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Graphics Final Paper

11 May 2025

Abstract: The goal of this project was to explore low light ray tracing environments using moon scenes. To explore this problem, scenes were created using a light source (sun), a reflected object (moon) and a scene on earth. The first scenario used a constant scene and showed the effect parameters such as samples per pixel and ambient lighting had on low light scenes. The second scenario used image texturing and motion to recreate moon phases naturally. Both of these scenes showcase effective methods for generating ray tracing images in low light.

Introduction: Ray tracing is a graphical method that uses random sampling of ray paths to generate an image. Random sampling creates difficulties in low light environments. This is due to the fact that an individual pixel value is defined as the sum of all of the reflected samples. If there is insufficient sampling in the direction of the light, the pixel will have a high level of noise. This effect is amplified when the light source for a scene is composed of reflected light. For this reason, the first setup had 3 bodies: sun, earth, and moon. The light from the sun could not reach the scene on earth, resulting in all of the scene's light coming from the moon. In the results section, I will discuss how to change sampling methods to optimize picture quality and reduce noise.

The second scene uses the moon's natural parth to recreate moon phases.The setup consists of a camera at the origin that always points at the moon, the moon rotating a fixed distance around the camera, and the sun stationary far away. Ideally we will be able to see each phase illuminated in a manner similar to nature.

Prior Work: To prepare for this project, resources such as the *Ray Tracing in One Weekend* series were used to develop a background for basic scenes. Information on ray tracing specific sampling and colors was also used. Finally, Professor Kruger's ray tracing framework that utilizes configure files was used and expanded on in this project.

Results: The first scene showed the power of ambient lighting in ray tracing. With no background light, the scene took at least 50k samples per pixel to start looking decent. This takes an incredibly long time to render (on CPU) and is very inefficient. Adding ambient lighting (RGB(0.01, 0.01, 0.01) and making the moon a light source allows for the creation of better quality images in 1,000 samples per pixel.

The second scene was able to achieve the goal of creating each moon phase. Adding the image textures made each phase distinct. The video and images in the presentation match those of nature. In terms of lighting, the ambient light used was meant to match the background light of space (RGB(0.001, 0.001, 0.001)) and only 500 samples per pixel were required. The samples per pixel was reduced due to the fact that the moon was not reflecting light onto anything besides the camera, unlike in the first example.

A third scene was added of the earth rotating about its axis and the moon rotating around the earth. This example showcases image texture rotation as well as moving multiple objects within a movie. The lighting settings are the same between the last two examples.

Conclusion:

In order to create high quality images in low light environments, tricks can be used to optimize computation time and minimize noise. Some of these techniques were outlined in the paper above as well as in this presentation. The github repository for this project is located here. This project was very enjoyable and I am glad to have learned about ray tracing as it is a very powerful tool.

Sources:

Shirley, Peter. *Ray Tracing in One Weekend*. 3rd ed., 3 May 2020, https://raytracing.github.io/books/RayTracingInOneWeekend.html.

Shirley, Peter. *Ray Tracing The Next Week*. 4th ed., 25 April 2025, https://raytracing.github.io/books/RayTracingInOneWeekend.html.

University of Nebraska–Lincoln. "Lunar Phase Simulator – Background 2." *Nebraska Astronomy Applet Project*, https://astro.unl.edu/naap/lps/lunarPage2.html. Accessed 2 May 2025.