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A Fast and Accurate Light Reflection Model

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Abstract

This multimedia paper elaborates on the comprehensive physically-based light reflection model introduced by He *et al.* [1]. To explain the model more fully, the paper gives an overview of the light reflection process at a surface, and employs an interactive graphical tool to demonstrate the reflection model's directional behavior. To make the model more practical, the paper describes an accurate approximation of the reflection model, based on a spline surface, that is much faster to compute. The paper concludes with two animated sequences, which demonstrate some features of light reflection that are accounted for by the model. The full paper demonstrates the potential of interactive multimedia. It is written using MediaView [2], a system for authoring documents that include graphics, sound, video, and computer animation.

CR Categories and Subject Descriptors: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism; I.3.3 [Computer Graphics]: Picture/Image Generation; J.2 [Physical Sciences and Engineering]: Physics.

Additional Key Words: reflectance model, multimedia.

1 Introduction

For photorealistic image generation it is essential to use a comprehensive light reflection model that provides a smooth transition from specular to diffuse behavior. In addition, to ensure accuracy the model must be physically based.

For these reasons, a new general light reflection model was presented by He *et al.* at SIGGRAPH '91 [1]. The model is based on physical optics and describes specular, directional diffuse, and uniform diffuse reflections off a surface. The reflected light pattern depends on wavelength, incidence angle, two surface roughness parameters, and the surface refractive index. The model applies to a wide range of materials and surface finishes, and has been experimentally verified.

However, the model also has some disadvantages. It contains an infinite summation term that converges very slowly. In addition, because the model is complex, it is difficult to understand.

In this multimedia paper we address both of these issues. To help explain the light reflection model, the paper gives a graphical overview of the light reflection process at a surface, and employs an interactive graphical tool to demonstrate the model's directional behavior. This tool allows the viewer to observe the effects on the various terms of the light distribution function as parameters are changed.

To make the model practical, the paper describes how the infinite summation term can be closely approximated by a spline surface and stored as a small lookup table of control points. This approximation allows very fast computation of the full BRDF, as demonstrated by the interactive sessions themselves.

Finally, the multimedia paper includes two animation sequences, which demonstrate some features of light reflection that are accounted for by the physically-based model and were not accounted for by previous models.

The full paper was written using the MediaView system, developed by Richard Phillips [2]. In this extended abstract, we attempt to give the flavor of the full multimedia document by using a sequence of illustrations from its interactive tools and animations.

2 Understanding the physically-based model

The bidirectional reflectance distribution function (BRDF) depends on a number of geometrical and physical parameters [1]. The geometrical parameters include, among other things, the polar angle of incidence θ and the solid angle of the incident beam $d\omega$. The physical parameters include the wavelength of the light λ, as well as some physical parameters of the surface—its "roughness," given by σ and τ, which specify the height and width of small statistical peaks on the surface; and its index of refraction $\hat{n}$, which is a function of λ.

The full BRDF can be divided into three major reflection components—specular, directional diffuse, and uniform diffuse—which in turn can be broken into smaller terms, such as Fresnel reflectivity, effective roughness, and surface masking and shadowing. Each of these terms can be written as a function of the various geometrical and physical parameters of the reflecting surface and the illuminating light.

In the multimedia paper, the reader learns about the behavior of the full BRDF by studying the effect of these various parameters on each of the model's terms. The user interacts with the model by varying the positions of sliders on the menu shown in Figure 2. To vary the index of refraction $\hat{n}$, the user changes the material "type" (e.g., aluminum is selected in Figure 2). In addition, by touching

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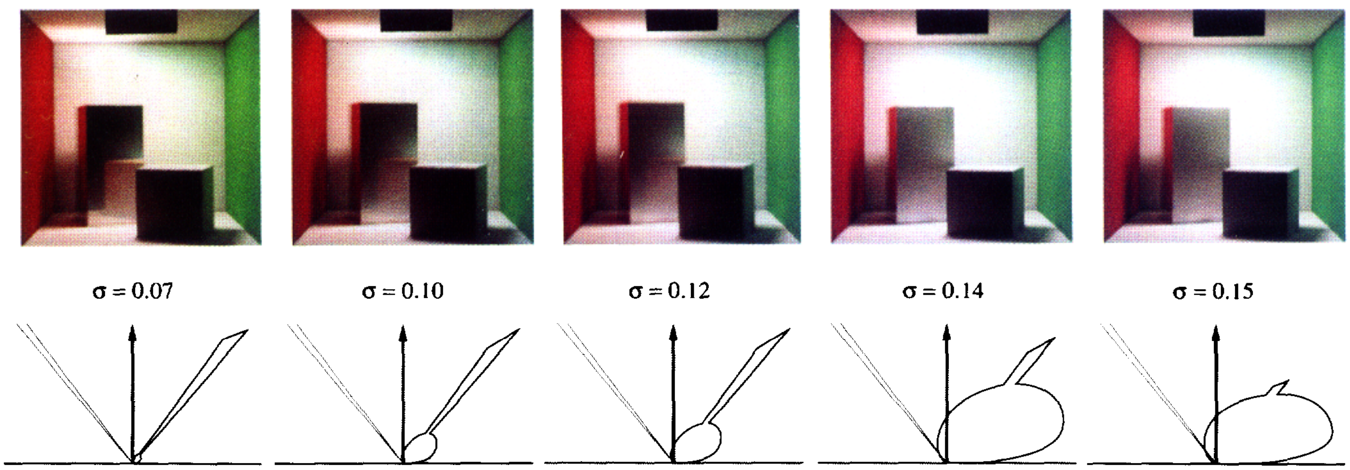

Figure 1: Effect of surface roughness σ (in μm) on light reflection

the "Play" button, the user can watch a "prerecorded" demonstration of this interaction, which is played back along with an audio track explaining the parameter effects.

The graphical style of this interactive tool is illustrated in the bottom row of Figure 1, which shows a sequence of polar plots of the full BRDF for aluminum as the surface roughness parameter (σ) is increased.

3 A fast approximation

In order to make the light reflection model computationally tractable, we describe how it can be approximated by a spline surface. This surface can be computed once for all materials and stored as a two-dimensional lookup table of control points. A table of 80×80 points allows any material's reflection function to be approximated to within a relative error of 1%. Using this spline approximation gives a two- to three-orders-of-magnitude speedup over computing the summation directly to within 1 % error.

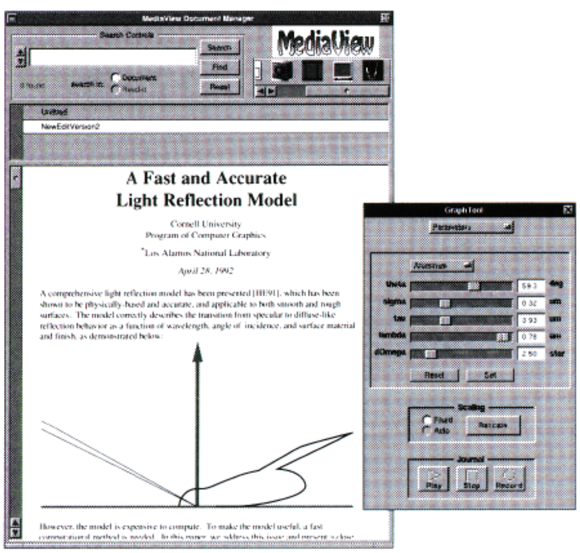

Figure 2: Control panel and document

4 Animated sequences

To demonstrate some features of the physically-based light reflection model that are not accounted for by previous models, the paper uses two animated sequences.

The first animation shows the transition of reflections on the faces of a roughened aluminum box as the surface roughness (σ) increases. Five frames of this sequence are shown in the top row of Figure 1. Above each frame is shown a schematic diagram of the BRDF for that value of σ.

The second animation shows the emergence of specular reflection off a gallery floor as the camera moves to grazing angles. Three frames of this sequence are shown in Figure 3.

Figure 3: Emergence of specular reflection

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