Directional Dipole Model for Subsurface Scattering

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Abstract

Modern techniques for rendering different materials on computer based systems only accounts for the interaction of light at the surface of an object. Rendering translucent materials using Monte Carlo ray tracing is compu- tationally expensive due to a large number of subsurface scattering events. Methods have been explored to improve the efficiency for such a kind of process based on analytical models derived from diffusion theory. These models might improve the efficiency while leaving some redering effects missing. The proposed approach presents an improved analytical model for subsurface scattering which captures translucency effects that are present in the reference solutions but remain absent with existing models. The proposed model(directional dipole) uses ray source diffusion instead of point source diffusion. Directional dipole is as computationally efficient as existing models while it includes single scattering without relying on a separate Monte Carlo simulation. The result of the proposed rendering model is significantly closer to the references.

1 Introduction

Subsurface scattering(SSS), also known as subsurface light transportation, is an optical physics based machanism describing the process of light penetrating translucent materials. Different models have been proposed in order to produce artifitial images of real life materials. Bidirectional reflectance distribution [4] function was introduced as a simple but efficient model for reflection of light at the surface of objects. Jensen et. al. [3] introduced an improved model: bidirectional subsurface scattering reflection distribution function(BSSRDF). The

BSSRDF can describe light transport between any two rays that hit a surface, whereas the BRDF assumes that light entering a material leaves the material at the same position BSSRDF can be described as following:

$$S(x_i, \vec{\omega_i}; x_o, \vec{\omega_o}) = S_d(x_i, \vec{\omega_i}; x_o, \vec{\omega_o}) + S^{(1)}(x_i, \vec{\omega_i}; x_o, \vec{\omega_o})$$

where S is the bidirectional subsurface scattering reflection distribution function. S_d and $S^{(1)}$ are the diffusion approximation and single scattering term.

The result of the rendering with BSSRDF would depend on the physical characteristics such as absorption coefficient, index of retraction, scattering coefficient, etc. A list of such parameters has been measured in Jensen's work. Gkioulekas et. al. [2] studied on the physical characteristics of daily materials. Gkioulekas et. al. used a series of techniques and algorithms in order to achieve a set of data for daily materials such as wine, milk, coffee etc. Based on their analysis we are able to achieve a better result in multimedia rendering.

2 proposal

Directional dipole [1] method is proposed to improve the efficiency and accuracy of translucent material rendering process. The dipole approximation for subsurface scattering has proven to be a fast practical way of rendering such materials. This standard dipole model is however built upon a number of assumptions which are often violated. One significant assumption is that incident light is directionally uniform. However, in real physical world, this assumption is rarely satisfied.

The standard dipole model should be integrated along the refracted ray. A standard dipole model uses two point sources to handle boundary conditions. The points are displaced along the normal at the point of inci- dence. Our model uses two directional sources that are displaced along the normal of a plane containing the points of incidence and emergence. It calculates the approximation of the multipole by capturing scattering due to a normally incident light ray. This displacement of the real source leads to a modified distance to the real source based on the assumption that the ray is normally incident on a planar surface.

Directional dipole method increases the rendering efficiency by conducting precomputation on the light source instead of displacing the real source.

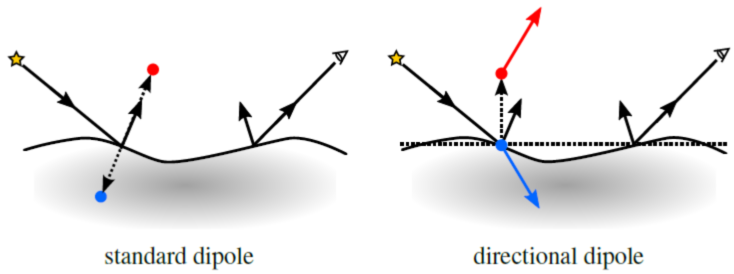

Figure 1: Standard dipole method(left) and directional dipole.

The proposed method focuses in this paper is to find an improved analytical model for subsurface scattering. The diffusive part of the proposed BSSRDF is as following:

$$S_d(\mathbf{x}_i, \vec{\omega_i}; \mathbf{x}_o) = S'_d(\mathbf{x}_0 - \mathbf{x}_i, \vec{\omega_{12}}, d_r) - S'_d(\mathbf{x}_0 - \mathbf{x}_v, \vec{\omega_v} d_r)$$

Details of the explaination will be given at the second presentation. 2 explains the dipole configurations of the proposed method. Similar to dipole with point sources, directional dipole uses ray sources.We mirror the direction of the refracted ray(blue) $\vec{\omega_{12}}$ in a modified tangent plane to find the direction $\vec{\omega_v}$ of the virtual source. The origin of the virtual source is displaced along the normal of this modified plane.

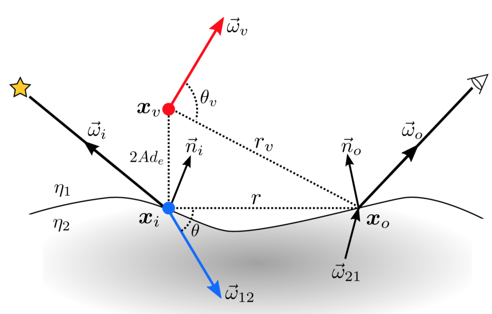

Figure 2: Directional Dipole

The implementation of directional dipole contains monte carlo integration, as well as Jensen's work. Directional dipole integrates the

BSSRDF in a progressive path tracer by distributing points evenly across the surface of the translucent object using a dart throwing technique. A new set of points is sampled iteratively, and, for every sampled surface point, the incident illumination is sampled from one direction. Photon mapping can also be done with other algorithms like k-nearest neighbor orkd-trees, as was also mentioned by Jensen.

For hierarchical integration, a simpler approach of utilizing the existing implementation of the hierarchical integration method is used.

References

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