MDCC 2016

中国移动开发者大会

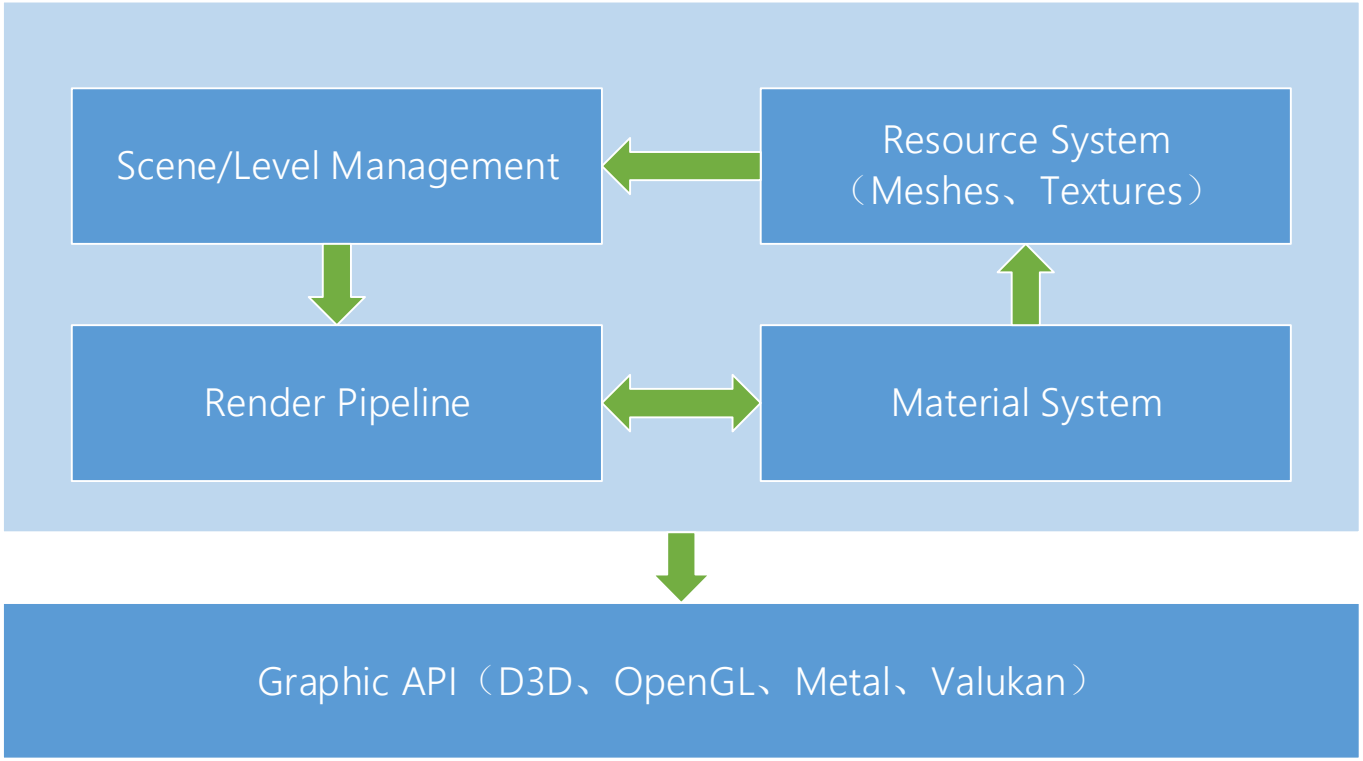
Mobile Developer Conference China 2016

# 虚幻4渲染系统结构解析

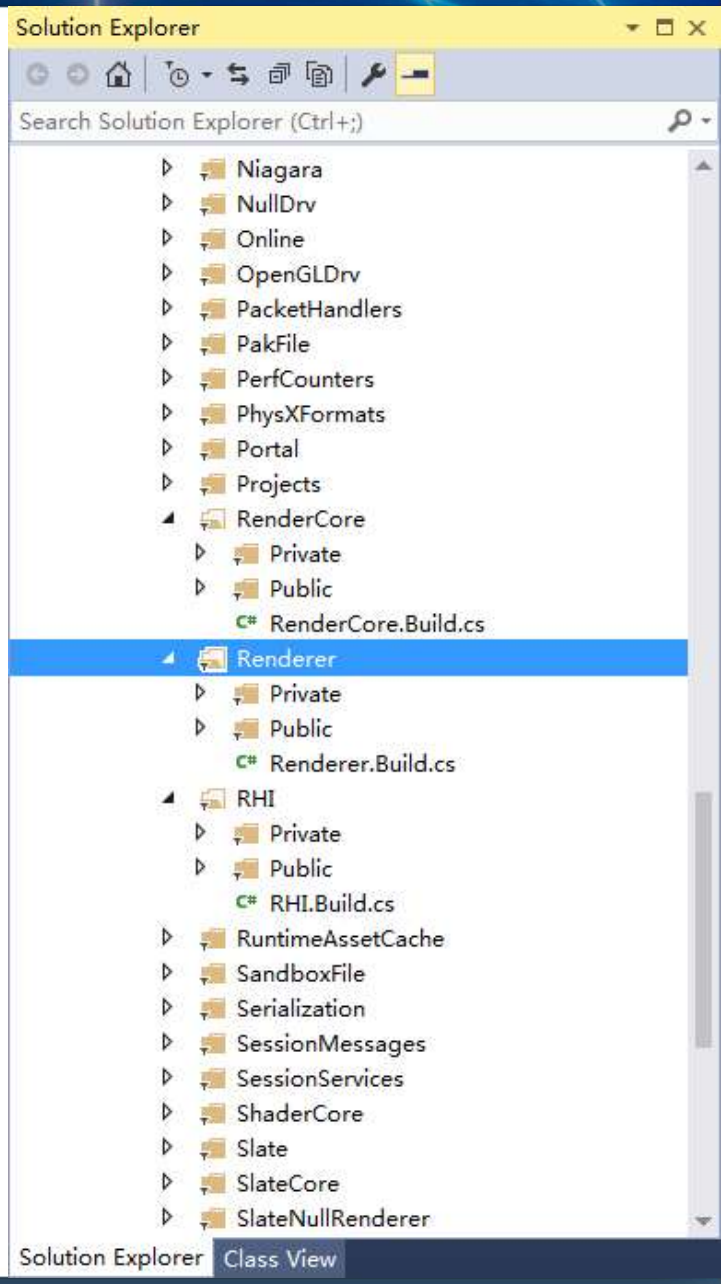
房燕良 2016年9月

- 自我介绍
- 3D引擎渲染系统概述
- 虚幻4渲染系统架构
  - 游戏线程&渲染线程
  - 场景管理与渲染数据管理
  - Deferred Shading Scene Renderer
- 虚幻4的VR渲染
  - 以Google VR HMD插件为例

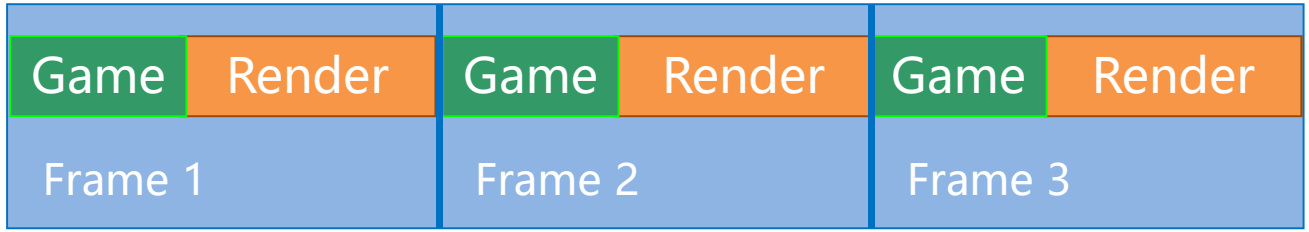
- 渲染系统架构
  - 场景管理与渲染器
  - 核心问题是管理复杂度和效率



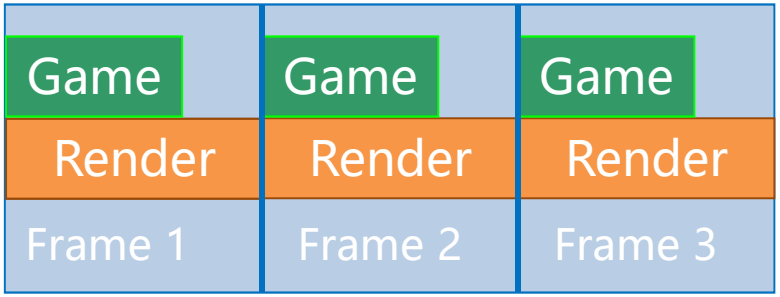
- Engine\Source\Runtime
- 核心代码模块
  - RenderCore
  - Renderer
- RHI抽象层
  - RHI：Render Hardware Interface
  - 基于D3D 11设计
- RHI实现层
  - EmptyRHI
  - Windows\D3D11RHI
  - Apple\MetalRHI
  - OpenGLDrv、VulkanRHI



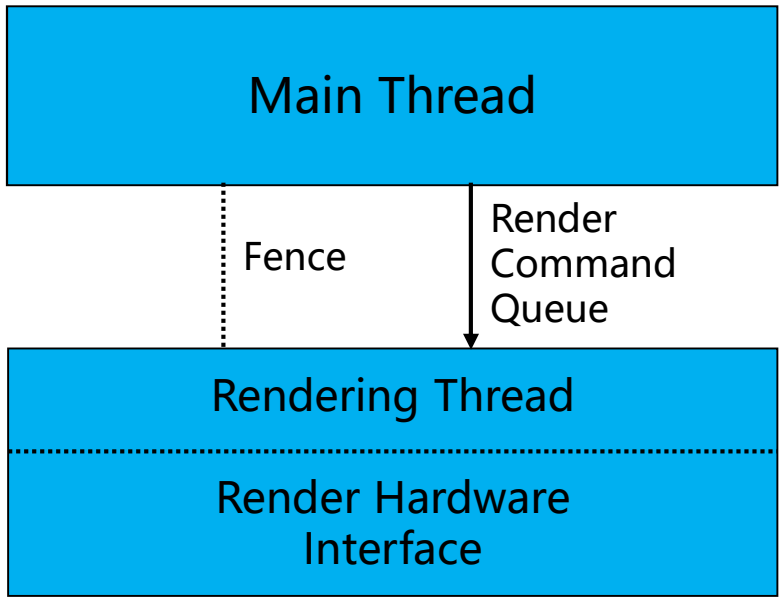
- 从虚幻3开始引入了渲染线程—Gemini
- 渲染线程对效率的提升
  - 最耗时的系统：渲染、游戏逻辑/脚本、物理模拟
  - 没有渲染线程




  - 使用渲染线程

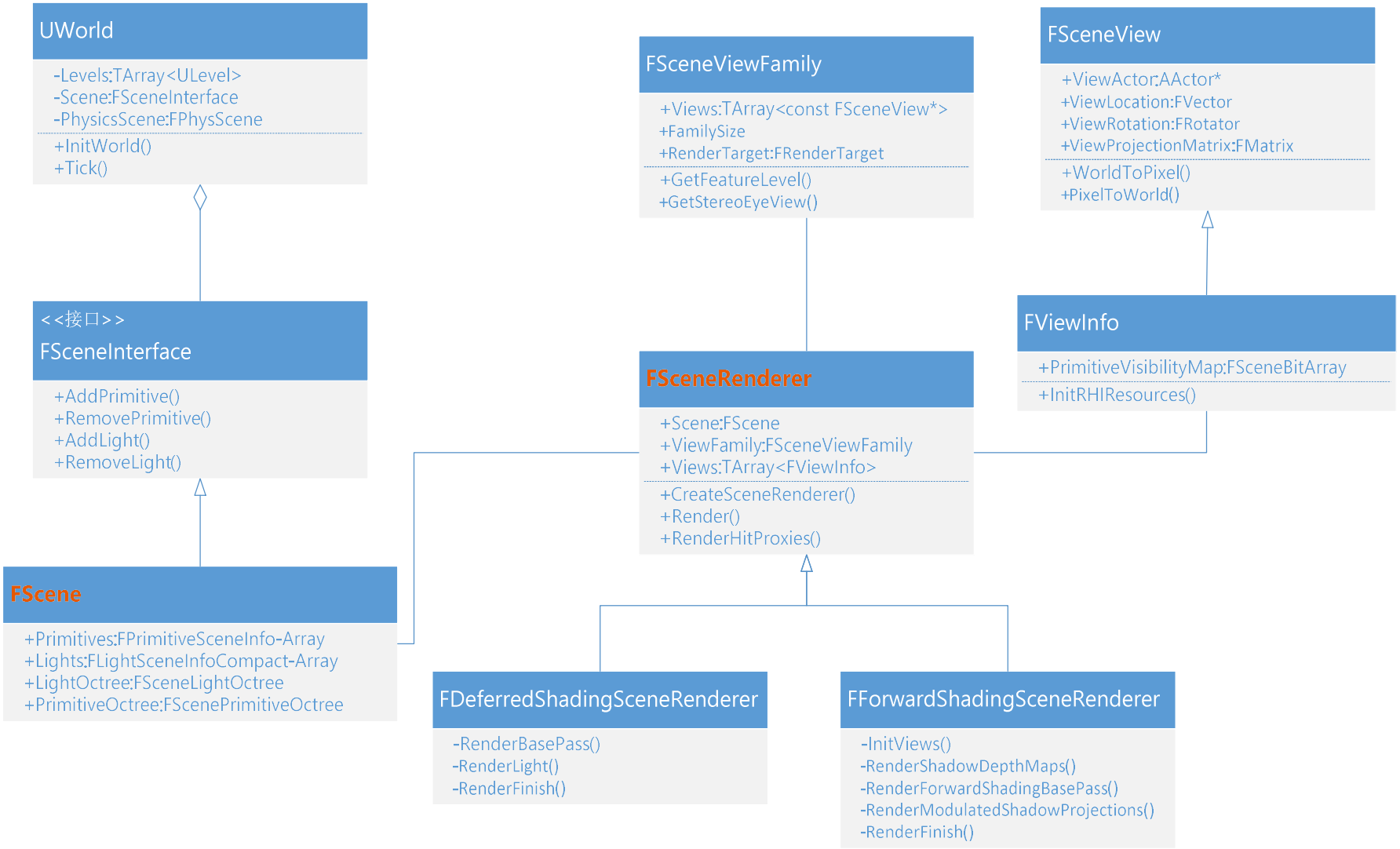



- 主线程领先2帧
  - Front Buffer： N， Render Thread： N+1， Game Thread: N+2
  - Render Command Fence： 防止Game Thread跑太快
- 场景数据管理
  - 主线程管理场景数据；渲染线程使用Proxy对象；
  - 渲染线程管理一份当前帧的拷贝



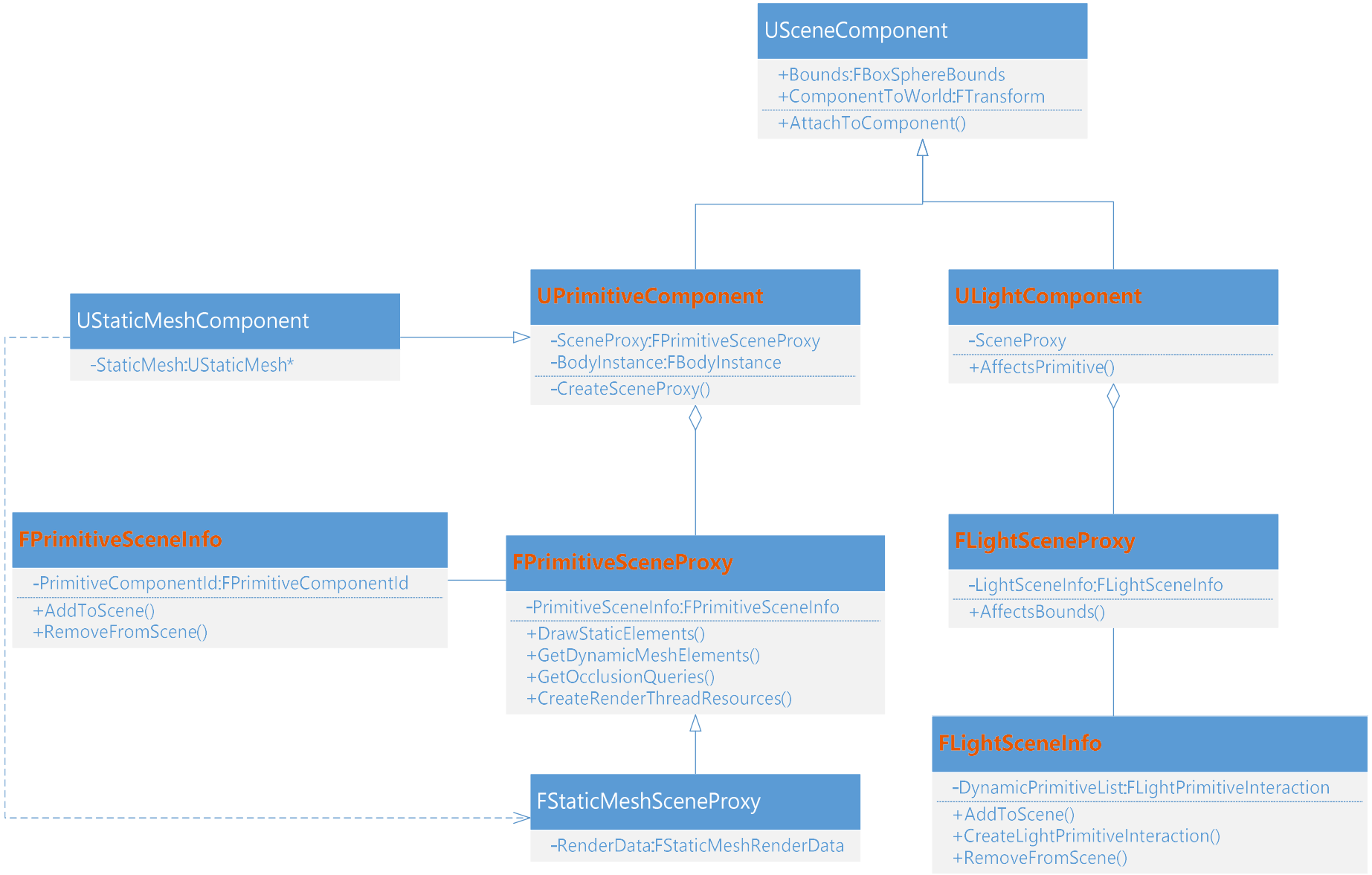
# 虚幻4渲染系统概述：核心类的静态结构





# 虚幻4渲染系统概述：核心类的静态结构





- Game线程

```
void UGameEngine::Tick( float DeltaSeconds, bool bIdleMode )
{
        UGameEngine::RedrawViewports()
        {
            void FViewport::Draw( bool bShouldPresent)
            {
                void UGameViewportClient::Draw()
                {
                  //-- 计算ViewFamily、View的各种属性
                  ULocalPlayer::CalcSceneView();

                  //-- 发送渲染命令：FDrawSceneCommand
                  FRendererModule::BeginRenderingViewFamily()

                  //-- Draw HUD
                  PlayerController->MyHUD->PostRender();
                }
}}}

FrameEndSync.Sync();
```

- Game线程

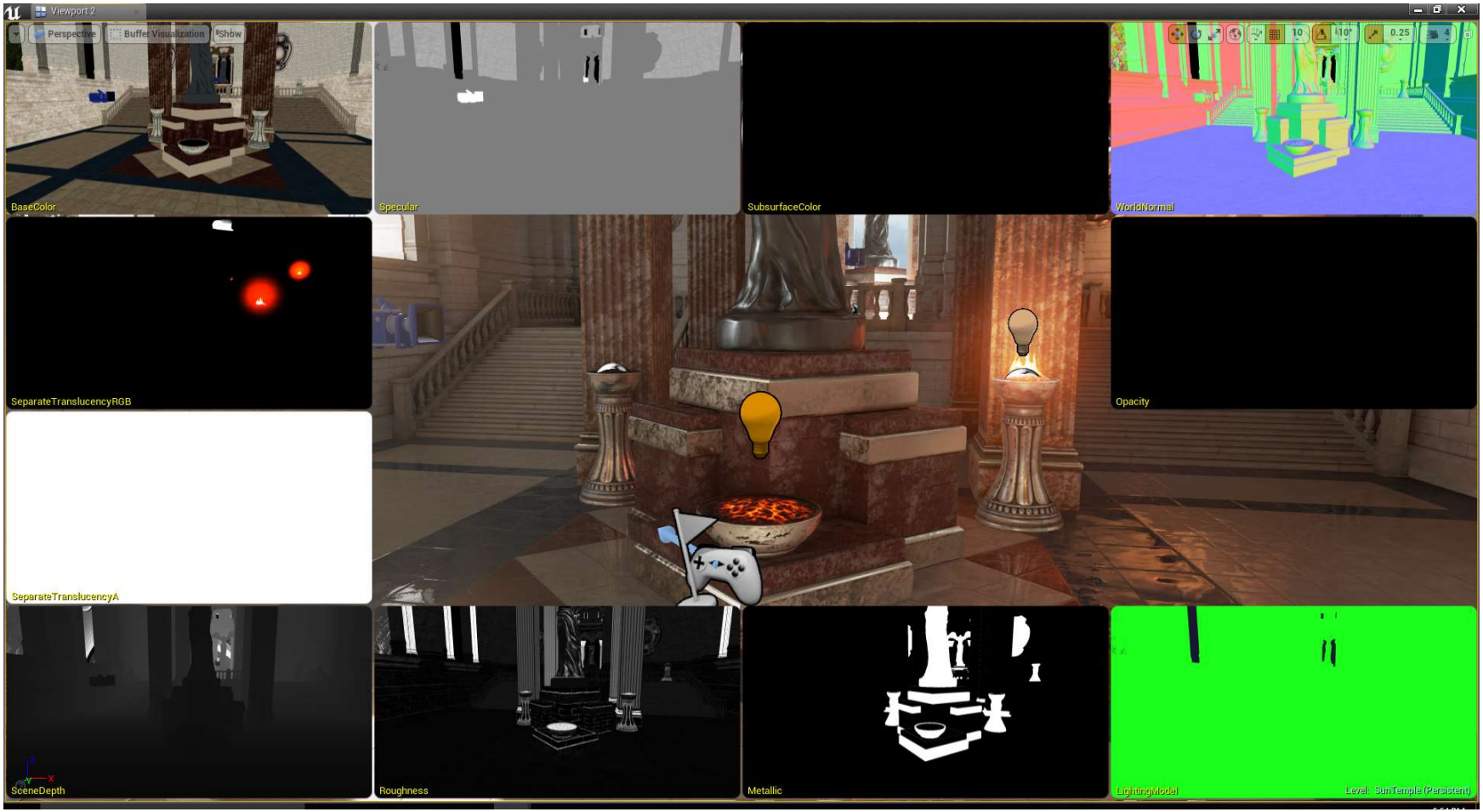
```
void FRendererModule::BeginRenderingViewFamily()
{
    // render proxies update
    World->SendAllEndOfFrameUpdates();

    // Construct the scene renderer.
    // This copies the view family attributes
    // into its own structures.
    FSceneRenderer* SceneRenderer =
        FSceneRenderer::CreateSceneRenderer(ViewFamily);

    ENQUEUE_UNIQUE_RENDER_COMMAND_ONEPARAMETER(
        FDrawSceneCommand,
        FSceneRenderer*,SceneRenderer,SceneRenderer,
        {
        RenderViewFamily_RenderThread(RHICmdList, SceneRenderer);
        FlushPendingDeleteRHIResources_RenderThread();
        });
}
```

- 渲染线程
  - RenderViewFamily_RenderThread()
  - FSceneRenderer::Render()
  - InitViews()
    - Primitive Visibility Determination： Frustum Cull+Occlusion Cull
    - Light Visibility： Frustum Cull
    - 透明物体排序： Back to Front
    - 不透明物体排序： Front to Back
  - 渲染Scene Color
  - Post Process

- FDeferredShadingSceneRenderer
  - GBuffers: class FSceneRenderTargets
  - DeferredShadingCommon.usf

| Name | Format | Usage |
| --- | --- | --- |
| GBufferA | PF_A2B10G10R10 | WorldNormal： xyz |
| GBufferB | PF_B8G8R8A8 | Metallic： r<br>Specular： g<br>Roughness： b<br>ShadingModelID： a |
| GBufferC | PF_B8G8R8A8 | BaseColor： rgb<br>GBufferAO： a |

- FDeferredShadingSceneRenderer

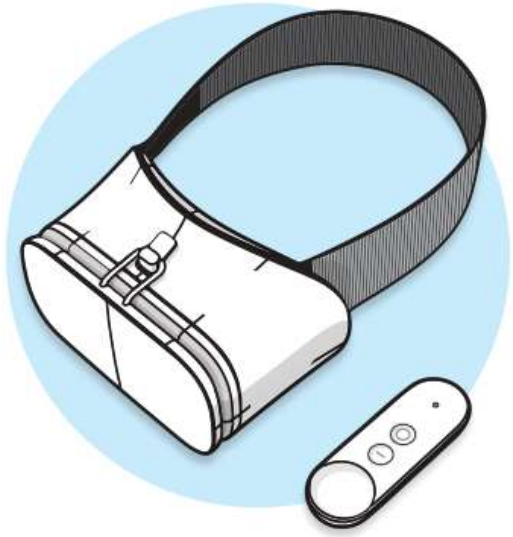


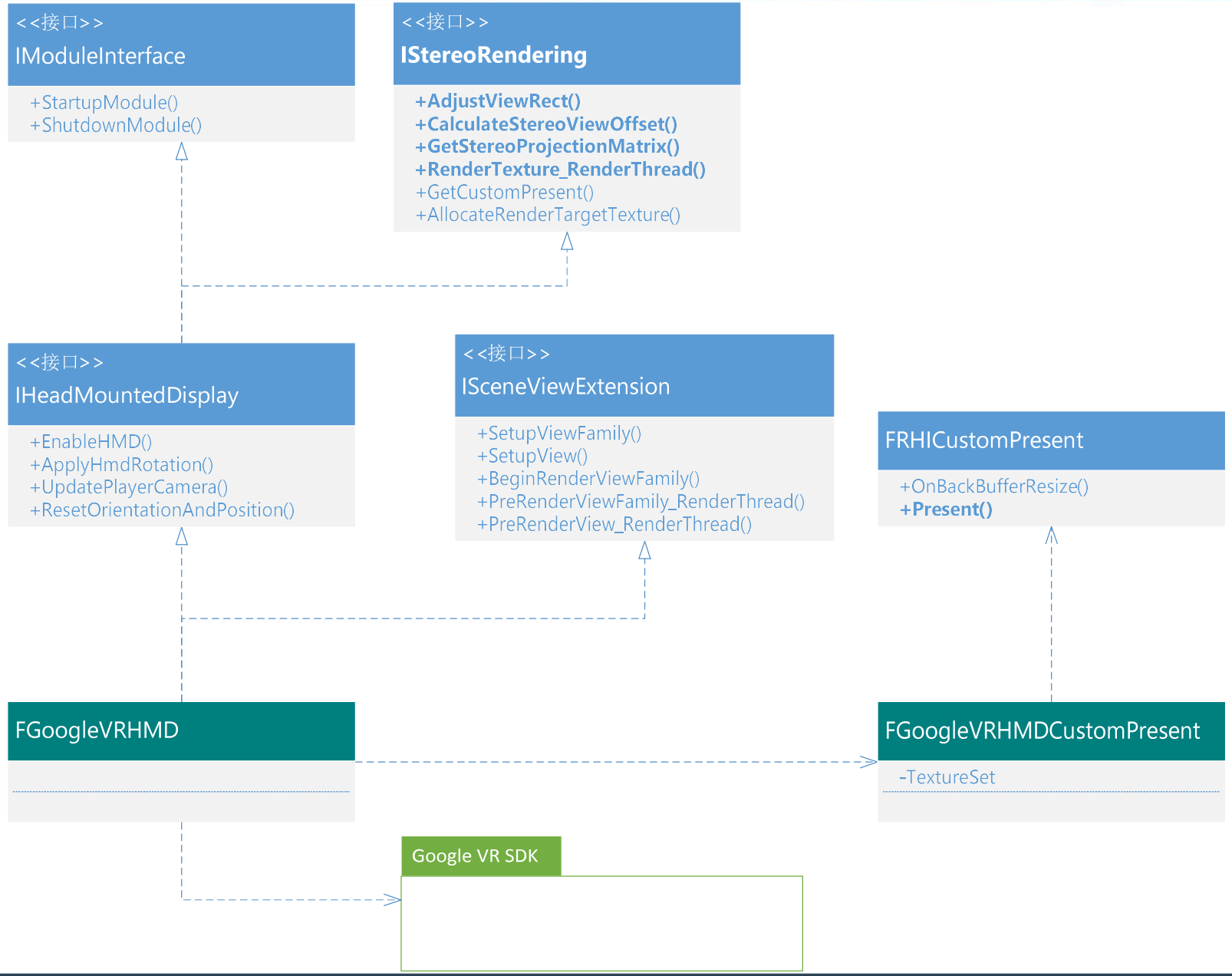
```
void FDeferredShadingSceneRenderer::Render()
{
        bool FDeferredShadingSceneRenderer::InitViews()
        {
        //-- Visibility determination.
        void FSceneRenderer::ComputeViewVisibility()
        {
                FrustumCull();
                OcclusionCull();
        }

        //-- 透明对象排序：back to front
        FTranslucentPrimSet::SortPrimitives();

        //determine visibility of each light
        DoFrustumCullForLights();

        //-- Base Pass对象排序：front to back
        void FDeferredShadingSceneRenderer::SortBasePassStaticData();
        }

        // 下页继续→
}
```

```
void FDeferredShadingSceneRenderer::Render()
{
    //-- EarlyZPass
    FDeferredShadingSceneRenderer::RenderPrePass();
    RenderOcclusion();

    //-- Build Gbuffers
    SetAndClearViewGBuffer();
    FDeferredShadingSceneRenderer::RenderBasePass();
    FSceneRenderTargets::FinishRenderingGBuffer();

    //-- Lighting stage
    RenderLights();
    RenderDynamicSkyLighting();
    RenderAtmosphere();
    RenderFog();
    RenderTranslucency();
    RenderDistortion();
    //-- post processing
    SceneContext.ResolveSceneColor();
    FPostProcessing::Process();
    FDeferredShadingSceneRenderer::RenderFinish();
}
```

```
void FDeferredShadingSceneRenderer::RenderLights()
{
        foreach(FLightSceneInfoCompact light IN Scene->Lights)
        {
          void FDeferredShadingSceneRenderer::RenderLight(Light)
          {
            RHICmdList.SetBlendState(Additive Blending);
            // DeferredLightVertexShaders.usf
            VertexShader = TDeferredLightVS;
            // DeferredLightPixelShaders.usf
            PixelShader = TDeferredLightPS;
            switch(Light Type)
            {
              case LightType_Directional:
                   DrawFullScreenRectangle();
              case LightType_Point:
                   StencilingGeometry::DrawSphere();
              case LightType_Spot:
                   StencilingGeometry::DrawCone();
             }
           }
        }
}
```

- 虚幻4的渲染系统与Unity3D的架构不同
  - 在Unity3D中，Camera管理一个渲染管线
  - 虚幻4将VR渲染流程整合进引擎底层
  - Scene View Family、Scene View
- Case Study：Google VR HMD插件
  - 代码目录：Plugins/Runtime/GoogleVR/GoogleVRHMD
  - VR渲染系统的静态结构
  - VR渲染流程概述




<<接口>>
IModuleInterface
+StartupModule()
+ShutdownModule()
<<接口>>
IStereoRendering
+AdjustViewRect()
+CalculateStereoViewOffset()
+GetStereoProjectionMatrix()
+RenderTexture_RenderThread()
+GetCustomPresent()
+AllocateRenderTargetTexture()
<<接口>>
IHeadMountedDisplay
+EnableHMD()
+ApplyHmdRotation()
+UpdatePlayerCamera()
+ResetOrientationAndPosition()
<<接口>>
ISceneViewExtension
+SetupViewFamily()
+SetupView()
+BeginRenderViewFamily()
+PreRenderViewFamily_RenderThread()
+PreRenderView_RenderThread()
FRHICustomPresent
+OnBackBufferResize()
+Present()
FGoogleVRHMD
FGoogleVRHMDCustomPresent
-TextureSet
Google VR SDK

- 创建HMD Device

```
//-- 在引擎启动时，会创建所有的HMD设备
void UEngine::Init()
{
    bool UEngine::InitializeHMDDevice()
    {
        for (auto HMDModuleIt = HMDModules.CreateIterator();
                HMDModuleIt; ++HMDModuleIt)
        {
            IHeadMountedDisplayModule* HMDModule = *HMDModuleIt;
            HMDDevice = HMDModule->CreateHeadMountedDisplay();

        }
    }
}
```

- 绘制流程入口

```
//-- 在View绘制时，如果是Stereo则绘制两个View
void UGameViewportClient::Draw()
{
        const bool bEnableStereo =
                        GEngine->IsStereoscopic3D(InViewport);
        int32 NumViews = bEnableStereo ? 2 : 1;

        for (int32 i = 0; i < NumViews; ++i)
        {
        }
}
```

- IStereoRendering接口调用

```
void UGameViewportClient::Draw()
{
  ULocalPlayer::CalcSceneView()
  {
    ULocalPlayer::GetProjectionData()
    {
     GEngine->StereoRenderingDevice->AdjustViewRect(StereoPass);
     GEngine->StereoRenderingDevice->CalculateStereoViewOffset(StereoPass);
     ProjectionData.ProjectionMatrix
          = GEngine->StereoRenderingDevice
                          ->GetStereoProjectionMatrix(StereoPass);
    }
   }
}
```

- GoogleVRHMD实现

```
void FGoogleVRHMD::AdjustViewRect(StereoPass, int32& X,
                    int32& Y, uint32& SizeX, uint32& SizeY) const
{
        SizeX = SizeX / 2;
        if( StereoPass == eSSP_RIGHT_EYE )
                X += SizeX;
}

void FGoogleVRHMD::CalculateStereoViewOffset()
{
    const float EyeOffset = (GetInterpupillaryDistance() * 0.5f)
    * WorldToMeters;
    const float PassOffset = (StereoPassType == eSSP_LEFT_EYE) ?
    -EyeOffset : EyeOffset;
    ViewLocation +=
    ViewRotation.Quaternion().RotateVector(FVector(0,PassOffset,0
    ));
}
```

- GoogleVRHMD实现

```
void FGoogleVRHMD::RenderTexture_RenderThread()
{
    gvr_distort_to_screen(GVRAPI,
        SrcTexture->GetNativeResource(),
        CachedDistortedRenderTextureParams,
        &CachedPose,
        &CachedFuturePoseTime);
}
```

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