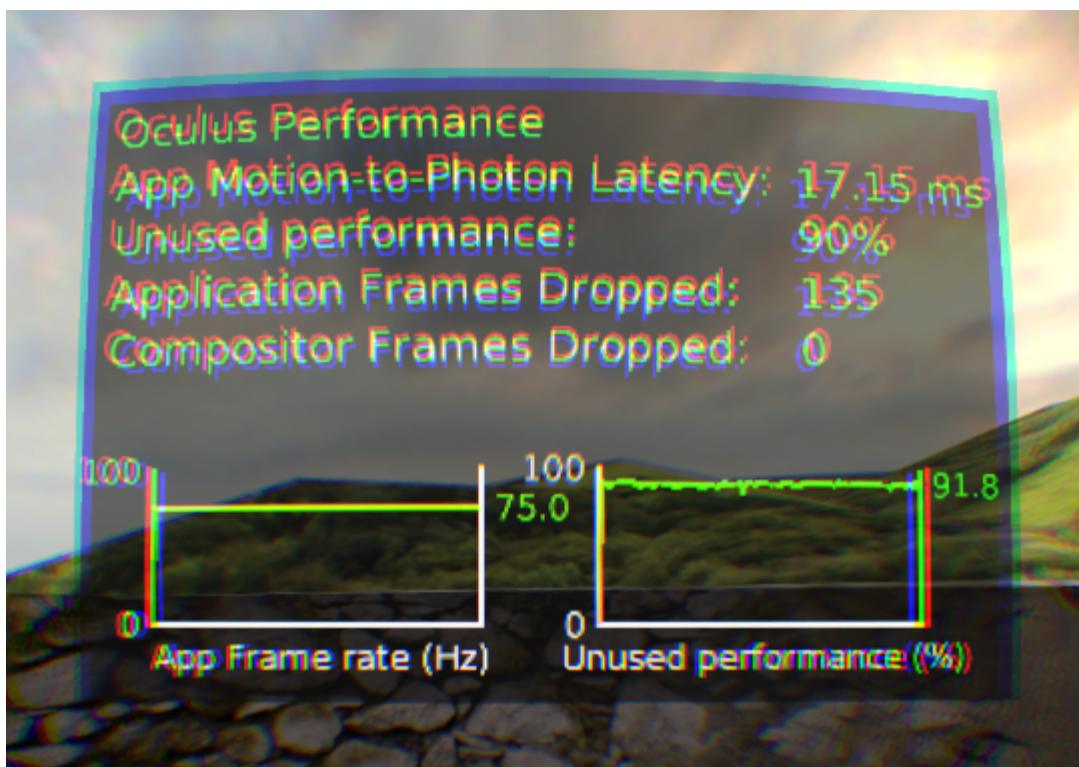
The Performance HUD screens are rendered by the compositor, which enables them to be displayed with a single SDK call. In the Oculus Debug Tool or OculusWorldDemo, you can toggle through the Performance HUD screens by pressing F11.

Performance Summary

The Performance Summary HUD displays the frame rate of the application and the unused hardware performance available. This HUD can be used by you or the user to tune an application's simulation and graphics fidelity. Because the user cannot disable V-Sync, it can be used to gauge performance instead of a frame rate counter. It is also useful for troubleshooting whether issues are related to the application or the hardware setup.

The following screenshot shows the Performance Summary HUD:

Figure 13: Performance Summary HUD



The following table describes each metric:

Metric	Description
App Motion-to-Photon Latency	Latency from when the last predicted tracking information was queried by the application using <code>ovr_GetTrackingState()</code> to when the middle scanline of the target frame is illuminated on the HMD display. This is the same information provided by the Latency Timing HUD.

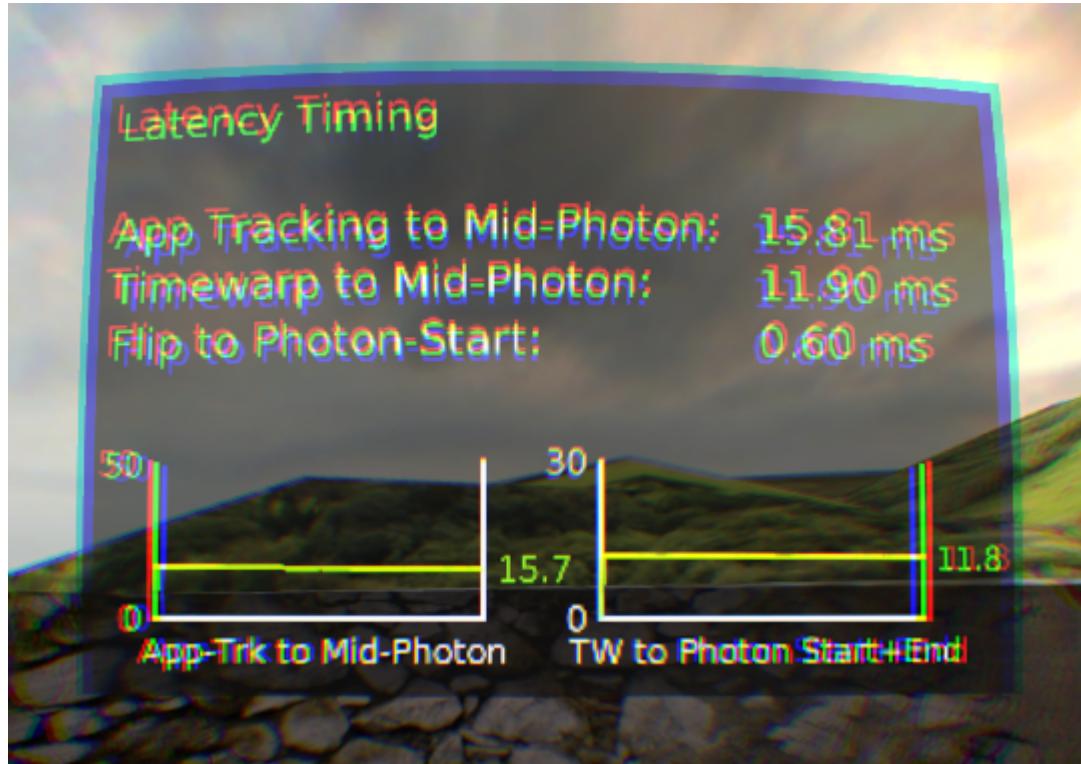
Metric	Description
Unused performance	<p>Designed to help the user verify that the PC is powerful enough to avoid dropping frames, this displays the percentage of available PC performance not used by the application and compositor. This is calculated using the CPU and GPU time tracked by the Application Render Timing HUD divided by the native frame time (inverse of refresh rate) of the HMD.</p> <p> Note: As GPU utilization approaches 100%, adaptive queue ahead will choose an earlier render start point. If this start point overlaps with the compositor process in the previous frame, the performance will appear spiky. If you start to lower utilization, the graph will show an initial drop before becoming more linear.</p>
Application Frames Dropped	Increments each time the application fails to submit a new set of layers using <code>ovr_SubmitFrame()</code> before the compositor is executed before each V-Sync (Vertical Synchronization). This is identical to App Missed Submit Count in the Application Render Timing HUD.
Compositor Frames Dropped	Increments each time the compositor fails to present a new rendered frame at V-Sync (Vertical Synchronization). This is identical to Compositor Missed V-Sync Count in the Compositor Render Timing HUD.

Latency Timing

The Latency Timing HUD displays the App to Mid - Photon, Timewarp to Photon - Start, and Timewarp to Photon - Start graphs.

The following screenshot shows the Latency Timing HUD:

Figure 14: Latency Timing



The following table describes each metric:

Table 1: Latency Timing HUD

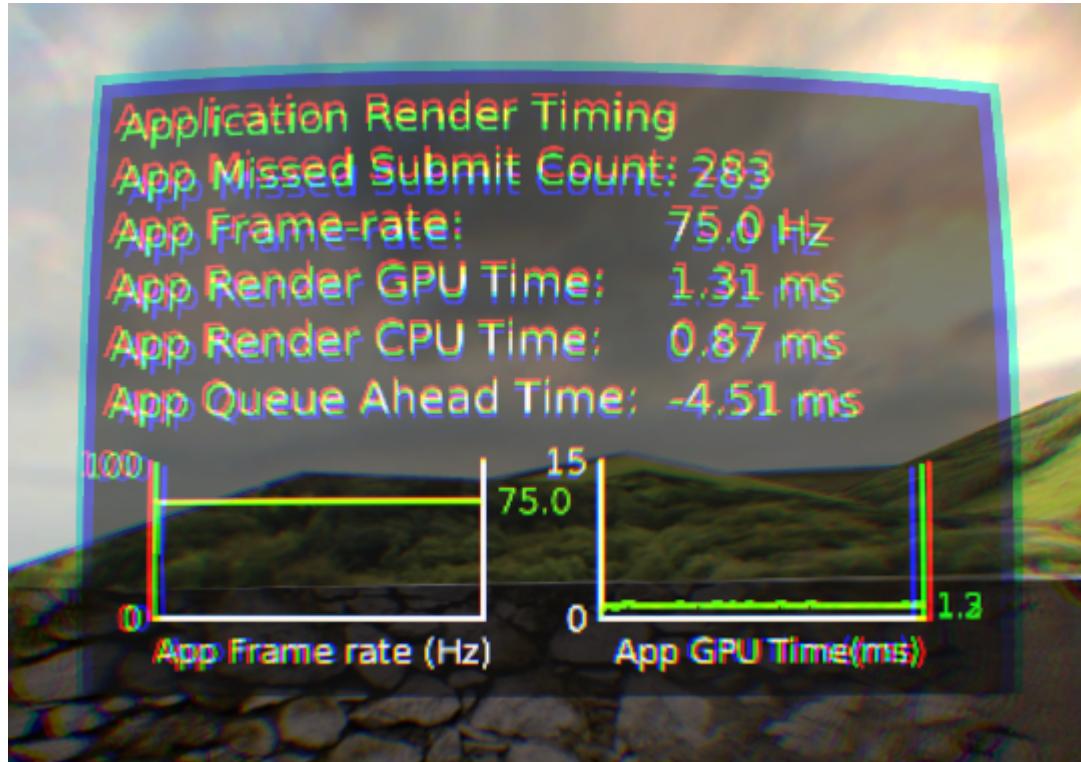
Metric	Description
App Tracking to Mid-Photon	Latency from when the app called <code>ovr_GetTrackingState()</code> to when the target frame eventually was shown (i.e. illuminated) on the HMD display - averaged mid - point illumination
Timewarp to Mid-Photon	Latency from when the last predicted tracking info is fed to the GPU for timewarp execution to the point when the middle scanline of the target frame is illuminated on the HMD display
Flip to Photon - Start	Time difference from the point the back buffer is presented to the HMD to the point the target frame's first scanline is illuminated on the HMD display

Application Render Timing

The Application Render Timing HUD displays application-specific render timing information.

The following screenshot shows the Application Render Timing HUD:

Figure 15: Application Render Timing



The following table describes each metric:

Table 2: Application Render Timing HUD

Metric	Description
App Missed Submit Count	Increments each time the application fails to submit a new set of layers using <code>ovr_SubmitFrame()</code> before the compositor is executed and before each V-Sync (Vertical Synchronization).
App Frame-rate	The rate at which application rendering calls <code>ovr_SubmitFrame()</code> . It will never exceed the native refresh rate of the HMD as the call to <code>ovr_SubmitFrame()</code> throttles the application's CPU execution as needed.
App Render GPU Time	The total GPU time spent on rendering by the client application. This includes the work done by the application after returning from <code>ovr_SubmitFrame()</code> , using the mirror texture if applicable.
	It can also include GPU command-buffer "bubbles" if the application's CPU thread doesn't push data to the GPU fast enough to keep it occupied. Similarly, if the app pushes the GPU close to full-utilization, the work on next frame (N+1) might be preempted by the compositor's render work on the current frame (N). Because of how the application GPU timing query operates, this can lead to artificially inflated

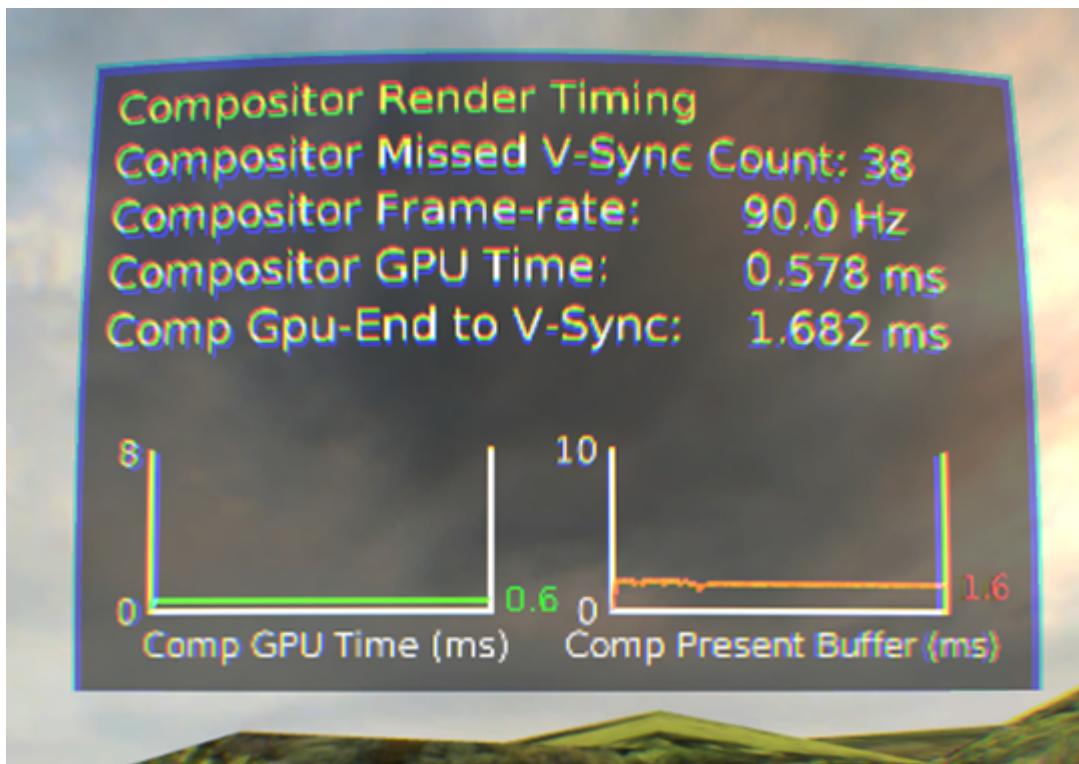
Metric	Description
App Render CPU Time	application GPU times as they will start to include the compositor GPU usage times.
App Queue Ahead Time	The time difference from when the application continued execution on CPU after ovr_SubmitFrame() returned the subsequent call to ovr_SubmitFrame(). This will show "N/A" if the latency tester is not functioning as expected (e.g., HMD display is sleeping due to prolonged inactivity). This includes the IPC call overhead to the compositor after ovr_SubmitFrame() is called by the client application.

Compositor Render Timing

The Compositor Render Timing HUD displays render timing information for the Oculus Runtime Compositor. The Oculus Compositor applies distortion and TimeWarp to the layered eye textures provided by the VR application.

The following screenshot shows the Compositor Render Timing HUD:

Figure 16: Render Timing



The following table describes each metric:

Table 3: Compositor Render Timing HUD

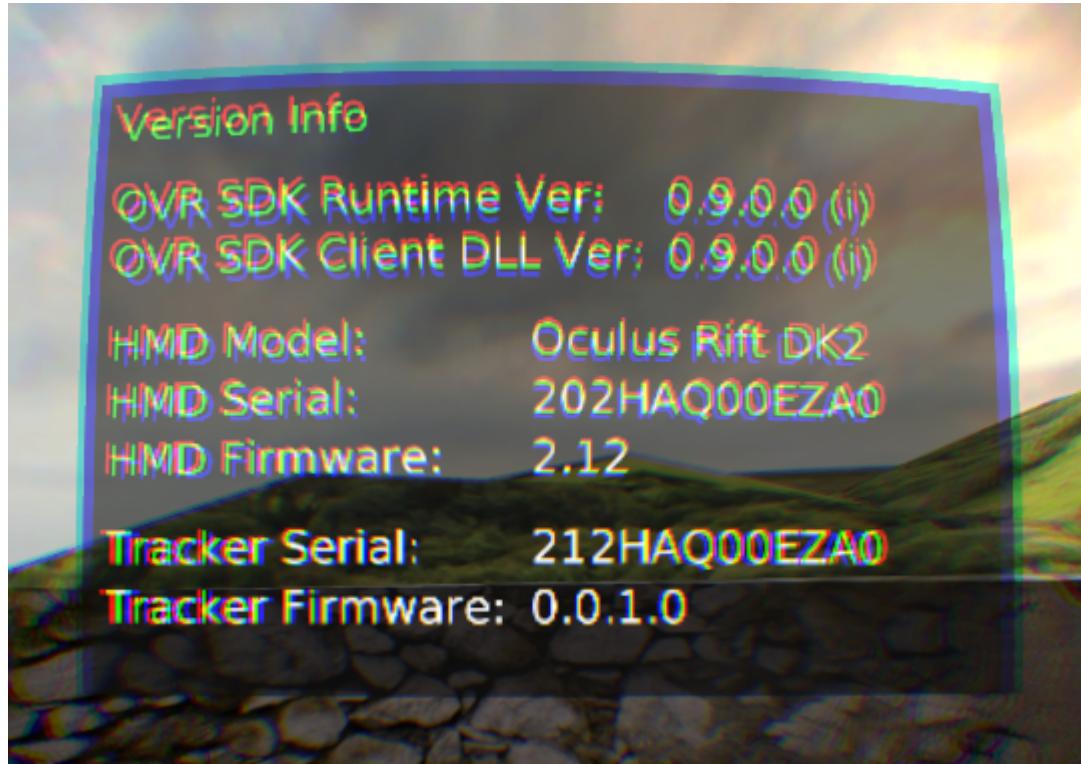
Metric	Description
Compositor Missed V-Sync Count	Increments each time the compositor fails to present a new rendered frame at V-Sync (Vertical Synchronization).
Compositor Frame-rate	The rate of the final composition; this is independent of the client application rendering rate. Because the compositor is always locked to V-Sync, this value will never exceed the native HMD refresh rate. But, if the compositor fails to finish new frames on time, it can drop below the native refresh rate.
Compositor GPU Time	The amount of time the GPU spends executing the compositor renderer. This includes TimeWarp and distortion of all layers submitted by the application. The amount of active layers, their resolutions, and the requested sampling quality can all affect the GPU times.
Comp Gpu-End to V-Sync	The amount of time between when the GPU completes the compositor rendering to the point in time when V-Sync is hit and that buffer starts scanning out on the HMD.

Version Information

The Version Information HUD displays information about the HMD and the version of the SDK used to create the app.

The following screenshot shows the Version Information HUD:

Figure 17: Version Info HUD



The following table describes each piece of information:

Name	Description
OVR SDK Runtime Ver	Version of the currently installed runtime. Every VR application that uses the OVR SDK since 0.5.0 uses this runtime.
OVR SDK Client DLL Ver	The SDK version that the client app was compiled against.
HMD Type	The type of HMD.
HMD Serial	The serial number of the HMD.
HMD Firmware	The version of the installed HMD firmware.
Sensor Serial	The serial number of the positional sensor.
Sensor Firmware	The version of the installed positional sensor firmware.

Pairing the Oculus Touch Controllers

After you receive your Touch Controllers, you need to pair them with the headset.

To pair your Touch controllers:

1. Make sure your headset is connected.
2. Launch the Oculus app.
3. Click the menu icon in the upper right to open the dropdown menu and select Settings.
4. Click Settings.
5. Click Devices.
6. Select Add Left Touch from Configure Rift and follow the on-screen instructions to pair the controller and update the firmware. When the process is finished, the Left Touch Paired screen displays.
7. Select Add Right Touch from Configure Rift and follow the on-screen instructions to pair the controller and update the firmware. When the process is finished, the Right Touch Paired screen displays.

 Note: If the Add Left Touch and Add Right Touch options do not appear, please contact Developer Relations.