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Unreal Engine 4 Rendering Part 3: Drawing Policies

(If you haven't read Part 2 in this series, it is available here)

Introduction

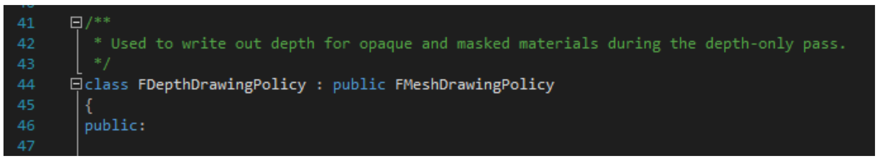
In this blog post we're covering drawing policies, drawing policy factories and how they interact with all of the systems we have learned up to this point. We also take a quick look at what actually makes Unreal draw a mesh!

Perspective
Lighting Only
Show
[Pilot Active - CineCameraActor18]
Level: Bust_ScanScene_Outdoors (Persistent)

A Lighting Only pass from Epic Game's Photo Realistic Character example

Drawing Policies

A Drawing Policy in Unreal is more of a concept than a specific class, as they don't all share the same base class. Conceptually the drawing policy determines which shader variations are used to draw something, but it doesn't pick what it draws or when it's drawn! We're going to look at two drawing policies, the one for Unreal's depth pre-pass, and the one for Unreal's base pass which is significantly more complicated.



```
/**
 * Used to write out depth for opaque and masked materials during the depth-only pass.
 */
class FDepthDrawingPolicy : public FMeshDrawingPolicy
{
public:
```

One of the many Drawing Policy style classes

FDepthDrawingPolicy

The depth drawing policy is a good example of how simple a drawing policy can be. In its constructor, it asks the material to find it a shader of a specific type for a specific vertex factory:

`VertexShader = InMaterial.GetShader<TDepthOnlyVS<false>>(VertexFactory->GetType());`

`TDepthOnlyVS` is an implementation of the `FMeshMaterialShader` and uses the appropriate macro to declare itself as a shader. Unreal handles trying to compile all possible permutations of material/shader/vertex factory, so it should be able to find this. If you have your `ShouldCache` functions set up incorrectly then this is the point where it fails and the engine throws an assert and makes you fix it!

Then, it looks at the material it's supposed to draw to determine if that material has tessellation enabled or not—if it does have it enabled then the depth drawing policy looks for a hull and domain shader:

```
HullShader = InMaterial.GetShader<FDepthOnlyHS>
(VertexFactory->GetType());
DomainShader = InMaterial.GetShader<FDepthOnlyDS>
(VertexFactory->GetType());
```

Drawing Policies also have the ability to set parameters on the shaders through the `SetSharedState` and `SetMeshRenderState` functions, though they usually just pass these on to the currently bound shaders.

FBasePassDrawingPolicy

Here's where Unreal starts to get tricky with their macros and templates. Let's think about the basepass in deferred rendering for a moment. You have lots of different materials using different hardware features (like tessellation), using different vertex factories, and you need light-specific variations. It's a huge number of permutations, and Unreal uses several macros to make this happen. **If this doesn't make a lot of sense, don't worry about it. It's not too important to making changes**, just be aware it exists.

First thing they do is they make a template `FBasePassDrawingPolicy` called `template<typename LightMapPolicyType> class TBasePassDrawingPolicy : public FBasePassDrawingPolicy` and the constructor simply calls another template function. That in turn calls another template function, but this time with a specific enum for each lighting type.

Now that they know what lighting policy they're trying to get a shader for, they use the same `InMaterial.GetShader` function as the Depth drawing policy does, but this time they're getting a shader class which is templated!

```
VertexShader =
InMaterial.GetShader<TBasePassVS<TUniformLightMapPolicy<Policy>, false> >(VertexFactoryType);
```

You're welcome to follow the template chain all the way down, but the important thing to know is how Unreal knows about all the possible implementations. And the answer to that is a couple of nested macros! Hop on over to the top of *BasePassRendering.cpp* and we'll look at them top to bottom.

The first macro is `IMPLEMENT_BASEPASS_VERTEXSHADER_TYPE` which registers vertex, hull and domain material shaders (using the `IMPLEMENT_MATERIAL_SHADER_TYPE` macro we talked about in the section on Shaders) for a given LightMapPolicyType, and LightMapPolicyName by creating new typedefs. So now we know that calling `IMPLEMENT_BASEPASS_VERTEXSHADER_TYPE` registers vertex shaders for us.

The second macro is `IMPLEMENT_BASEPASS_LIGHTMAPPED_SHADER_TYPE` which takes the LightMapPolicyType, and LightMapPolicyName and calls `IMPLEMENT_BASEPASS_VERTEXSHADER_TYPE`, and `IMPLEMENT_BASEPASS_PIXELSHADER_TYPE` (which we didn't talk about, but works in the same way as the vertex one). This macro therefor lets us create a full shader chain (vertex and pixel) for any given LightMap. Finally Unreal calls this macro 16 different times, passing in different combinations of LightMapPolicyTypes and LightMapPolicyNames.

At one point during the call of `InMaterial.GetShader<…>` functions from earlier, one of the functions had a big switch statement for each LightMapPolicyType to return the right one. So we know that Unreal is declaring all of our variations for us, so GetShader is able to get the right thing!

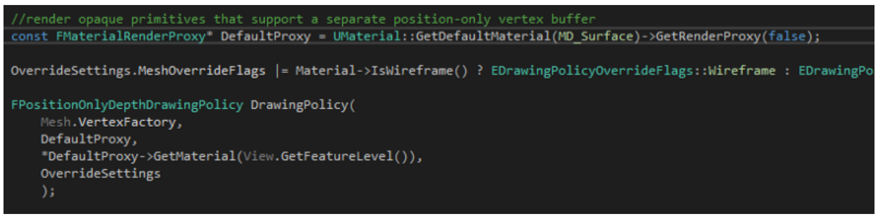
Drawing Policy Factory

So we know that a Drawing Policy figures out which specific shader to use for a given material and vertex factory, which allows Unreal to create policies like “get the depth only shaders” or “get the shaders that have code for point lights”. But what creates a Drawing Policy and how does it know which one to make? And how does it know what to draw? This is where Drawing Policy Factories come in. They examine the state of the material or vertex factory and then can create the correct drawing policy.

FDepthDrawingPolicyFactory

We will use the FDepthDrawingPolicyFactory as a (relatively) simple example. There’s only three functions, `AddStaticMesh` , `DrawDynamicMesh` and `DrawStaticMesh` . When `AddStaticMesh` is called the Policy Factory looks at settings about the material and asset that is to be drawn and determines the appropriate Drawing Policy to create. Then, Unreal puts that drawing policy into a list inside of the `FScene` which is about to be drawn.

For example, the `FDepthDrawingPolicyFactory` looks at the material to see if it modifies the mesh position. If it modifies the mesh position then it creates a `FDepthDrawingPolicy` and adds it to the “MaskedDepthDrawList” inside of `FScene` . If the material does not modify the mesh position then instead it creates a `FPositionOnlyDepthDrawingPolicy` (which looks for different shader variations!) and adds it to a *different* list in the `FScene` .



```
//render opaque primitives that support a separate position-only vertex buffer
const FMaterialRenderProxy* DefaultProxy = UMaterial::GetDefaultMaterial(MD_Surface)->GetRenderProxy(false);

OverrideSettings.MeshOverrideFlags |= Material->IsWireframe() ? EDrawingPolicyOverrideFlags::Wireframe : EDrawingPo

FPositionOnlyDepthDrawingPolicy DrawingPolicy(
    Mesh.VertexFactory,
    DefaultProxy,
    *DefaultProxy->GetMaterial(View.GetFeatureLevel()),
    OverrideSettings
    );
```

The Drawing Policy Factory creates Drawing Policies

The `FDepthDrawingPolicyFactory` also has the ability to draw a given mesh batch, which again examines the settings and creates a drawing policy. However, instead of adding it to a list it instead sets up the state for the GPU via the RHI layer, and then calls *another drawing policy* to actually draw the mesh.

Telling the the Drawing Policy Factory to Draw

Finally we learn the root of this and see how all of these pieces come into play. Remember how there was no shared base class for Drawing Policies, or Drawing Policy Factories? We've reached the point where the code just knows about them specifically and calls them at different times.

FStaticMesh::AddToDrawLists

Our `FDepthDrawingPolicyFactory` had a function called `AddStaticMesh` so it's no surprise that the class that creates it is related to static meshes! When `AddToDrawLists` gets called it examines the asset and project settings to decide what to do with it. The first thing it does is call `FHitProxyDrawingPolicyFactory::AddStaticMesh`, and then `FShadowDepthDrawingPolicyFactory::AddStaticMesh`, and then `FDepthDrawingPolicyFactory::AddStaticMesh` and finally `FBasePassOpaqueDrawingPolicyFactory::AddStaticMesh` and `FVelocityDrawingPolicyFactory::AddStaticMesh`, whew!

So we know when FStaticMesh is marked to be added to draw lists it creates a wide variety of Drawing Policy Factories (who then create Drawing Policies and add them to the correct list). The specifics of how this function is called aren't terrible important (though see `FPrimitiveSceneInfo::AddStaticMeshes` and go up from there), but we know that something has to tell the depth pass to draw before the base pass as well as doing shadows, etc.

Enter `FDeferredShadingRenderer` , a massive class that handles getting everything drawn in the right order. `FDeferredShadingRenderer::Render` kicks off the whole process and controls the order of the render operations. We'll look at the base pass drawing policy factory; The Render function calls `FDeferredShadingSceneRenderer::RenderBasePass` which in turn calls `FDeferredShadingSceneRenderer::RenderBasePassView` which calls `FDeferredShadingSceneRenderer::RenderBasePassDynamicData` which finally calls our `FBasePassOpaqueDrawingPolicyFactory::DrawDynamicMesh` in a loop, passing a different mesh to it each time.

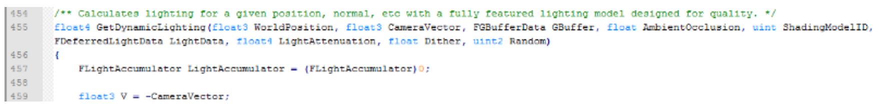
Whew.

Review

Drawing Policies find the right shader permutation for a given material, vertex factory, and shader combination. The developer specifies the shader type to accomplish different things depending on the policy. Drawing Policy Factories handle creating Drawing Policies and adding them to the appropriate lists. Finally, through a long chain of inheritance `FDeferredShadingRenderer::Render` ends up looping through the various lists and calling their Draw function.

Next Post

We've made it to the end of the C++ side! We've covered a huge amount of information which hopefully gives you a good overview of how the pieces connect together. We learned how scenes create drawable data (`UPrimitiveComponent`) and how that data gets to the render thread (`FPrimitiveSceneProxy`), and how that render thread gets the data onto the GPU in the right format (`FVertexFactory`). Then we learned how Drawing Policies find the right shaders for a developer's intent, and how Drawing Policy Factories abstract away the details of having multiple types of Drawing Policies, and then we took a quick look to see how these Drawing Policy Factories are called.



```
/** Calculates lighting for a given position, normal, etc with a fully featured lighting model designed for quality. */
float4 GetDynamicLighting(float3 WorldPosition, float3 CameraVector, FGBufferData GBuffer, float AmbientOcclusion, uint ShadingModelID,
FDeferredLightData LightData, float4 LightAttenuation, float Dither, uint2 Random)
{
    FLightAccumulator LightAccumulator = (FLightAccumulator)0;

    float3 V = -CameraVector;
```

The Deferred Shading Shader

In our next post, we're moving onto the GPU side! We're going to take a look at the shader architecture, mostly focusing on the Deferred Shading renderer. We'll be looking at what shader files and functions modify what part of the expected outcome and how shading is calculated. We won't be investigating the specifics of the Deferred Shading pipeline on a technical level as that's beyond me! The next post is available here!