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# Material and Shader Best Practices for Unreal Engine

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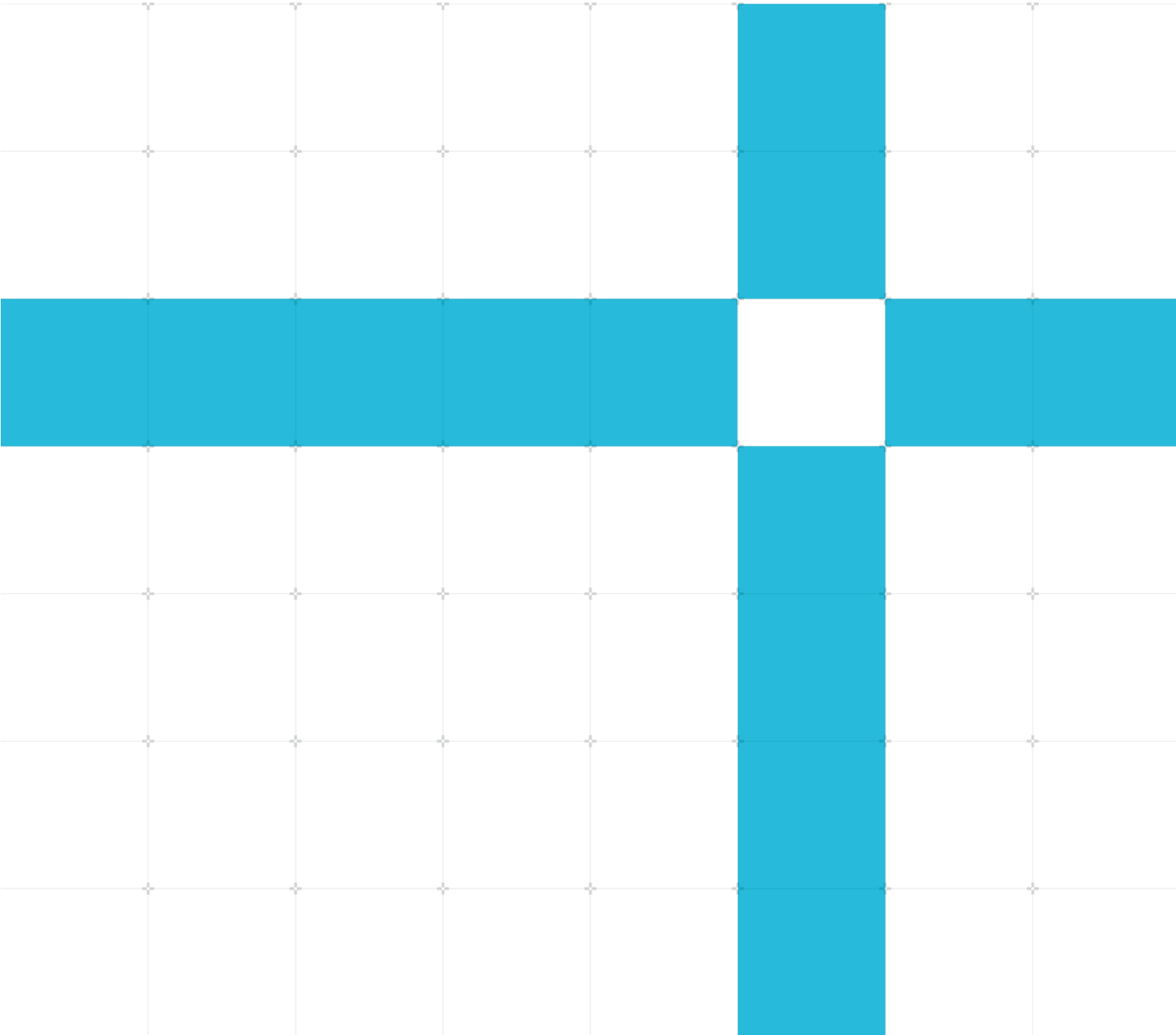

# Unreal Engine

## Material and Shader Best Practices for Unreal Engine



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## Product Status

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# Contents

# 1 Overview

In this guide you will learn about how to use materials and shaders accurately and effectively in Epic's Unreal Engine game engine. Everything in this guide is from the perspective of a technical artist targeting a mobile platform.

By the end of this guide, you will understand the following:

- The difference between a material and a shader
- The best practices and game engine best practices for materials and shaders
- Transparency best practices for artists
- Reducing shader complexity

# 2 What is a material and a shader?

A material is something that can be applied to an object or mesh to define the visual look of that object. A material is used to set the value of a parameter that is available from a shader, such as the color, numeric values, and so on.

A shader is a small program that tells the GPU how to draw an object on the screen and the calculations needed to happen on the object.

Shaders have the following prerequisites:

- A shader needs to be attached to a material used
- A scripting language used to author shaders, such as HLSL and GLSL

A shader and a material can be used in different ways, depending on the game engine. In Unreal Engine, the shader used can be based on the target platform selected. The following image shows a shader and material in Unreal Engine:

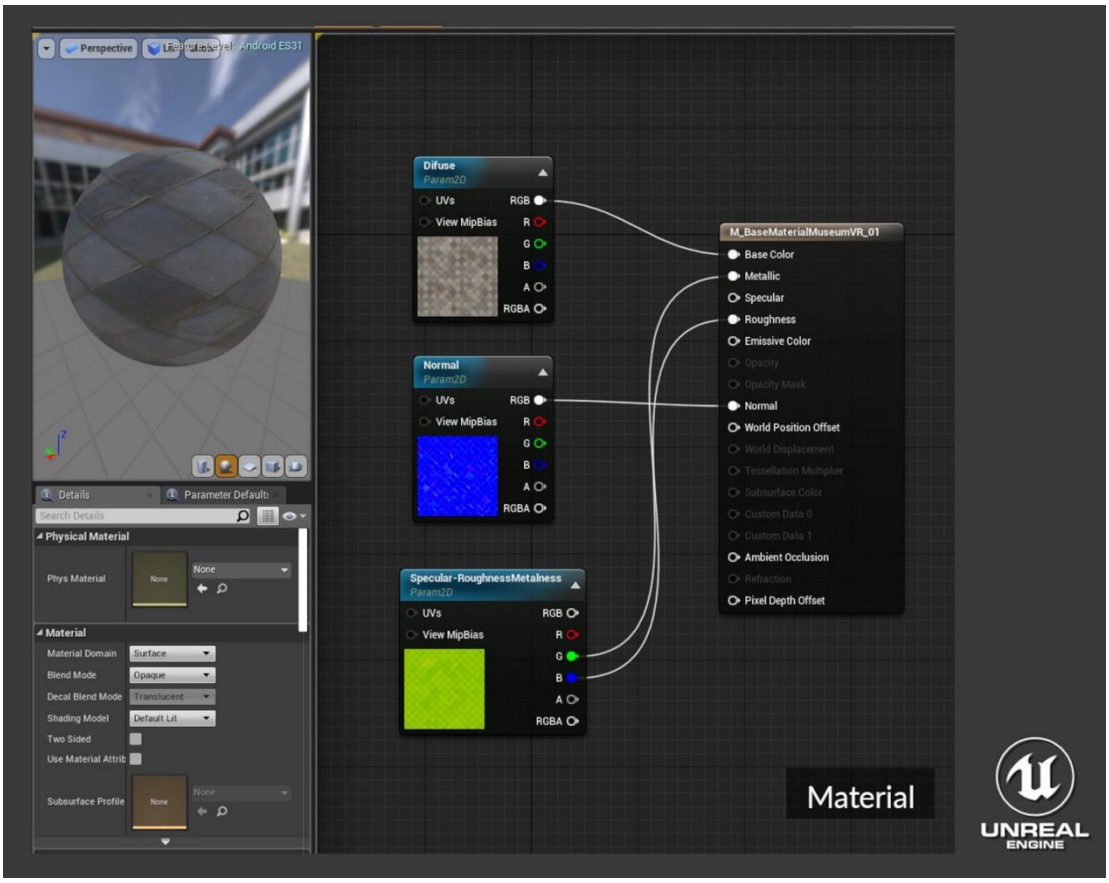


**Figure 1: Shader and Material screen**

# 3 Shaders for mobile platforms

Unreal Engine uses the most relevant mobile shader depending on the target platform selected. Using this mobile shader results in a different look compared to the default Shader Model 5. To better visualize the final look in the device within the editor, change the Preview Rendering Level, as shown in the following screenshot:

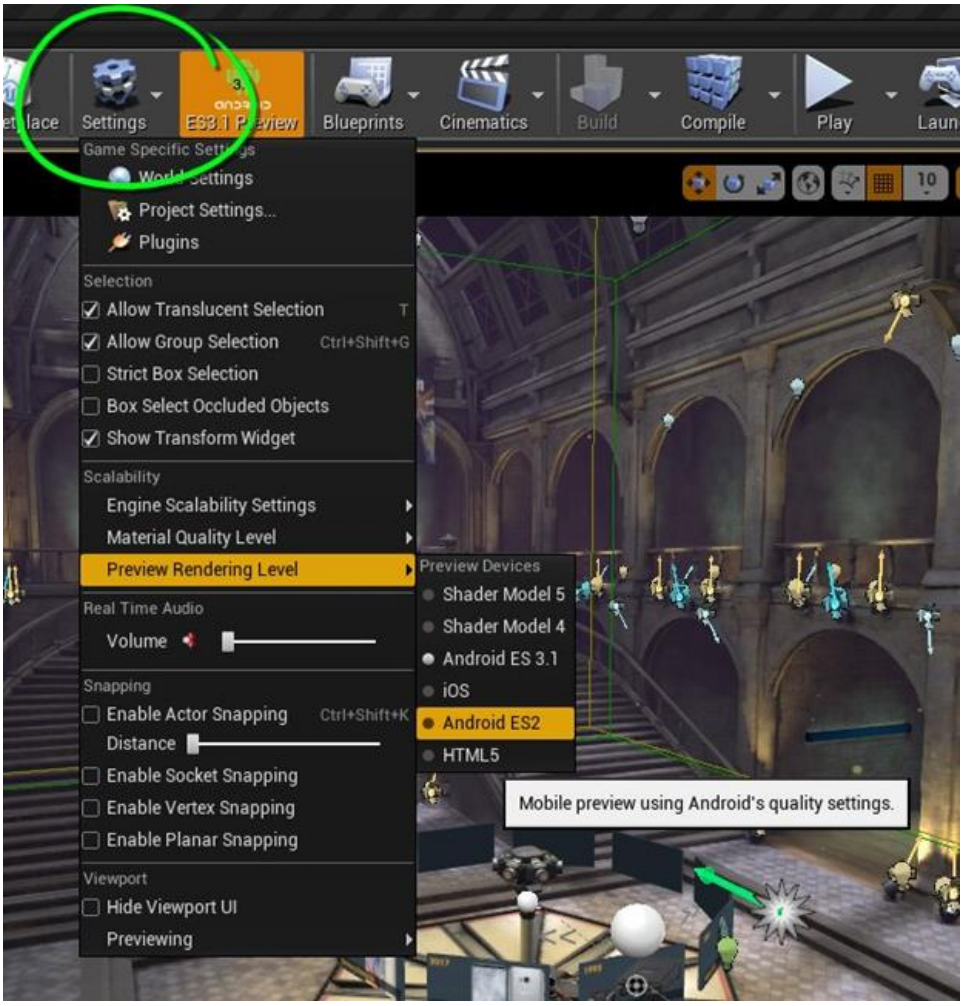


**Figure 2: Preview Rendering Level menu**

Unreal Engine's material on mobile platforms is created using the same process as other platforms, so they have similar visuals and behaviors.

Unreal Engine compiles the shader based on the material settings. By removing features that are not needed such as color tinting and detail maps, the shader will be less complex overall. Removing unused features can help with performance on mobile platforms.

## 3.1 Texture samplers

For mobile platforms, it is recommended that you use as few textures as possible. This is because more textures can result in more texture fetches, and the extra bandwidth will affect battery life. Also, because these textures are saved in memory, the application size increases.

The following are suggestions for using texture samplers on mobile devices:

- In Unreal Engine, the recommended maximum number of texture samplers for mobile is five. For more information, see the Unreal Engine Materials for Mobile Platforms documentation.
- If possible, use the least number of textures. It is considerably more expensive to use all five texture samplers in a material.
- Use texture packing to reduce the number of textures. For example, instead of using individual textures for roughness or metallic, pack the textures into channels of a single texture. An example of texture packing is shown in the following screenshot:

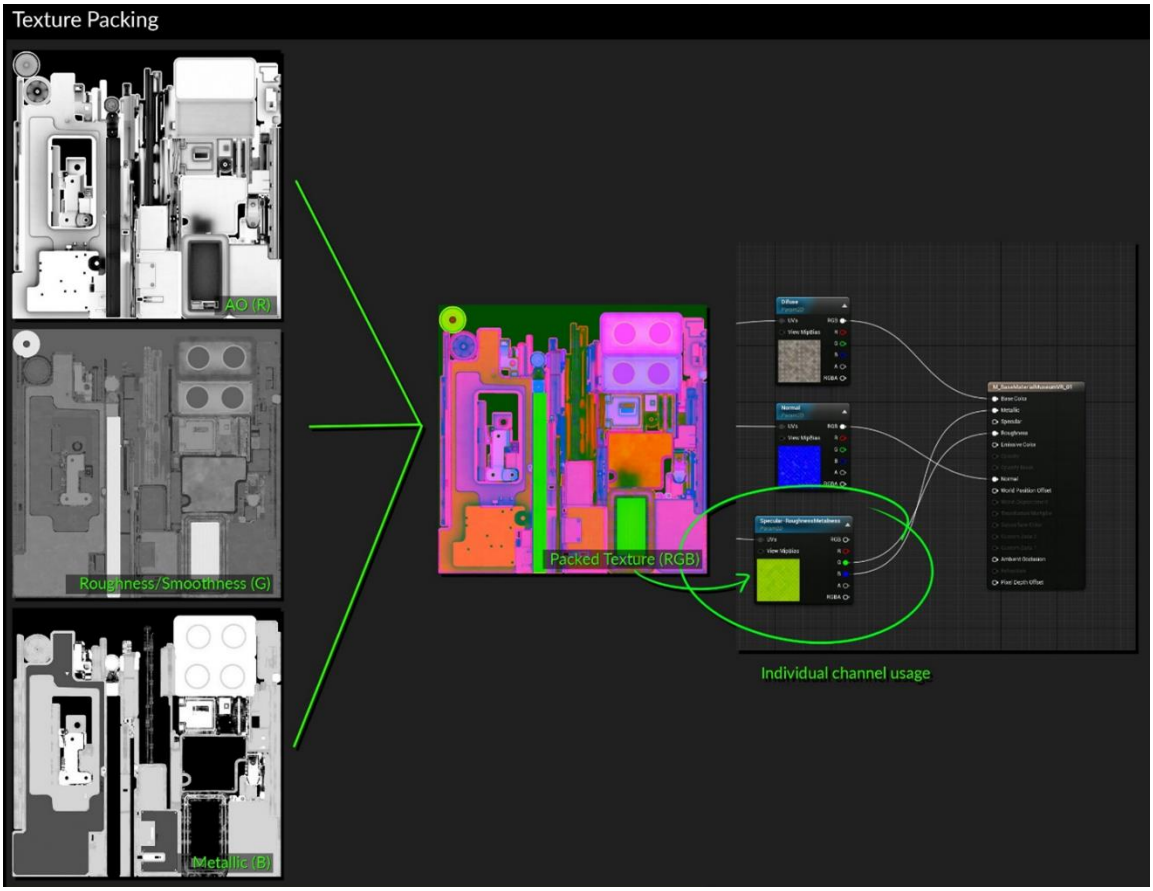


**Figure 3: Texture Packing screenshot**

We can also use a numerical value instead of a texture for some parameters such as metallic, roughness, or smoothness. Using a numerical value will further reduce the number of textures used. In Unreal Engine, add constant to the parameter slots to use numerical values.

## 3.2 Unlit and lit shaders

When creating a shader, we can decide how the material reacts to light. The most used shaders in mobile games are lit or unlit shaders. Use an unlit shader to reduce the number of textures used, because the material is not affected by light and will not need roughness or metallic texture.

Unlit is the fastest and cheapest shading model. Use unlit shaders if you are targeting lower-end devices.

The following tips will help you get the most benefits from shaders:

- Use an unlit shading model as much as possible, especially if the game is targeting lower-end devices.
- An unlit shading model is not affected by lighting and only outputs emissive as color.
- Because an unlit shader is not affected by light, many calculations are not needed such as specular, shadow, and so on. This reduction in calculations results in cheaper and faster rendering.
- Use stylized or cartoon art with unlit shading when making games for mobile platforms.

Default lit shaders need extra processing, compared to unlit shaders. More processing is needed for lit shaders, however the surface can be affected by light and have specularity. For most games, lit shaders is the shading model that is used, as shown in the following image:

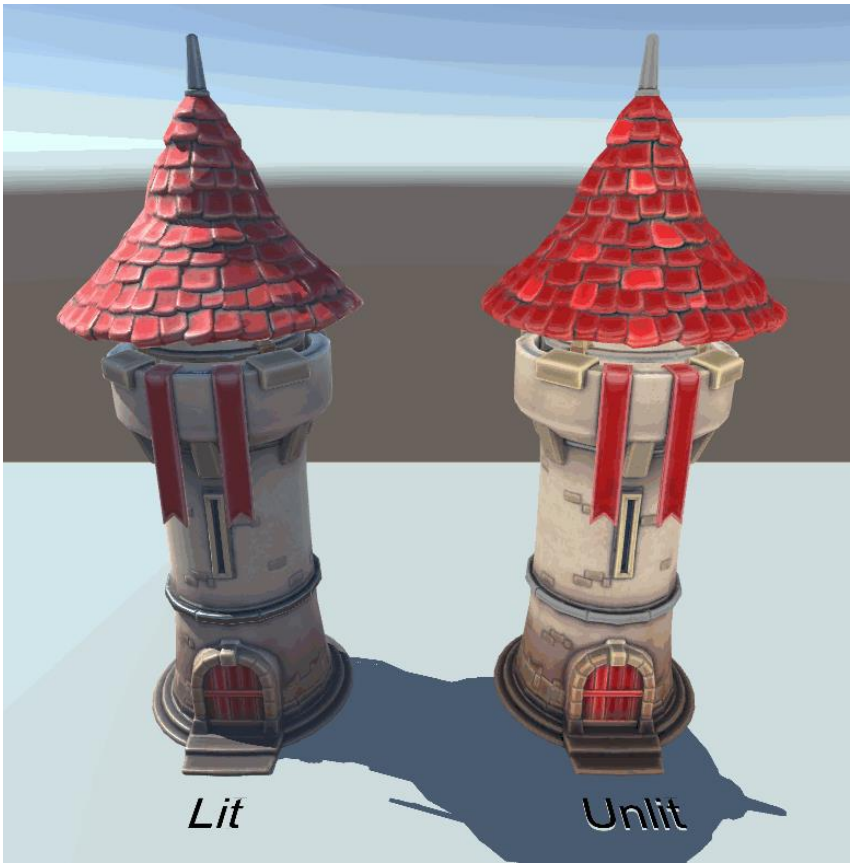


**Figure 4: Lit shaders example**

# 4 Transparency considerations

We recommend that you avoid transparency and use an opaque material when possible. On mobile platforms, only use transparency if necessary because transparency will be more expensive than opaque.

Having many transparent objects in games affects performance when objects are rendered on top of another several times. This rendering problem is known as overdraw, when the same pixel is drawn multiple times. The more layers of transparency we have, the more expensive the rendering becomes. For mobile platforms, overdraw can severely affect performance; therefore, be careful when building levels and keep overdraw to a minimum. In a situation where overdraw is unavoidable (such as when using particles) make the shader as simple as possible.

Unreal Engine can visualize overdraw track the severity of overdraw in each scene, as shown in the following screenshot:

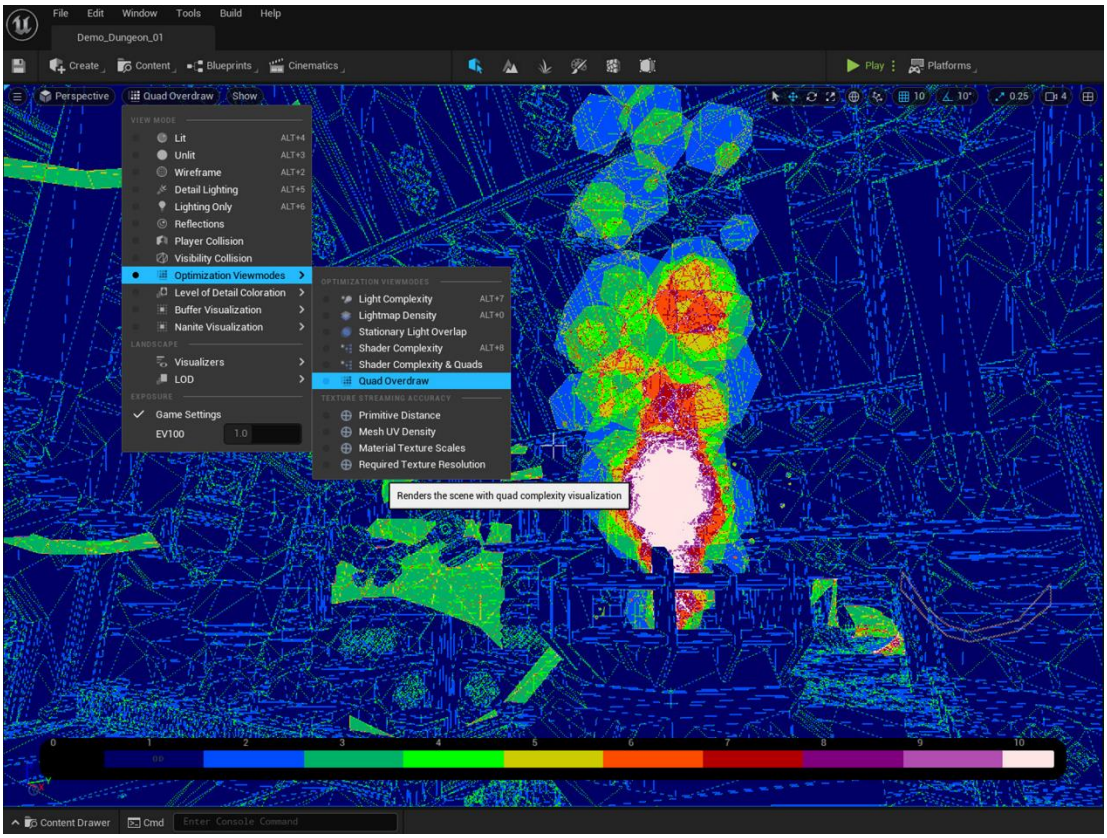


**Figure 5: Overdraw example**

This image visualizes overdraw. Using the key on the bottom of the image, you can see hot spots of over draw. Areas that colors are on the right side of the key need optimization.

If we use transparency in a game, profile the performance and compare between the different implementations.

The most common ways to do transparency in a shader are alpha test and alpha blend. There are best practices for each method, but the result will vary for different use cases. The best practice is to always profile the performance difference between the two methods. For mobile platforms, you can use Streamline, a tool developed by Arm to collect the performance data of a device.

## 4.1 Alpha test

The alpha test implementation makes the object material look either 100% opaque or 100% transparent. We can also set the threshold of the cutout for the mask. In Unreal Engine, the term used is Masked blend mode. The following is a list of best practices when using alpha test:

- Avoid Masked blend mode material unless necessary. Using Masked blend mode contributes to overdraw and using this mode too much can negatively influence performance.
- Alpha test is recommended in mobile platforms because it disables some of the optimization features in the GPU. However, you can profile and compare the performance to test performance.

## 4.2 Alpha blend

Visually, alpha blend allows the material to have a range of transparency and can make an object look partially transparent, instead of completely opaque or transparent. Unreal Engine calls this blend mode Translucent.

A comparison of alpha blend and alpha test is shown in the following example:

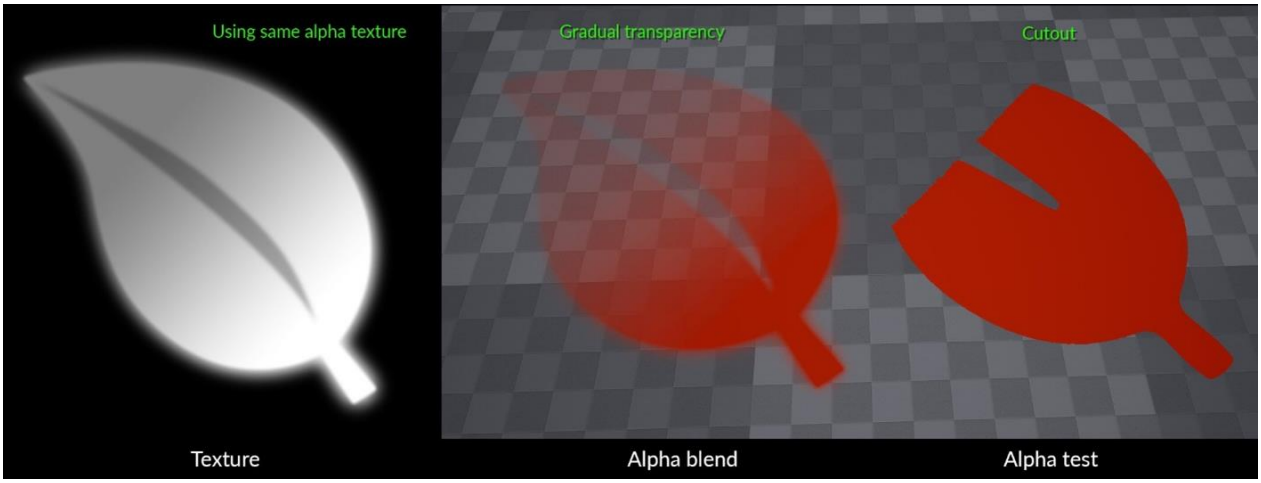


**Figure 6: Alpha blend and alpha test**

Alpha blend allows partial transparency while alpha test results in a sharp cutout.

The following is a list of best practices when using alpha blend:

- In general, alpha blend and all translucencies should be avoided on mobile platforms. Using translucency contributes to overdraw, using too much can negatively influence performance.
- Avoiding adding unneeded overdraw to maintain performance.

- If we use alpha blend in games, make the coverage of the blend area small. The more area that translucency covers; the more pixels need to be redrawn.

## 4.3 Alpha test transparency for foliage

The following image shows alpha test and alpha blend transparency in foliage:

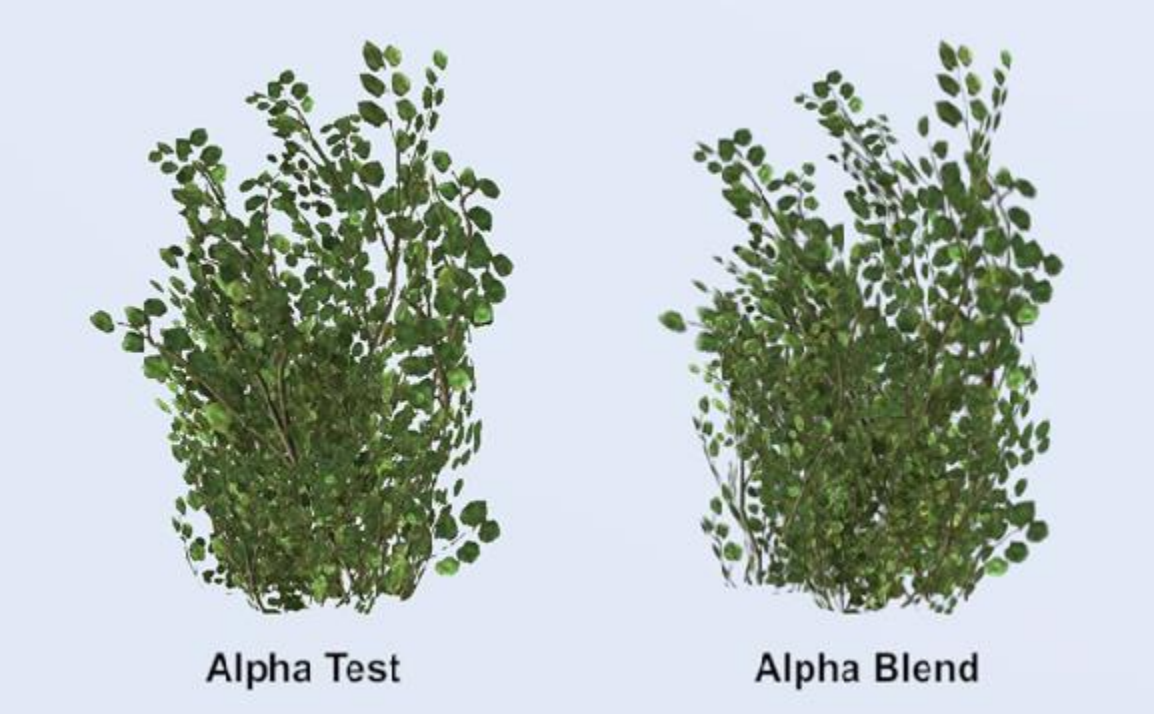


**Figure 7: Alpha test and alpha blend for foliage**

The alpha blend looks slightly better due to the soft edges compared to the sharp cut in alpha test.

However, in motion, alpha blend leaves do not seem to render in the correct order. Alpha test handles the transparency and order of the leaves better, but the edges are harsher and aliased. Generally, the alpha test visual quality will be acceptable.

# 5 Profile and visualize shader complexity

Adding more texture samplers, transparency, and other features can make a shader become more complex and affect the rendering.

Use Viewmodes in Shader Complexity to check shader complexity inside the level. This view gives estimates and provides an early indication of how expensive the shaders are. In the following example screenshot, green is in the good range and red is more complex:

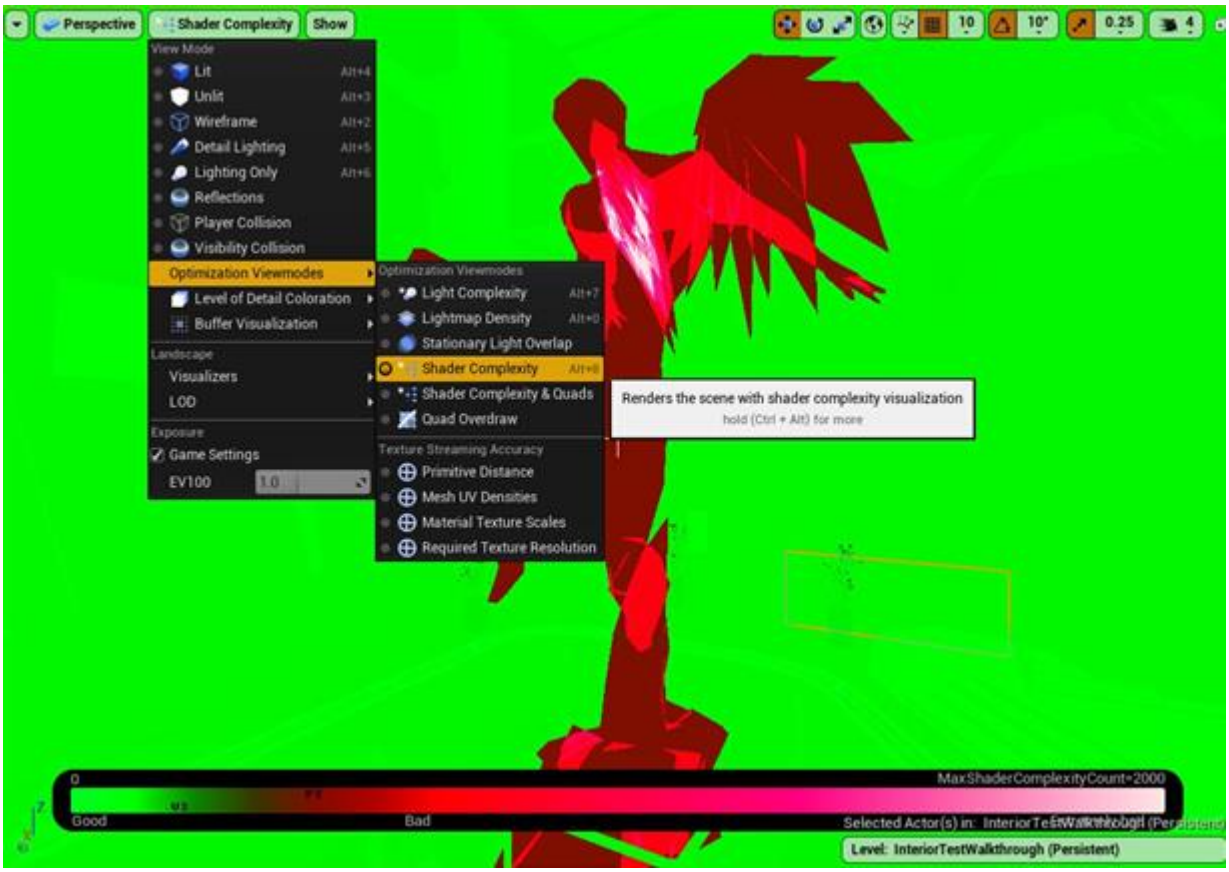


**Figure 8: Shader Complexity menu**

In Unreal Engine, use the material stats feature to quickly profile the materials early in the process, as shown in the following screenshot:

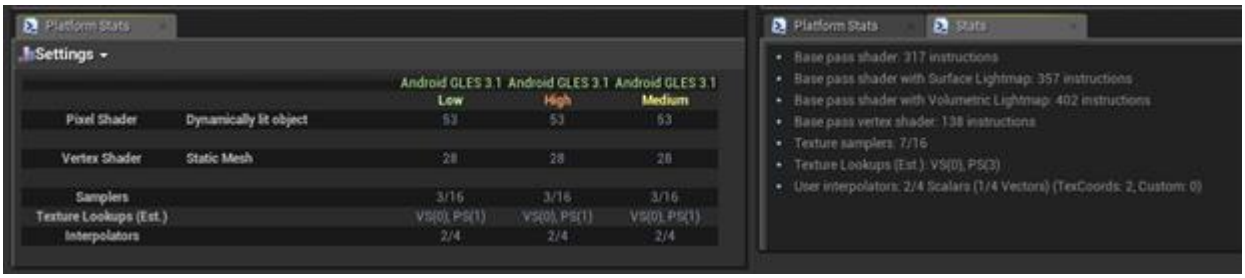


**Figure 9: Material stats example**

This view mode is a good guideline for artists. To look further into profiling, you can use tools such as Streamline for Arm Mali. These tools require further graphics knowledge to understand more about how the GPU works.

## 5.1 Do operations in vertex shader

The most common shader used in projects is a combination of vertex shader and pixel shader. Vertex shader works on every vertex and pixel shader runs on every pixel. Usually there will be more pixels rendered than there are vertices on a screen, which means there will be more computation happening for pixels than vertices. It is recommended to move computation from the pixel shader to the vertex shader where possible.

When you move this operation to vertex shader, you also move the processed data to fragment. This data shared between the vertex and fragment shaders are called varyings. We must pay attention to the tiler in case it then becomes an obstruction.

We need to do further profiling after working on optimizations using the Customized UVs feature in Unreal Engine. Then we connect nodes and use a Texture Coordinate node in the pixel shader to target the customized UV. For more information, see the Unreal Engine documentation on Customized UVs.

## 5.2 Reduce the number of math operations

We use mathematical operations in the shader to customize the look and behavior. For example, multiplication, addition, power, floor, and logarithm.

These math operations are not equal in terms of performance cost; therefore, we need to pay attention to their usage. Some of the more costly operations are sin, pow, cos, divide, and noise. Basic operations such as additions and multiplications, are generally faster. Try to keep the number of expensive math operations as low as possible. This number particularly needs to be kept lower on older devices, such as devices with GLES 2.0.

## 5.3 Performance profiling

As a general best practice, never make assumption and do some profiling to understand where the obstructions are in an app. Further profiling is also recommended to compare the effects of any optimizations.

# 6 Related information

The following is related to material in this guide:

- Unreal Engine documentation
- Use Streamline to Optimize Applications for Mali GPUs

# 7 Next steps

This guide has introduced you to using materials and shaders in the Unreal Engine game engine. You learned about shaders for mobile platforms, the difference between transparency methods, and how to reduce shader complexity.

After reading this guide, you can use these best practices to optimize the performance of your apps on mobile devices that use Unreal Engine.