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Real-Time Physically Based Wet Microfacet Surface Rendering

Description of Problem:

Physically based rendering utilizing a microfacet model, most commonly the Cook-Torrance model, has gained recent popularity over the last decade in real-time simulation usage. The extension of shaders to support more complex operations, as well as the increase in GPU computation ability, has allowed for an entirely physically based lighting pipeline. However, these simulations tend to utilize texture hacks when rendering wet surfaces rather than correctly modeling the physical behavior of microfacet surfaces covered by a layer of water. This technique requires more memory for storing "wet" textures, as well as the technique lacks physical accuracy. In this work, I plan to address this problem by incorporating a physically based simulation of wet microfacet surfaces into the existing Cook-Torrance lighting model.

Importance of Problem:

This problem is important for two domains; both the video game industry, and the self-driving car industry. In video games, artists want to model dynamic environments as realistically as possible. As GPUs continue to increase in computational power, while continuing to experience a memory bottleneck, it would be useful to model wet surfaces via a computational method rather than storing separate textures for surfaces. In addition, the wet surfaces, if modeled using a physically correct model, would look physically accurate under all lighting conditions in a dynamic simulation. In the auto industry, wet surfaces continue to be problematic. As self-driving networks are beginning to be trained on virtual simulations, it is important that wet surfaces be modeled as accurately as possible in order to train a more useful model. By using a physically accurate wet surface model, these virtual simulation environments can be shifted even closer to real world behavior, and thus allow for more accurate trained neural nets.

Previous Work on Problem:

Previous work in the area of rendering wet surfaces primarily falls into two categories, the study of how light interacts with a wet surface in the real world, and the proposal of simulation techniques to model wet surface behavior.

One specific work [1] explores the probability of absorption or reflectance of light at every boundary in the material fully submerged by a layer of water case. This model explores multiple reflectance cases in which water that transmits through the air-water boundary initially would then have a percentage of reflectance that would then experience total internal reflectance off the bottom of the water-air boundary. Over multiple bounces, this causes less light to return to the eye and thus the surface appears darker.

Another work [2] explores how light behaves in a basic model of a material submerged by water. In this work, they use photon tracing and model three main propagations of light; the reflectance of light at the air-water boundary, the reflectance of light off the material, and the total internal reflectance at the water-air boundary. In addition, this work explores the subsurface scattering of light in a dry and wet porous material, discussing how a wet porous material experiences a greater amount of light scattering as the light propagates through the surface.

Proposal of Work:

For this project, I plan to begin by extending the Cook-Torrance model to support physically based rendering of microfacet surfaces fully submerged under a layer of water. This will involve combining the statistical analysis of wet materials in the previous work with the Cook-Torrance microfacet model, specifically by modeling reflection of light at the air-water boundary, as well as modeling the total internal reflection of the water-air boundary. I would also like to expose a [0, 1] wetness parameter to allow an artist to modify the wetness of the surface at runtime.

Finally, if I am able to accomplish this in a reasonable amount of time, I would like to explore modeling the drying and wetting of water such that the water level is located in the microfacets themselves. The goal of this is to model more correct drying of surfaces dynamically at run time.

Originality:

While modeling wet surfaces has been explored before, modeling the light via microfacet models has not been explored to my knowledge. In addition, the modeling of wet surface rendering with water interaction within the microfacets themselves has also not been explored to my knowledge.

List of Goals:

By Update Point:

- Implement a real time physically based rendering system with Cook-Torrance
- Extend this model to support rendering of microfacet surfaces with layer of water submerging the entire surface
- Simulate both a dynamic drying as well as a dynamic wetting of different types of surfaces in real time

By Final Point

- Rendering wet surfaces with water levels within the microfacets of a surface
- Explore physical behavior of water at the microfacet level, i.e. water tension and behavior of water as the depth of water decreases

References

[1] John Lekner and Michael C. Dorf, "Why some things are darker when wet," Appl. Opt. **27**, 1278-1280 (1988)

[2] Henrik Wann Jensen, Justin Legakis, and Julie Dorsey. 1999. Rendering of wet materials. In *Proceedings of the 10th Eurographics conference on Rendering* (EGWR'99), G. Ward and D. Lischinsky (Eds.). Eurographics Association, Aire-la-Ville, Switzerland, Switzerland, 273-282.