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Rendering of Single Scattering using Types of Light Sources : Review

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Abstract— **In spite of their diverse applications, realistic rendering of light scattering in participating media is still very challenging due to the complexity of the variety radiative transport processes. In this study, we address several types of light models that play important role in realistic images synthesis and determine the advantages and shortcomings of each of them. Our study focus is on the interaction between the light models with particles in the air such as dust, fog, mist, haze, smoke, etc. We seek to provide information to help the reader to select the optimal and suitable light model with numerous of applications in computer graphics.**

Keywords - Photorealistic Rendering; Lighting; Light Scattering; Light Properties; Caustics Rendering;

I. Introduction

There are a lot of factors that influence realism rendered scenes in computer graphics, one of more important is scattering of the light. Assuming interaction light with participating media according to radiative translate equation. Additional types of light in computer graphics ambient light, diffusive light that cast unfocused light in all directions. Directional lights that cast parallel beams of light in one direction, target spotlights that cast a focused beams of light towards target and the free spotlights that cast a focused beam of light in a direction. Diffusive lights and spotlights can be attenuated, but there is no attenuation for ambient of directional lights. The light intensity diminishes linearly between the start range and end range such that it is zero at the end range [1].

Previous research of photo-realistic image synthesis techniques on special media effects rendering has demonstrated that the computational effort required to produce the images excludes interactive nature of the stochastic rendering systems. However, the application of advanced parallel processing methods should allow the interactive visualization of volumetric models under various conditions and thus further more understanding of lighting requirements.

Local illumination refers to direct interaction between one light source and one object surface. Global illumination refers to the interaction of light between all surfaces in a scene. Depending on the spectrum perceptible by the human visual system, our eyes respond to the Hue (or color of the light). Brightness (Luminace) of the light which corresponds to the total light energy, and the Saturation (or purity) of the light which describes how close a light appears to be a pure spectral color (ex. Pastel and pale colors). Chromate, a term describes the characteristic of the hue and saturation of an object [2].

Interested with the planetary atmospheres, [3] was opener to present the rendering of participating media. For a widely far distant light source and observer, it is better to use an analytical model for the single-scattering in isotropic and optically thin media. After that techniques have considered illumination from directional light [4], [5] and single point light sources to simplify assumptions such as single scattering [6].

In this paper, we present various categories of light sources such as omnidirectional point light sources, spotlight sources, directional light sources and area light sources to explain each type. We discuss characterizes, advantages and disadvantages when interaction of this light models to enable the researchers to choose the optimal light source that meets the requirements of various applications in computer graphics.

II. Single scattering in participating media

Chandrasekhar introduced the radiative transport equation [7]. This equation describes the propagation of light in participating media. We define the tiny particles that scatter and absorb light in the 3D coordinate system as Participating media. It is the combined effect of these particles that provides the participating media with its overall scattering properties.

The single scattering describes only scattered radiation event once along its path from a surface to the viewer [8]. According to nature of single light scattering that dominate visual effect is assumed that all light scattering occurred at surfaces, this means radiance which leaving a surface preserves the energy unchanged until it strikes another surface. In real life, this assumption doesn't work because participating media typically occupied the space between all objects by Infinitesimal particles [9].

The color of the light that reaches to the viewer is not the pure light of the surface of objects. The light had been scattered before it reaches viewer. Therefore, color of the light of an object is not same as color of the light in front of our eyes [10].

Therefore when the light travels from one point to another in space, the photons can change their paths and transform their powers due to interact with a participating media such as fog, dust, smoke and the particles in the air. Even in case clear air, the photons collide with small microscopic particles, they will either be absorb or scattered in another direction (So sky is bluish) [11]. The change of radiation based on the properties media, leads to increase the challenging of rendering of participating media due to spectral dependence of medium and the complex interaction between radiance and media. The phenomena that occur in the media to participate involve of many difference effects of scattering such as absorption and emission. Figure 1 illustrates single light scattering.

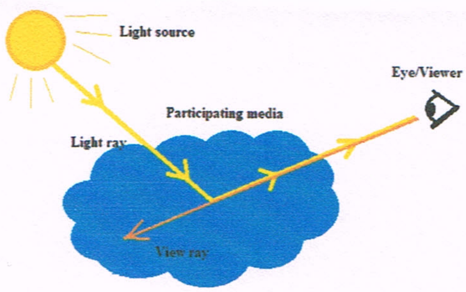

Figure 1 Single light scattering model.

Uhl et al [12] introduced the situation when participating medium do not scatter the light (scattering = 0). In such cases, occurs an explosion that shows the light with high emission which leads to the neglect of all types of scattering. For instance, the rendering equation become as in equation 1:

$$L(x) = t_a(x_0, x)L(x_0) + \int_{x_0}^{x} t_0(u, x)k_a(u)L_e(u)du \qquad \text{(Equation 1)}$$

where transmittance:

$$t_a(x_0, x) = e^{-\int_{x_0}^{x} k_a(u)du}$$

when homogeneous non-emitting medium

k_a = constant and $L_e = 0$

in this case rendering equation reduces to:

$$L(x) = e^{-k_a\|x_0 - x\|}L(x_0)$$

$L(x_0)$: the emitted light from point x_0

$L(x)$: the emitted light from point x

According to Jarosz, W. [13], the Radiative Transfer Equation consists of the four scattering events as he described are absorption, out-scattering, emission, and in-scattering. Equation 2 show the complete model of how light behaves in a participating medium by combining each of the four equations, as:

$$(\vec{\omega} \cdot \nabla) L(\mathbf{x} \to \vec{\omega}) = \underbrace{-\sigma_a(\mathbf{x}) L(\mathbf{x} \to \vec{\omega})}_{\text{absorption}} \underbrace{- \sigma_s(\mathbf{x}) L(\mathbf{x} \to \vec{\omega})}_{\text{out-scattering}} \underbrace{+ \sigma_a(\mathbf{x}) L_e(\mathbf{x} \to \vec{\omega})}_{\text{emission}} \underbrace{+ \sigma_s(\mathbf{x}) L_i(\mathbf{x} \to \vec{\omega})}_{\text{in-scattering}} \qquad \text{(Equation 2)}$$

$(\vec{\omega} \cdot \nabla) L(\mathbf{x} \to \vec{\omega})$: A change of radiance through participating media

$\vec{\omega}$: Normalized direction (away from surface)

x : Position

$\sigma_a(\mathbf{x})$. : Absorption coefficient at x

$L(\mathbf{x} \to \vec{\omega})$: Radiance at x in direction $\vec{\omega}$

$\sigma_s(\mathbf{x})$: Scattering coefficient at x

$L_e(\mathbf{x} \to \vec{\omega})$: Emitted radiance at x in directio $\vec{\omega}$

$L_i(\mathbf{x} \to \vec{\omega})$: In-scattered radiance at x in directio $\vec{\omega}$

For more details on this equation, it is advised to refer to Jarosz, W. [13].

III. Point Light Sources

When, emitted rays outward from single point with a zero area in all directional, this so called point light sources as Figure 2. They are many practical types to represent infinitely small light source that lead to tremendously simplify radiative transfer equation. Point light sources are used to compute contributions of the single light scattering in volume lighting [14]. In case point light sources are moving within isotropic participating media Lecocq et al. [6] work on reformulating the shaft light model after that same researchers used light shaft model of Nishita et al [15] to a driving simulator in order testing of headlights in participating media [14].

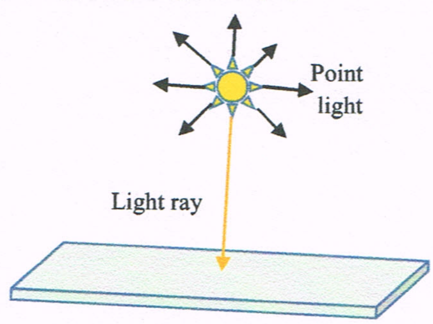

Figure 2 Point Light Sources

IV. SPOT LIGHT SOURCES

Spot light represents light emission from a single point in space has a cone of effect on a specific direction as figure 3. Spotlights have applied to generate light shafts using ray casting [15].

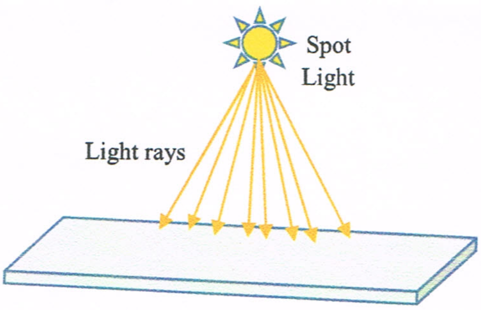

Figure 3 Spot light Sources

V. DIRECTIONAL LIGHT SOURCES

A directional light source is represented as a collimated ray. In this situation, light reaches objects in parallel rays Figure 4. Lecocq [16], deals with directional light sources in order to increase the rate frame rendering in the process of light scattering participating media. Lecocq also explains the Deterministic methods of the developed expression is performed.

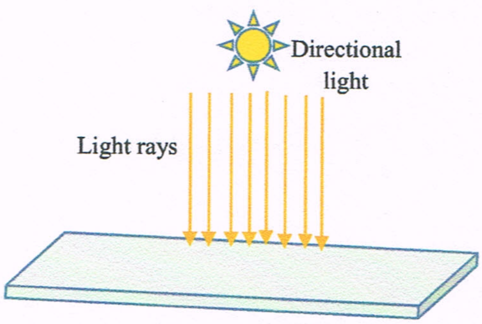

Figure 4 Directional light sources

VI. AREA LIGHT SOURCES

Area light sources are light emitters out from a surface. To compute for its contribution in reflection light as figure 5. Johnson et al. [17] proposed technique to compute penumbra shadow of area light source.

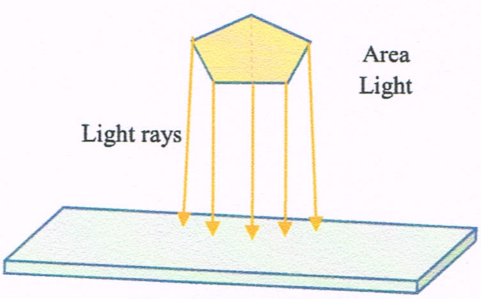

Figure 5 area light sources

VII. DISCUSSION TYPES OF LIGHT SOURCES

Wyman, et al [18] presented technique to calculate light scattering at low resolution, that leads to the expansion of rendering scenes using textured spotlights with an increase in cost is negligible. On other hand, this technique compatible with GPU implementation. In addition, employ ray tracing implementations possible to reduce standard GPU limitations, like solely using point light sources. For example, penumbra wedges are used rather than geometry-based shadow, in order to generalize this technique.

M. Sunar et al. [19] proposed research describes use Visible-Non Visible algorithm in virtual environment illuminated by a movable light source to increase rate frame. This study based on generate shadow volume in real time.

Markus Billeter [20] proposed method avoided use ray-marching by computing the true amount of light of shafts for each pixel. The key idea of this method is the realization that an image-based shadow generated for a point light source really defines a volume enclosing the lit space. In case a directional light source, the edges of the image-based shadow are connected to the place to the light source to define an enclosed light volume.

Elek O. [21] describe directional light distribution using a single scalar value per grid cell in the local anisotropy. But a point light source. Lecocq P., et al. [6] depended on polynomial approximation to find simple solution for a homogeneous point light source. On other hand, the computation of the equation for directional light source is more complex.

VIII. CONCLUSION

In this paper, we address the impact of the several types of light sources on light scattering in the case of participating media. We simplified the explanation of the methods to compute light transport equation. The point light source was the simplest model to explain the rendering equation. Other models, such as directional light source, spotlight source and area light source are used to produce more complex computations for more realistic scenes. Our recommendation for future work is to use area light source to get more details to increase realistic with maintain on rate frame.

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IX. REFERENCES

[1] V. Pegoraro and S. Parker, "An analytical solution to single scattering in homogeneous participating media," *Comput. Graph. Forum*, 2009.

[2] V. Pegoraro, M. Schott, and S. Parker, "An analytical approach to single scattering for anisotropic media and light distributions," *Proc. Graph. Interface* ..., 2009.

[3] J. F. Blinn, "Light reflection functions for simulation of clouds and dusty surfaces," *ACM SIGGRAPH Computer Graphics*, vol. 16, no. 3. pp. 21–29, 1982.

[4] N. Hoffman and A. Preetham, "Rendering outdoor light scattering in real time," *Game* ..., 2002.

[5] K. Riley, D. Ebert, and M. Kraus, "Efficient rendering of atmospheric phenomena," *Proc.* ..., 2004.

[6] P. Lecocq and S. Michelin, "Mathematical approximation for real-time lighting rendering through participating media," *Comput. Graph.* ..., 2000.

[7] S. Chandrasekhar, "Radiative transfer," 1960.

[8] T. Engelhardt and C. Dachsbacher, "Epipolar sampling for shadows and crepuscular rays in participating media with single scattering," ... *2010 ACM SIGGRAPH Symp.* ..., 2010.

[9] Y. Dobashi, T. Yamamoto, and T. Nishita, "Interactive rendering of atmospheric scattering effects using graphics hardware," *Proc. ACM SIGGRAPH* ..., 2002.

[10] K. Hoshang and M. Sunar, "Real-time outdoor rendering using hybrid shadow maps," *Int. J. Innov.* ..., 2012.

[11] T. Nishita, Y. Dobashi, and E. Nakamae, "Display of clouds taking into account multiple anisotropic scattering and sky light," ... *23rd Annu. Conf.* ..., 1996.

[12] F. Uhl and J. Blanc-Talon, "Rendering explosions," *Simul. Ser.*, 1997.

[13] W. Jarosz, *Efficient Monte Carlo methods for light transport in scattering media*. 2008.

[14] N. Max, "Light diffusion through clouds and haze," *Comput. Vision, Graph. Image Process.*, 1986.

[15] T. Nishita and Y. Dobashi, "Modeling and rendering of various natural phenomena consisting of particles," *Comput. Graph. Int. 2001.* ..., 2001.

[16] P. Lecocq and S. Michelin, "Simulation temps-réel d'éclairage en présence de brouillard," *Rev. Int.* ..., 2001.

[17] G. Johnson, W. Hunt, and A. Hux, "Soft irregular shadow mapping: fast, high-quality, and robust soft shadows," *Proc.* ..., 2009.

[18] C. Wyman and S. Ramsey, "Interactive volumetric shadows in participating media with single-scattering," *Interact. Ray Tracing, 2008. RT 2008.* ..., 2008.

[19] M. Sunar and H. Kolivand, "Real-time volume shadow using visible-non visible algorithm," *J. Comput.* ..., 2011.

[20] M. Billeter, E. Sintorn, and U. Assarsson, "Real Time Volumetric Shadows Using Polygonal Light Volumes," in *Proceedings of the Conference on High Performance Graphics*, 2010, pp. 39–45.

[21] O. Elek and T. Ritschel, "Interactive light scattering with principal-ordinate propagation," *Proc. 2014* ..., 2014.