

Global Illumination and Ray Tracing

Bo Yang

University of California, Santa Cruz,
California, United States, boyang@ucsc.edu

1. Introduction

Global Illumination refers to a system in which light bounces off of surfaces and continues to illuminate other surfaces. It can be thought of as indirect lighting as light is not simply calculated with a straight line from a light source to a surface but is a complex web of sight beams that creates a lighting scenario similar to the real world. Raytracing is a necessary tool for global illumination. Raytracing in this context refers to the process of tracing rays from a light source across the image plane in a scene to calculate where light should reach. Global illumination uses raytracing to find surfaces that are directly in view of a light source and then bounces the rays off of the surface at a mirrored angle. These rays continue moving, allowing the program to detect objects outside of the view of the light source that should be naturally lit.

1.1 Global Illumination and Ray tracing in Unreal Engine

In this write up, we will be discussing the ways in which one can implement global illumination, raytracing, and other lighting effects to make a scene with more realistic lighting.

2. Direct X

DirectX is a new form of ray tracing developed by Microsoft in 2018. DirectX is a form of ray tracing that is ideal for global illumination and is a new option on Unreal

Taylor Infuso

University of California, Santa Cruz,
California, United States, tinfuso@ucsc.com
Engine for this purpose. DirectX is a process where 3d geometry for a scene is loaded into the current engine (in our case, Unreal Engine), rays are drawn from light sources where they collide with this geometry and bounce off of the geometry in the way stated above, and then information about ray

intersections is discovered. Light textures are applied to areas based off of the amount of intersections at a point in the image. This design allows for areas more visible to a light source directly to be brighter than those that are only lit via indirect lighting (the intersections found after light rays have already collided with surfaces).

2.1 Direct X Implementation

Unreal Engine makes the implementation of DirectX especially easy. Under project settings, there is a tab for platform settings. Within this tab, there are settings to alter the render hardware interface, where an option for DirectX exists. Switch the option to DirectX 12, the most up to date form of Direct X.

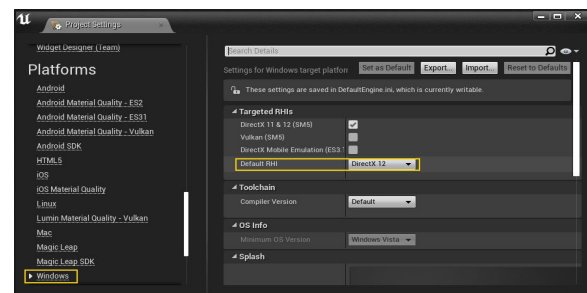


Figure 1: Showcasing system setting for enabling DirectX.

2.2 Enabling Raytracing

After turning on DirectX 12, make sure to determine if Unreal Engine's setting to conduct ray tracing is enabled. This is found under the project settings under Engine's subsection for Rendering.

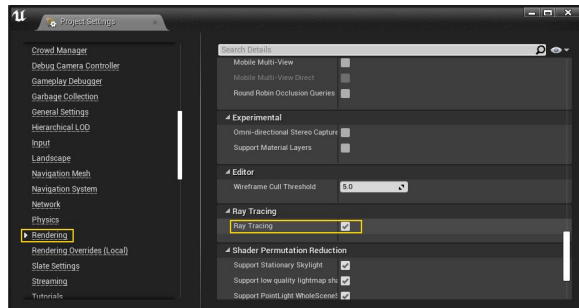


Figure 2: Showcasing system setting for enabling ray casting.

3. Indirect Lighting

As stated previously, indirect lighting is produced by light ray casts not directly illuminating surfaces but through light rays bouncing off of surfaces and reaching areas not directly in the line of sight of a light source.

3.1 Indirect Lighting Intensity

The intensity of indirect lighting refers to how much indirect light is generated from a light source. A high intensity leads to many areas outside of the light's point of view becoming brighter, potentially as bright as surfaces within the light's point of view. Low intensity lowers the effect of global illumination. Lower intensity leads to scenes with darker shadows as the effects of global illumination are lower and thus, areas within the perspective of the light source and areas outside of this perspective are more clearly defined.



Figure 3: Low indirect lighting intensity.



Figure 4: High indirect lighting intensity.

3.1.1 Editing Indirect Lighting Intensity

Within Unreal Engine, there is an indirect lighting intensity switch within the details panel for light sources. Altering the amount on it allows for the manipulation of the indirect lighting intensity.



Figure 5: Indirect Lighting Intensity Value

3.2 Reflected Light Color

Light reflects off of surfaces in an indirect lighting model. The intensity of the indirect lighting is not the only factor to reflected light, the color is also alterable. The reflected color can be different from the color of the source light. There are several advantages for this. The first is to create heavy distinctions between areas directly in the field of view of light sources and areas outside of light sources. Remember, global illumination with high intensity causes light rays to reflect onto shadowy surfaces. If the reflected color is a dark color, these

shadowy surfaces will actually appear darker than they did previously.

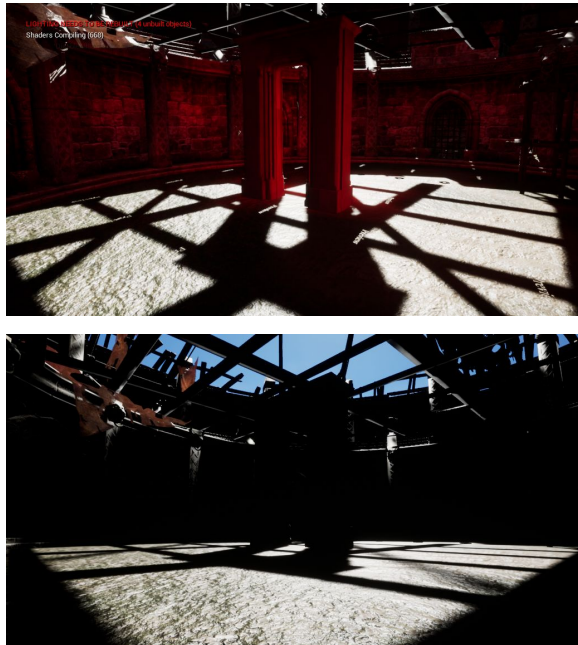


Figure 6: In the first image, the reflected light is the same color as the light source, being standard white. The second image reflects almost pure black. This makes the image actually much darker due to the heavier shadows obscuring geometric details.

The second use of reflected light color is more subtle. This use is to alter the coloration in a scene without altering the colors of lights.

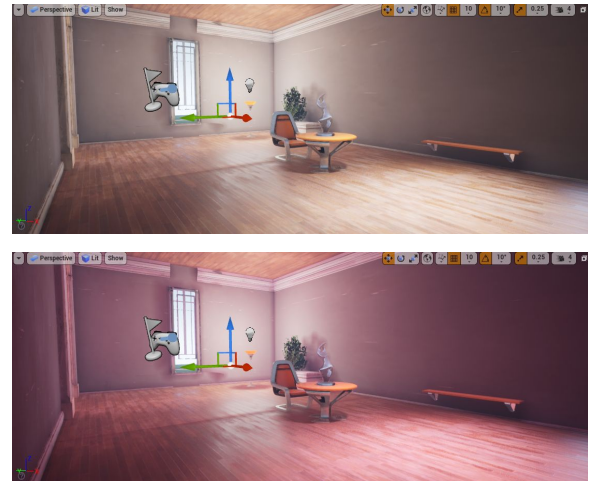


Figure 7: The first image has reflected light as the same color as the light sources. The second image as the reflected light reflect purple.

3.2.1 Changing Reflected Light Color

Altering the reflected color requires the use of post processing effects. Post processing effects are visual effects generated only after a scene has been built. Simply drag a post processing effect into the scene. Within the post processing effect details page, find the tab for global illumination. Within it is a setting for reflected color.



Figure 8: The option to change the reflected light color.

4. Ray Tracing Shadow

Ray Traced Shadows is one of the features of ray tracer which simulate soft area lighting effects for objects in the environment. This means that based on the light's source size or source angle, an object's shadow will have sharper shadows near the contact surface than farther away

where it softens and widens.

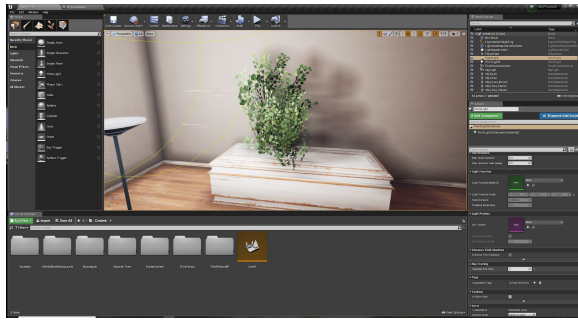


Figure 9: Without Ray Tracing Shadow

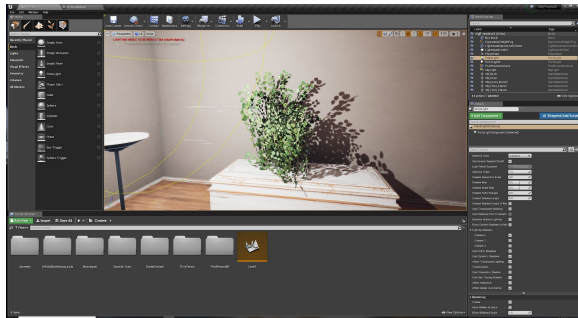


Figure 10: With Ray Tracing Shadow

5. Lightmass Importance Volume

Global illumination is a powerful tool but it is also a costly one. Calculating all the light reflections and implementing all of the post processing effects can lead to considerable slowdown. This problem can be subverted with the lightmass importance volume. The lightmass importance volume is a space in which these rendering techniques are utilized. By cutting down the amount of space that these tools are used in, the less computation must be done in Unreal Engine. The lightmass importance volume is only used in Unreal Engine, but other techniques to cut down on these lighting techniques may exist in other engines.

5.1 Implementing Lightmass Importance Volume

Implementing the lightmass importance volume is very easy. All that needs to be done is to drag a lightmass importance volume object from the class menu into the scene and rescale it to fit the desired area. Everything within this object will experience global illumination.



Figure 11: The lightmass importance volume contains this house. Everything within the house will experience global illumination.

6. Ambient Occlusion

Ambient occlusion is a shading and rendering technique used to calculate how exposed each point in a scene to ambient lighting. For example, the interior of a tube is typically more occluded than the exposed outer surfaces, and the deeper you go inside the tube, the more occluded and darker the lighting becomes. Ambient occlusion can be seen as an accessibility value that is calculated for each surface point. In scenes with open sky this is done by estimating the amount of visible sky for each point, while in indoor environment only object within a certain radius are taken into account and the walls are assumed to be the origin of the ambient light. The result is a diffuse, non-directional shading effect that casts no clear shadows but that darkens enclosed and sheltered areas and can affect the rendered

image's overall tone. It is often used as a post-processing effect.

6.1 Ambient Occlusion in Unreal Engine 4

In Unreal Engine 4, the feature of ambient occlusion are a part of the ray tracer. Since the ray tracing are enabled, it will be a result can be viewed at the detail panel. In Unreal Engine 4, it's called Ray Traced Ambient Occlusion (RTAO) which accurately shadows areas blocking ambient lighting better grounding objects in the environment, such as shadowing the corners and edges where walls meet or adding depth to the crevices and wrinkles in skin.

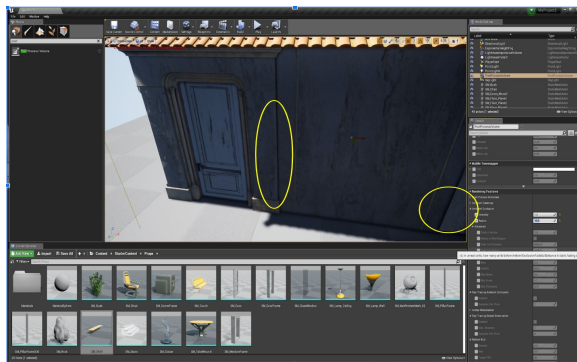


Figure 12: Ambient Occlusion with Low Radius

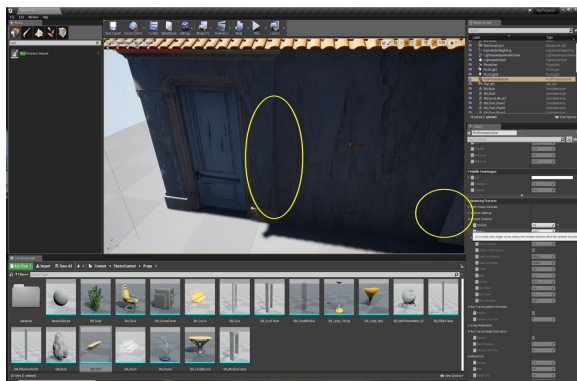


Figure 13: Ambient Occlusion with High Radius

7. Post Process Volume

For Ray tracer in Unreal Engine 4, post process volume is the main method to make computer focus on the areas which are covered by the post process volume to calculate ray comes into this area.

Post-processing is the process of applying full-screen filters and effects to a camera's image buffer before it is displayed to the screen. Can be used to improve the visuals like the Anti-aliasing effect or to apply a distortion like the motion blur effect of some racing games, or even to add more details like an Outline effect. And Volumes can be added to different areas for interiors and exteriors to enable you to apply the features and quality level you want. From these volumes, you can control Ray Traced Reflections, Translucency, Global Illumination, Ambient Occlusion, and the Path Tracer.

7.1 Post Process Volume Implementation

To use the post-processing in our level we need to add a post processing volume to the level map, can be found in the Modes tab.

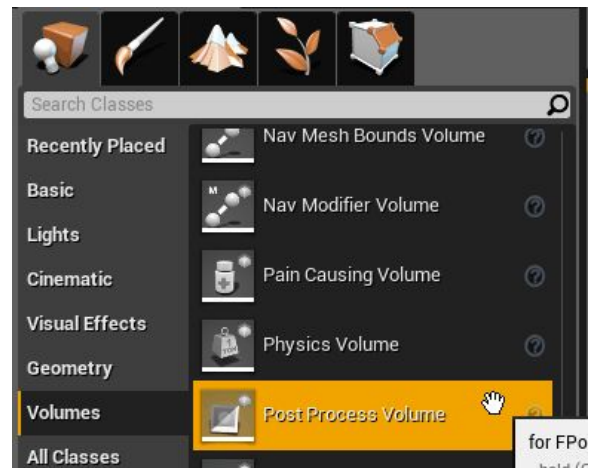


Figure 14: Set up Post Process Volume

The properties can be changed in the detail panel.

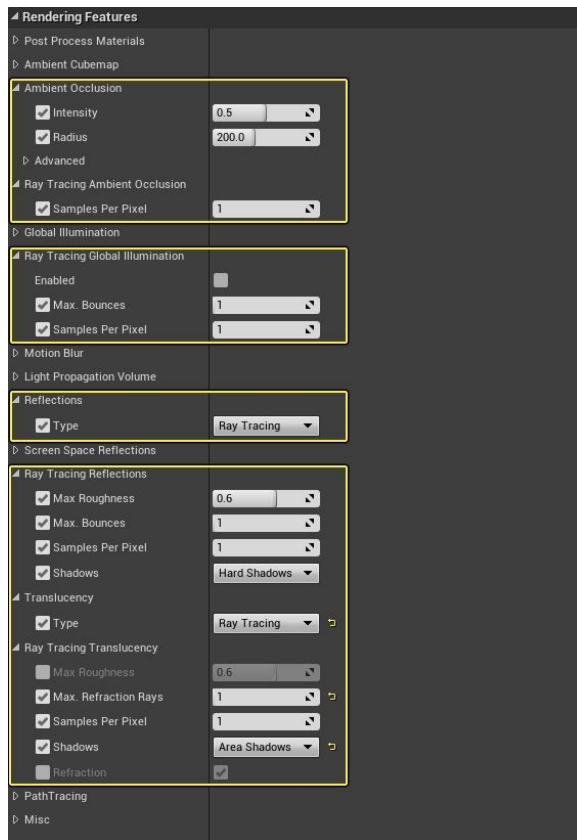


Figure 15: Features of Post Process Volume

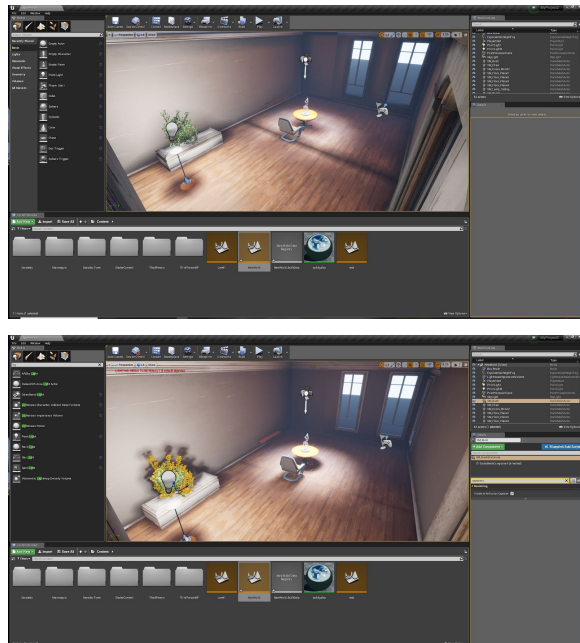


Figure 16: comparison of Without and with Post process Volume

REFERENCES

[1] Miller, Gavin (1994). "Efficient algorithms for local and global accessibility shading". *Proceedings of the 21st annual conference on Computer graphics and interactive techniques*. pp. 319–326.

[2] Post Process Effects
<https://docs.unrealengine.com/en-US/Engine/Rendering/PostProcessEffects/index.html>

[3] Real-Time Ray Tracing
<https://docs.unrealengine.com/en-US/Engine/Rendering/RayTracing/index.html>

[4] DirectX
<http://www.visualextract.com/posts/introduction-to-dxr/>