Material simulation based on Phong illumination model

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Abstract

Realistic material simulation is one of the major works in rendering realistic graphics. In this paper, we have studied and discussed the effects of rendering realistic graphics by simulating some materials under different illumination conditions and material attributes and emission based on the OpenGL graphics technology and Phong illumination model. Experimental results show effects of emission on specular and non-specular materials and demonstrate the emission effects to some degree.

Keywords: Phong illumination model, Realistic graphics, Material simulation, Emission

1 Introduction

Realistic picture rendering is one of the most important parts of computer graphics. The major work in rendering realistic graphics is simulating illumination and material attributes of object surface. That means, if we deal with them correctly we can create realistic graphics. In generally, we use some illumination model to calculate the brightness values under imaginary lightings, textures and material attributes, when we render realistic pictures. Phong illumination model is good at simulating shading and lighting effects. Moreover, its computational complexity is very low [1].

OpenGL can be used to simulate the real world based on given illumination conditions, it also can be used to control the relation between lighting and objects, and generate many different varieties of visual effects. In order to render realistic pictures, we need to simulate not only the lighting effect but also the effects of absorbing and reflecting light of objects surface. Besides, the attributes of material such as emission and reflection have great impact on rendering realistic pictures. In this paper, we will study and discuss the effects of rendering realistic graphics under different material attributes and emission values based on Phong illumination model.

2 Illumination Model

In the process of rendering realistic 3D object, we need to calculate the brightness of each pixel on visible object surface according to illumination model [2]. Illumination model is the base of rendering realistic pictures in computer graphics [3]. According to the relevant law of optical physics, illumination model calculates the light brightness and colour of each point on the surface of 3D objects projected on the observer's eyes. It defines the characteristics of light source, geometric distribution of light intensity on object irradiation surface and reflection characteristics of surface to light, and it contains many other factors such as the type of objects, lighting attributes in the scene.

Phong illumination model is a kind of local illumination model. It has been often used in 3D computer graphics. All light sources in Phong illumination model are simulated as point light source, which only consider the effects of light direct exposure to the surface and then directly reflect to the viewpoint. The core of Phong illumination model is how light reflects from the surface and Phone illumination uses the cosine angle between reflection vector and the view vector to simulate specular reflection light.

2.1 CALCULATION OF PHONG ILLUMINATION MODEL

Phong illumination model [4] contains three different lighting types: ambient light, diffuse light and specular reflection light [5], which can be expressed as follow:

$$I = I_{amb} + I_{diff} + I_{spec}, \tag{1}$$

where ambient light I_{amb} is also called background light in Phone illumination model, which is formed by multi-reflecting of light from light source. It is the most basic illumination model in 3D scenes [6]. It enters to object surface uniformly from surrounding and reflects evenly in all directions. It is a uniform distribution of light and can be described as follow:

$$I_{amb} = k_a I_a, \tag{2}$$

where k_a is reflection coefficient of ambient light, I_a is ambient intensity.

Diffuse reflected light is a kind of uniformly reflecting light into space. It is not related with the

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observer position and it has same brightness regardless of the position of the observer. In calculating diffuse reflected light, the position of light source should be considered, which is different from ambient light. Diffuse illumination model follows Lambert law [7, 8, 9], which can be described by two vectors: Vector L and Vector N.

As illustrated in fig. 1, vector L describes the position of light source, and vector N describes the vertex on object surface. The less the angle between vector L and vector N is, the greater the diffuse reflected light is. When L and N are in the same direction, diffuse reflected light is greatest. Diffuse reflected light can be expressed as follow:

$$I_{diff} = k_d I_l \cos\theta \,, \tag{3}$$

where k_d is percentage of diffuse light in the incoming light, the values range from 0 to 1 [10], I_l is lighting intensity, and $\cos\theta = N \bullet L$.

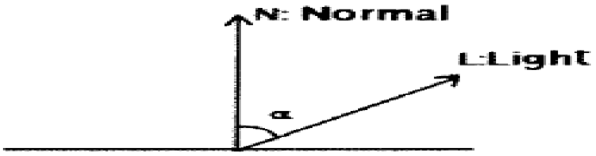

FIGURE 1 Diffuse reflected light

Specular reflection light comes from a specific direction and goes to a specific direction. In Phone illumination model, the colour of specular reflection component is independent of any material attributes [11]. It is often used to simulate the shiny surface of object, such as metal and glass bottle. In the specular reflection model, two vectors are used to calculate the specular reflection component, which are observation point vector V and reflection vector R illustrated in fig.2. The former describes the relative position of observation point (or the camera), the latter describes the reflection direction of light.

As illustrated in fig. 2, the less the angle β between V and R, the brighter the reflection light. Besides, there is an exponent n to represent gloss properties. Specular reflection light can be expressed as follow:

$$I_{spec} = k_s I_l COS^n \beta \,, \tag{4}$$

where k_s is reflection coefficient of specular light, I_l is light intensity, $\cos\beta = V \bullet R$.

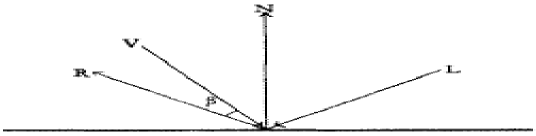

FIGURE 2 Specular reflection

From above description, we can see that the calculation formula of three components (ambient light, diffuse light and specular reflection light) in Phone illumination model can be better to reflect corresponding lighting information in the realistic lighting environments. Ambient light, diffuse light and specular reflection light are combined to construct Phone illumination model. In RGB 3-color system, Phone illumination model can be expressed as follow:

$$\begin{bmatrix} \mathbf{r} \\ \mathbf{g} \\ \mathbf{b} \end{bmatrix} = k_a \begin{bmatrix} \mathbf{r}_{pa} \\ \mathbf{g}_{pa} \\ \mathbf{b}_{pa} \end{bmatrix} + \sum \left[\begin{bmatrix} \mathbf{r}_{pd} \\ \mathbf{g}_{pd} \\ \mathbf{b}_{pd} \end{bmatrix} \cos\theta + k_s \begin{bmatrix} \mathbf{r}_{ps} \\ \mathbf{g}_{ps} \\ \mathbf{b}_{ps} \end{bmatrix} \cos^n \beta \right], \tag{5}$$

where $[r_{pa}, g_{pa}, b_{pa}]$, $[r_{pd}, g_{pd}, b_{pd}]$, $[r_{ps}, g_{ps}, b_{ps}]$ are the corresponding colour of brightness I_{pa}, I_{pd}, I_{ps} respectively. Users can directly specify the colour of ambient light, diffuse reflection light and specular reflection light, and then they can generate the pictures with different colour. By changing the parameters on above formula, different materials effects can be displayed.

2.2 MATERIAL

Material is what the object looks like. In the rendering process, material is the combination of each visual attribute. These visual attributes include colours, textures, smoothness and reflection of material surface. Only if we assign proper materials to objects, the rendering results can be realistic. If there is no illumination model, there will be no realistic material.

The colours we see are decided by the illumination in the scene and reflection of material. The wavelength of reflected light decides the colour of material. If the light falls on a surface with smoothness and brightness, the material will reflect most of the incident light. When light falls on an object, it will be grey after it equally absorb all visible light. Like light characters, material has own ambient light, diffuse light and specular reflection light, but material ambient light is affected by ambient light of panoramic view and all light sources. Specular reflection light of materials are usually decided by the light source. Besides, material has glossiness and emission. Glossiness presents roughness of the material. It affects the reflection of the object. Emission is irrelevant to any kind of illumination and the higher the value, the brighter the material gets.

3 Algorithm Description

This experiment is carried out under the win7 operating system, using VS2005 as development platform and programming under OpenGL1.2. The experiment algorithm is described as follow:

(1) Create a 3D teapot model, define normal vector of each vertex.
(2) Create lighting locations and types. In this paper, we use Phong illumination model.
(3) Create a point source and enable it.
(4) Define material attributes. In OpenGL, glMaterialfv is used to describe the material. GL-EMISSION is used to simulate the luminous intensity.

4 Experiment Results and Analysis

Illumination in OpenGL is an approximation of real illumination. In OpenGL, we use four parameters build material model: ambient, diffuse, specular and emission, the first three parameters individually present three illumination reflect by the objects, the last one present the emission. In addition, the first three parameters are respectively composed of four components R, G, B, A, which represents red, green, blue, and alpha respectively. The values range from zero to one. We adjust the parameters to achieve some realistic material. Table 1 is some values of the material attributes used in out experiment according to the above model.

TABLE 1 Parameters of the material

Material	Ambient R, G, B, A	Diffuse R, G, B, A	Specular R, G, B, A	Emission
Plastic (a)	0.31, 0.31,0.31,1.0	0.12, 0.1,0.55,1.0	0.2, 0.2, 0.2, 1.0	0.25
Plastic (b)	0.31,0.31,0.31,1.0	0.12,0.1,0.55,1.0	0.2, 0.2, 0.2, 1.0	0.5
Plastic (c)	0.31,0.31,0.31,1.0	0.12,0.1,0.55,1.0	0.2, 0.2, 0.2, 1.0	1.0
Aluminum (a)	0.4, 0.4, 0.4, 1.0	0.4,0.4, 0.4,1.0	0.7, 0.7, 0.8, 1.0	0.25
Aluminum (b)	0.4, 0.4, 0.4, 1.0	0.4,0.4,0.4,1.0	0.7, 0.7, 0.8, 1.0	0.5
Aluminum (c)	0.4, 0.4, 0.4, 1.0	0.4,0.4, 0.4,1.0	0.7, 0.7, 0.8, 1.0	1.0

In this paper, we simulate two types of materials: non-specular material such as plastic, specular material such as aluminium.

Fig.3 shows non-specular material under Phong illumination model, the background is black. From left to right, the value of emission becomes larger, the teapot becomes brighter. At last, purple teapot turns shiny white. Under this condition, emission mainly affects the colour.

Fig. 4 shows specular material under Phong illumination model, the background is also black. From left to right, the value of emission becomes larger, the teapot becomes brighter. Eventually, the teapot turns white and there is no specular on the surface.

In this experiment, the teapot is opaque; the reflected light decides the colour of the teapot. When emission value grows larger, object surface becomes brighter, and vice verse. Under non-specular material condition, the object colour becomes more and brighter with the self-luminous value become large and until the whole object become white. Under specular material, the teapot colour also becomes more and brighter with the self-luminous value become large and until the object becomes white. Moreover, at this time the colour will not be changed with self-luminous value changing. Because specular reflected light is white, teapot eventually performances white and there is no specular reflection. As we can see from the fig.3 and fig. 4, teapot looks like a light source when emission values is 1.

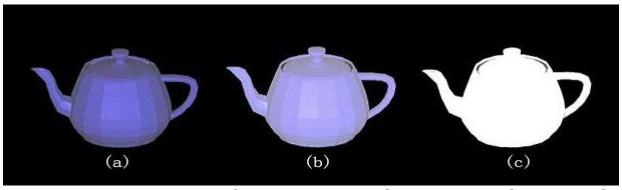

FIGURE 3 Using material parameters simulate non-specular material (plastic)

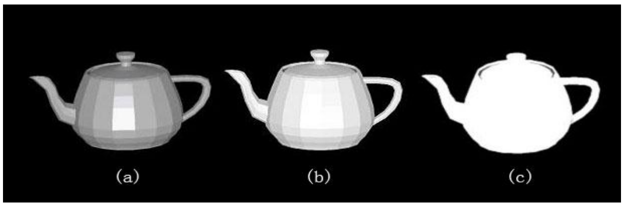

FIGURE 4 Using material parameters simulate specular material (aluminium)

5 Conclusions

Phong illumination model describes the surface characters of the luminous object, and it only shows the most obvious difference between reflective light and non-reflective light. However, it cannot show the viewer's feelings of luminance. In this paper, we have simulated realistic materials in the case of different emission values in Phong illumination model, and mainly discussed the effects of emission on non-specular material and specular material and demonstrated the emission effects material to some degree. In the future, we will focus on how to performance the true colour specular material effects.

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References

[1] Phong B T 1975 Illumination for Computer Generated Pictures *Communications of the ACM* **18**(6) 311-7 *(In Chinese)*

[2] Qunsheng Peng, Hujun Bao, Xiaogang Jin 1999 *Procedural Elements for Computer Graphics* science Press, Beijing 27-34 *(In Chinese)*

[3] Jia Ren, Jing Gan 2010 Illumination Simulation for Photo-Realistic Rendering of Diverse Materials' Color Texture *Microcomputer Applications* **31**(2) 38-43 *(In Chinese)*

[4] Ruchuan Wang, Beiji Zou 2002 *Computer Graphics* Beijing Posts & Telecom Press 240-1 *(In Chinese)*

[5] Xiaogang Chen, Lin Lu, Xiangyang Liu 2009 Accurate estimation of face image illuminating direction based on classical lighting model *Computer Engineering and Applications* **45** 203-5

[6] Hui Wang 2009 Basic research and program realization of illumination model in three-dimensional scene *China Science and Technology Review* **17** 101-2 *(In Chinese)*

[7] Haipeng Chen, Xuanjing Shen,Yinda Lv 2011 Blind Identification for Image Authenticity Based on Lambert Illumination Model *Journal of Computer Research and Development* **48**(7) 1237-45 *(In Chinese)*

[8] Chuang Zhang, Donghui Lv 2011 Research and Application of Single Image Light Direction Estimation Algorithm *Television Technology* **35**(15) 41-5 *(In Chinese)*

[9] Wei Dong Zhong, Zhu Jun Jie, Li Xian Wei, et al. 2012 A new algorithm to exposing image forgeries by detection ambient illumination consistency *Advanced Materials Research* **433-440** 5463 - 8

[10] Hongan Jiang, Cunhua Li 2005 The Realistic 3D Terrain Simulation Based on Phong Model *The simulation technology academic conference proceedings* **3** 359-360 *(In Chinese)*

[11] Foley J D 2002 Computer Graphics: Principles and Practice Second Edition in C *Pearson Education* 429-34

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