Subsurface Scattering and Refraction of Ice

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Background

The quest of capturing the true look of translucent materials, such as marble, skin, snow, and ice, in computer graphics has no solid beginning, however, a 1977 paper by James Blinn [5] contained a model of light reflection which was an early key to achieving this goal. Blinn developed the Torrance-Sparrow Model (named after Kenneth Torrance and E. M. Sparrow, who developed a theoretical version of the model in 1967) that took a smooth surface and turned it into numerous minute surfaces with randomly assigned normals (later to be known as microfacets). Thus, when a light struck the surface, it would have a random distribution and emulate a primarily diffused surface, with hints of specular highlights.

In 1982, Cook & Torrence advanced Blinn's microfaceting model [4] as Blinn developed a new technique [3] called "scattering" which was used to simulate dust covering a surface. In this model, a light ray would strike the dust surface, penetrate deep enough to strike the true surface, and then be reflected back out of the dust (see figure 1).

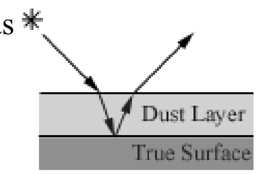

Figure 1: Scattering

It was soon discovered that the scattering ideas Blinn created could be extended to work with much more than a surface coated with dust. In 1999, a paper by Dorsey et al. [6] discussed findings dealing with rendering weathered stones such as granite, sandstone, and marble. While they were unable to create an exact stone weathering model, significant advancement was made in the theory of subsurface scattering.

In 2001, a paper by Jensen et. al. [1] introduced the Bidirectional Surface Scattering Distribution Function (BSSRDF) model which quickly became the standard method of rendering a translucent homogeneous material using a Monte Carlo ray tracer. This model was successfully utilized to accurately render materials such as apples, marble, milk, and skin. While Jensen's model works only for a single, homogeneous layer, it is an excellent foundation for future research.

Goals

The goal of this research experience is to develop a model for subsurface scattering across a non-homogeneous material, namely ice. Applying the Jensen et al. [1] BSSRDF model and adjusting it to allow a light-penetrated object to have varying densities, a 3D model may be assigned the property of ice sculpture and it will be realistically rendered.

The model must take into account real properties of ice including the fact that ice is denser in the middle than at the edges, and air pockets may sometimes be found inside the ice block. Two factors that will require investigation are whether ice is different depending on how fast it was frozen, and at what temperature the ice is kept.

The final results of the research project will be delivered as a software program with statistical information about each rendered scene, and a written paper documenting the entire process and the final conclusions.

Process

From January 2004 to March 2004 I developed a distributed raytracer. This software will be adapted to first implement the BSSRDF model Jensen [1] discussed in his paper, and then extended to implement rendering non-homogeneous material. Direct illumination with photon mapping may also be added to get realistic caustics and color bleeding within the ice sculpture.

I will begin with research about various states of ice and its formation depending on temperature and how quickly it was frozen. Following the research into physical properties of ice, a theoretical model will be developed that will accurately show how light transports through an object of ice. This model will then be integrated into my raytracer to be verified.

References

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[6] J. Dorsey, A. Edelman, H. Jensen, J. Legakis, H. Pedersen, *Modeling and Rendering of Weathered Stone*, Proceedings of the 26th annual conference on Computer graphics and interactive techniques, July 1999