Final project 5607

Physics based rendering

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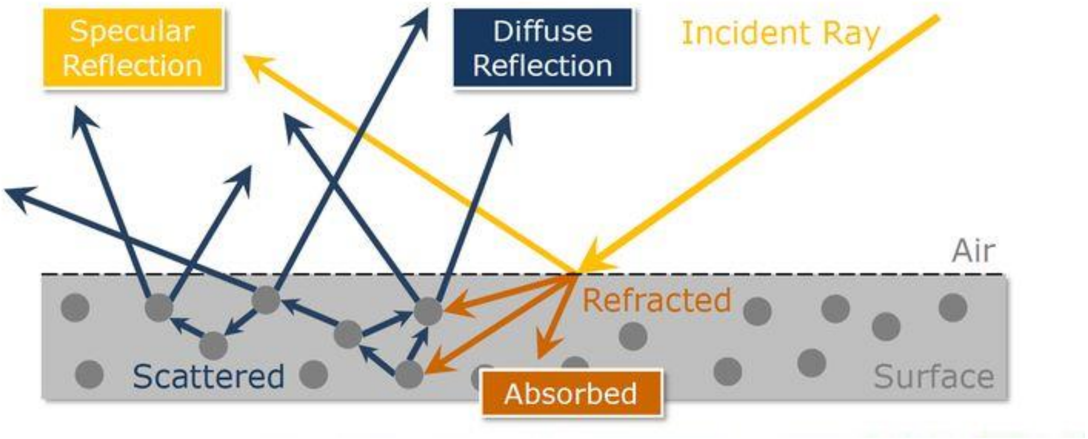
Progress Description & Overview:

For the final project of computer graphics, I decided to work on physics-based rendering as known as PBR. There are six big topics in PBR, microfacet theory, energy conservation, Fresnel reflection, linear space, tone mapping, and substance optical properties. I intended to work on energy conservation and Fresnel reflection. But due to an unsolving bug in project3, I only finished the energy conservation part. In the following paragraph, I will briefly explain these concepts and the possible ways to implement them.

Microfacet theory means dividing object surface into subsurface forward in random directions. When building object mesh, the art team could use roughness to represent this property. Energy conservation: this is a famous principle in physics. In computer rendering, when one ray hit the object surface, due to diffuse or reflection, there could exist multiple ray shooting in different directions. However, based on the energy conservation, the energy of the sum of those output rays should equal or less than the input ray. For a simple version, energy could be represented by the intensity of the light. The main focus of my final project is energy conservation. In project3, our ray-tracing model took four main contributions: diffusion, specular, reflection, and refraction. And the latter two are used for recursion tracing. But we only added up four terms for a single color pixel. For real-world material, it will become more complex. We have to consider the physics principle behind the lighting process. A stream of light is photons, which carry energy. When these photons hit the material, part of the photons merges into the material (which may cause the photoelectric effect). The other part of photons will reflect based on the normal. Since the surface of the material is not a perfect mirror, it is composed of many micro-surface forwards to different directions, which caused the diffusion.



An image demonstration the different contributions

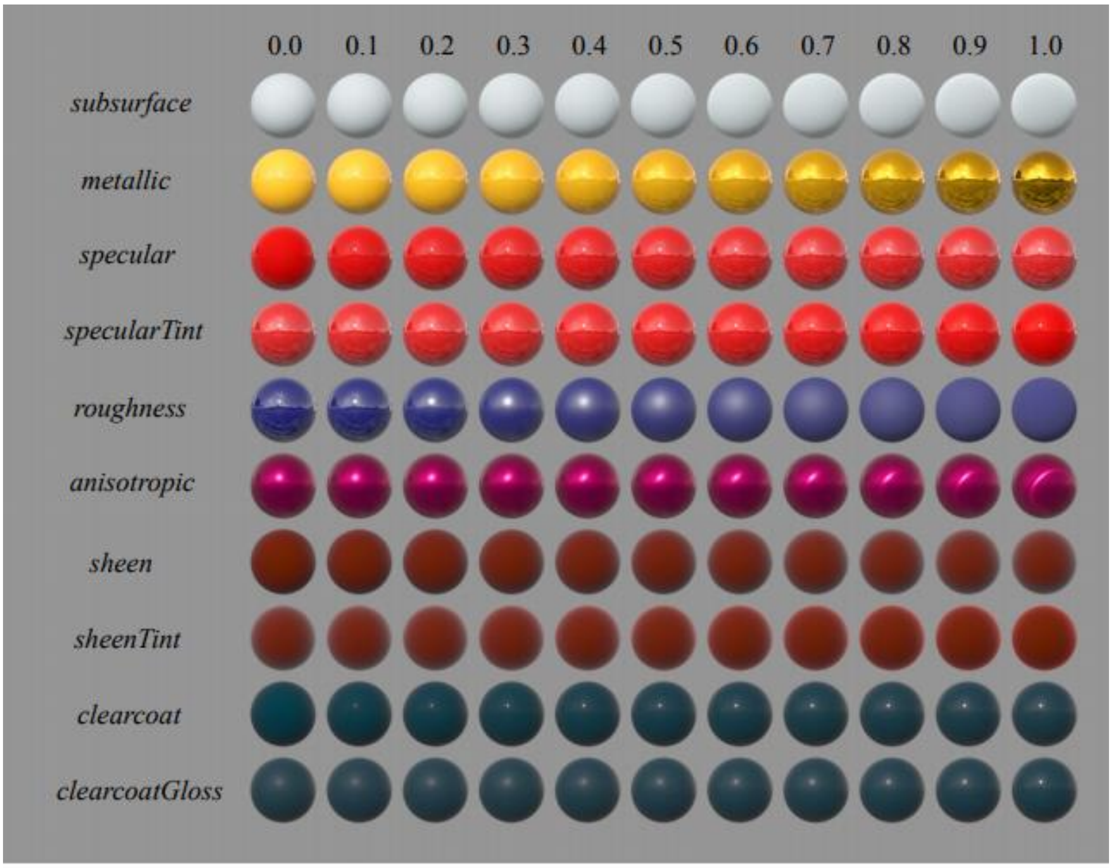
In my final project, I mimic the physics-based rendering process. Originally, the material we used in project 3 includes diffusive, specular, reflection, refraction. In my project, I imported two new parameters: metallic and roughness. Both parameters range from 0 to 1. Metallic determines the ratio of reflection and absorption. A material with a metallic value of 1 means this material will reflect all the light. A material with a metallic value of 0 means this material will absorb all the light. Roughness determines the range of diffuse. A material with roughness 1 means this material will diffuse random rays in a range of 180 degrees. A material with roughness 0 means this material will diffuse only in the reflected direction. In Disney principle PBR, there are other different properties of the material. Due to the limitation of time, I only worked on these two.

Connection to our class:

In the modern game and movie industry, Physics-Based rendering is very popular in the big industry. Our class introduces the history of computer graphics, so I think it necessary to keep exploring modern computer graphics. Compared to the normal shader, PBR focused on the physics principle. It uses a different light model (or extended version). Introducing more parameters makes the rendering process more realistic and fascinating.

Key Features & Images:

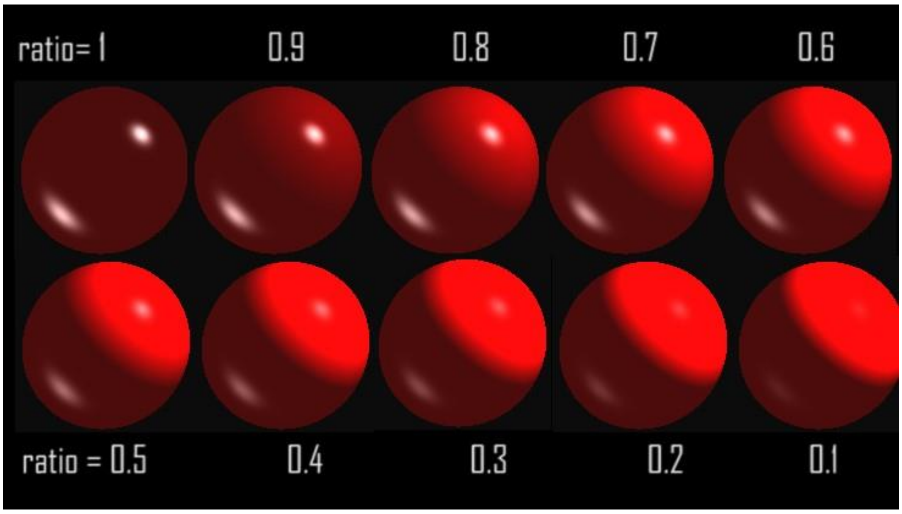
I was trying to explore some parameters under the Disney principle. Here is a picture of all the parameters:



Picture from Physically-Based Shading at Disney

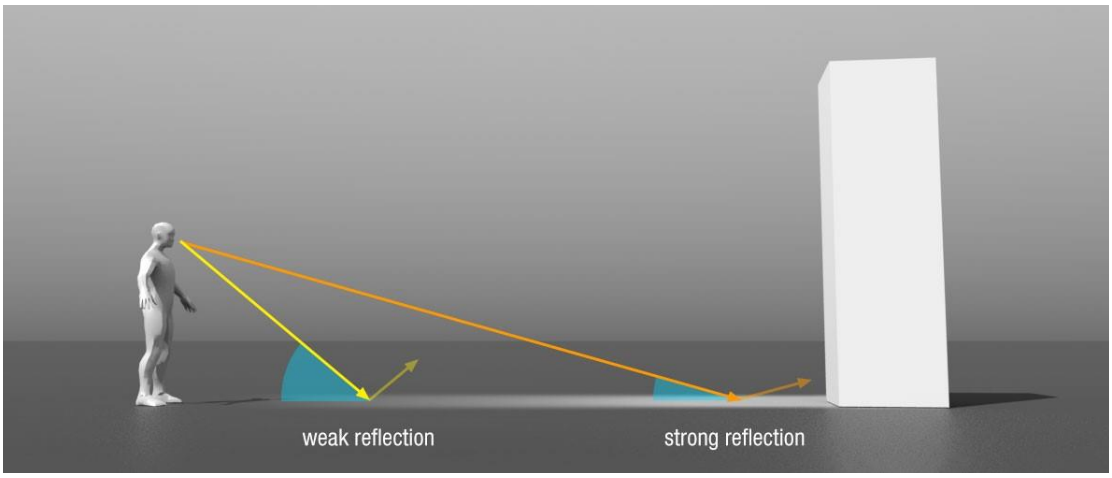
The roughness parameter controls diffuse and specular response. It is also related to the micro subsurface. A rough material means the subsurface is more density, therefore the range of response will more widely. In my code, I assume roughness 1 material will reflect up to 180 degrees, while roughness 0 material will only reflect one specific direction.

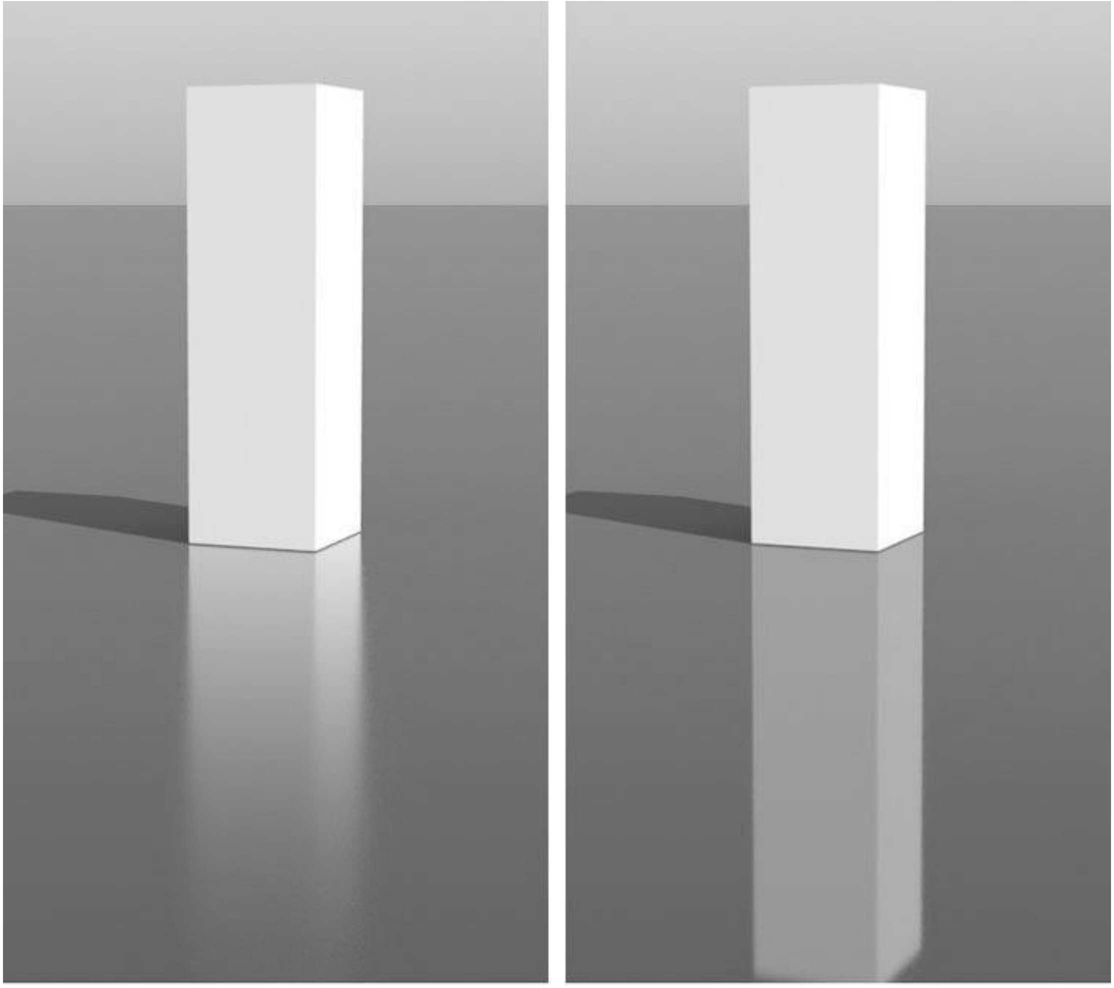
The metallic parameter controls how much light is absorbed by the material. Metallic 1 material will reflect all the light. Metallic 0 material will absorb all the light. Diffusion comes from the scattered wave going inside the material. So if the metal will reflect all the light coming in, there will be no light going into the material. Then the diffusion contribution will be 0. A simple diagram could show how the diffusion and specular contributed to the final rendering:



The ratio means how much the specular contributed to the final rendering. Ratio 1 means no diffusion contributed, only specular contributed.

The Fresnel effect is an interesting aspect I intended to work out. Based on the viewing distance, the reflection ray could decay. I wrote the code, but due to the broken reflection part, there is no image for my project. Here are some images for success version:





with fresnel　　without fresnel

Future Works:

Fixing the reflection part is most important. I spent a long time on project 3B and in the final project, but it still doesn't work. I guessed I couldn't work this out on my own. With reflection works, the Fresnel effect can be implemented easily. About the energy conservation, I think I could implement it using the rendering equation instead of simplifying the version. BXDF is also a possible way to digging into more. Reflected scatter distribution represents the light scattering on the top of the surface, while Transmitted scatter distribution represents the light scattering inside the surface, which is related to the material's transmission parameter.