

The Improve Algorithm of the Sky Illumination Rendering

Wenlong Yu^{*1}, Limin Zhang²

^{1,2}Naval Aeronautical Engineering Institute, Department of Electronics and Information Industry, Yantai, China

*Corresponding author, e-mail: ywl19811230@yahoo.cn

Abstract

This paper proposed the algorithm of the sky color rendering based on the relationship between the height of viewpoint and the altitude of scattering point with atmospheric density after the study of atmospheric absorption and scattering and sky illumination simulation methods. It proposed the simplified algorithm of the sky perspective illumination. The geometrical model of the sky dome and rotation and the sun location is presented. The rendering method based on GPU is designed. The results of experiment show that the rendering effect of the sky illumination based on this algorithm is realism.

Keywords: Atmospheric scattering, sky color, Sky perspective illumination, Algorithm

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1. Introduction

The simulation of the sky light has already begun in the late of 1980s. Natural light mainly comes from the sunlight, it is an important aspect in the simulation of natural scenes. Kaneda [1] adopted the model of single scattering and the parallel spherical hierarchical to simulate the sky color on the basis of the atmospheric density will become thin for the increasing of height. Nishita [2] extended the model to the calculation of multiple scattering. But the method is based on the physical simulation and the calculation is complicated. It is not suitable for real-time rendering. With the emergence and development of programmable graphics hardware, real-time simulation of the sky illumination is proposed. Dobashi [3] proposed to construct a set of sampling plane in the front of the projector screen, the light scattering property is obtained through texture sampling on the grid dot of every sampling plane. This method can render high quality atmosphere lighting effects, but the computational cost is expensive. Hoffman [4] proposed simple drawing equations of atmospheric light processing algorithms. In the algorithm, atmospheric density and the location of the viewpoint which can only be set on the ground is fixed. The realism is poor although the rendering speed has been improved. This paper proposed simplified rendering algorithm of the sky and the sky perspective illumination based on these algorithms. The geometrical model is presented in the sky illumination calculation. The rendering method based on GPU is designed.

2. The Model of Atmospheric Scattering and Absorption

The atmosphere is mainly composed of a variety of gases, water, vapor, and particles. The internal properties of the molecules and particles decide they absorb the energy of the different attributes. Light is scattered except some is absorbed in the atmosphere. Light in the atmosphere may occur single scattering or multiple scatterings. Rayleigh function [5] describes the scattering properties of molecules in the atmosphere and its function is shown as:

$$\beta_R(\theta) = \frac{\pi^2(n^2-1)^2}{2N\lambda^4} (1 + \cos^2\theta) \quad (1)$$

where θ is the angle of scattering. n is refraction coefficient of the air. N is the density of molecules. λ is the wavelength of the light. The scattering coefficient β_R is the integral of Rayleigh function in the spherical solid angle. It can be shown as:

$$\beta_R = \int_0^{4\pi} \beta(\theta) d\varphi = \frac{8\pi^3(n^2-1)^2}{3N\lambda^4} \quad (2)$$

Mie function [4] describes the scattering properties of any size particles in the atmosphere. In order to simplified calculate the particles of large size and small size are usually described separately. The particles of small size can be directly described using the Rayleigh function. The particles of large size can be directly used the approximate computation function Henyey-Greenstein. it is shown as:

$$f_{HG}(\theta) = \frac{1-g^2}{4\pi(1+g^2+2\cos\theta)^2} \quad (3)$$

where g is the factor of direction. Usually light attenuation in the atmosphere is the exponential form of the optical depth. Given light intensity I_0 , the light intensity I after attenuating can be expressed as $I = I_0 e^{-t}$. t is the optical depth. $t = \int_0^S \beta(x) dx$. $\beta(x)$ is the scattering coefficient. It is the sum of the Rayleigh scattering coefficient β_R and Mie scattering coefficient β_M .

3. Improved Algorithm of The Sky Perspective Illumination

Usually the rendering of the sky illumination is divided into two cases: one is the calculation of the color of the sky dome. The other is the calculation of the sky perspective illumination. The distant objects are blurred boundary under the action of the sky illumination and gradually blend into the background.

The rendering of the sky illumination is the calculation of the color of the sky dome. As shown in Figure 1, assuming P_v is the location of the viewpoint, the point E is the vertex of sky along the sight line. The point Q is the vertex of the sky in the direction of the sun. The point R is different scattering point on the line of sight. Light on the path PE is scattered into the viewpoint P_v , then the light intensity entering the viewpoint can be shown as:

$$E_v = \int_P^E E_s e^{-\beta L_{QR}} \beta(\theta) e^{-\beta L_{RP}} dx \quad (4)$$

Where E_v is the light intensity entering the viewpoint. E_s is the sunlight intensity. θ is the scattering angle. β is the sum of Rayleigh scattering coefficient and Mie scattering coefficient. L_{RP} is the optical path from the point R to point P . L_{QR} is the optical path from the point Q to point R .

To enhance the realism of rendering, this paper proposed functional relationship between the altitude of viewpoint and the height of scattering point with atmospheric density. The different of the altitude of scattering point influent the atmospheric density. The optical depth also will be changed. The sky color will change smoothly. Because the optical path L and the L_z from viewpoint to the sky vertex was proportional relationship, the angle θ between them can be calculated. The different of the height of viewpoint changes the angle θ . It will influent the scattering phase function. The altitude of scattering point Q can be expressed as $h + y \cos \phi$.

In the case of considering the single scattering and sunlight as the only incoming parallel light, this paper simplifies the algorithm. Assume ignoring the light attenuation from point of incoming sunlight to scattering point. The distance from point P to point E is S . The distance from point R to point E is x . The formula (4) can be approximatively shown as:

$$E_v = \int_P^E E_s \beta(\theta) e^{-(\beta_R + \beta_M)L_{RP}} dx \quad (5)$$

$$E_v = \int_P^E E_s \beta(\theta) e^{-(\beta_R \int_0^{S-x} \rho_R dy + \beta_M \int_0^{S-x} \rho_M dy)} dx \quad (6)$$

where $\rho_R = e^{-\frac{(h+y \cos \theta)}{H_R}}$ $\rho_M = e^{-\frac{(h+y \cos \theta)}{H_M}}$ H_R, H_M is the constant of exponential attenuation.

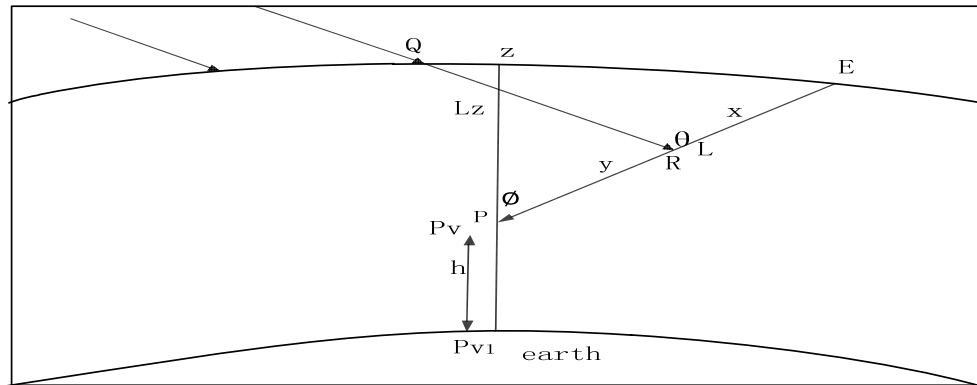


Figure 1. The Diagrammatic of The Sky Illumination

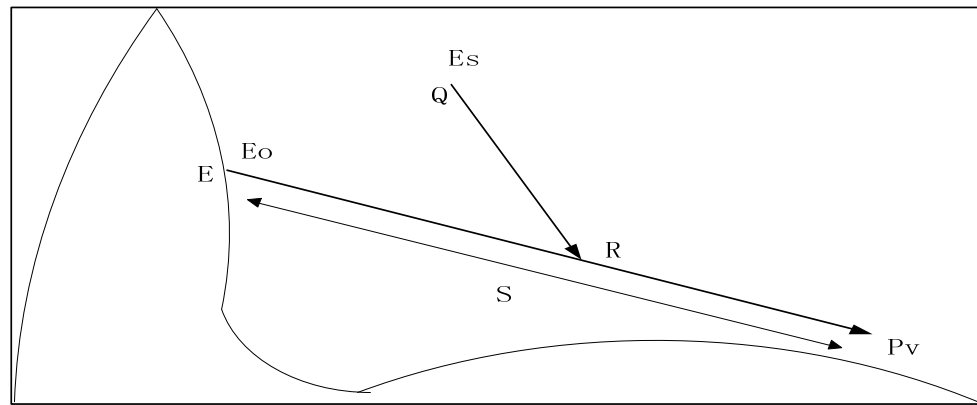


Figure 2. The Diagrammatic of The Sky Perspective Light

As shown in Figure 2, E_0 is the incoming light intensity of distant objects. E_s is the incoming light intensity of sunlight. E_{si} is the light intensity of entering viewpoint through in-scattering. In the rendering of the sky perspective light, it is assumed that the medium density in the sight line direction is a constant for the sight line is basically close to the Earth's surface. The optical path L_{PE} can be approximated by the representation of S . So E_0 enters the viewpoint P_v after the distance S . f is the attenuation factor of light energy. Assume ignoring the light attenuation from point of incoming sunlight to scattering point. The light intensity of entering the viewpoint can be shown as:

$$E_{vi} = fE_0 + E_{si} \tag{7}$$

$$E_{vi} = e^{-\beta S} E_0 + \int_0^S E_s \beta(\theta) e^{-\beta L_{RP}} dx = e^{-\beta S} E_0 + \int_0^S E_s \beta(\theta) e^{-\beta(S-x)} dx \tag{8}$$

where $\int_0^S E_s \beta(\theta) e^{-\beta(S-x)} dx = E_s \frac{\beta(\theta)}{\beta} (1 - e^{-\beta S})$

In the rendering of the sky perspective illumination, the light intensity entering the viewpoint can be shown as:

$$E_{vi} = e^{-(\beta_R + \beta_M)S} E_0 + E_s \frac{\beta(\theta)}{\beta} (1 - e^{-\beta S}) \tag{9}$$

4. The Presentation of Geometrical Information in Illumination Calculation

Realistic sky is helpful to improve the visual sense of immersion, the classic sky rendering algorithms typically use a static background image or sky bounding box. But neither of these two methods can better performance in real sense. The position of the sun can be expressed as the geometric information, such as the elevation angle and azimuth angle [4]. In our model the sun light is assumed to be a parallel light source, so the unit vector and quaternion method is used to describe the direction of rotation from the sun to the center point of the earth. The surface of the earth is covered by the atmosphere, so the spherical model can be used to model the sky dome. When the observer moves, the sky, the top zenith should always be above the observer. For the rotation of the sky dome, the quaternion method is introduced to calculate the rotational of sky [6]. Vertex standing for the sky is represented by 4 dimension vector in which $P=\{x, y, z, \theta\}$, θ is the angle between the optical path L and the optical path from view point to the sky vertex. In order not to frequently implement sky dome rotation transformation calculation, a rotation transformation is implemented when quaternion product reaches a threshold value. The position of the sun is changed over time and seasons.

5. Summary

The previous algorithms in which the density of propagation medium is same and the viewpoint location is same are improved. This paper proposed the improved algorithm which the different of the altitude of scattering point and the height of viewpoint influent the atmospheric density and the scattering phase function. The optical depth also will be changed. The color of sky will change smoothly. This algorithm of rendering sky illumination is more realism. The algorithm of the sky perspective illumination is simplified. It is assumed that the medium density in the sight line direction is a constant for the sight line is basically close to the Earth's surface. The calculation is more convenient.

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