A task submitted in partial fulfillment for course assessments

# Computer Graphics Fundamental: Lighting and Shading

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***Abstract* — Lighting and shading is important for realistic look rendering. This work is presented the overview of lighting sources, reflection models and shading model which can be applied in computer graphics. Moreover the examples of those formulations are also discussed.**

***Keywords - computer graphics, graphics, fundamental of CG, lighting, Shading, lighting sources.***

## I. INTRODUCTION

Computer graphic technology has ability to produce a realistic looking three dimensional object on a two dimensional output device like computer screen or printed paper. This ability is achieved by rendering methods in which shading is applied for more realistic rendering. Shading uses to compute the amount and color of the light that emitted from every point of the surface. According to [1] describe that the resulting shaded image can be basically depended on the following entities:

1. The light source. The intensity, color, shape, direction and distance of the light source are considered and it also can be point source or a large source, such as a window or a light fixture.
2. The surface of the object. The object can be from very shiny to from smooth to rough, and from bright to dark. It can have several colors can be opaque, transparent or translucent.
3. The environment. Objects seen in empty space, without any background to reflect light on them, look harsh. Imagine a spaceship in deep space, away from any reflecting planets. Those parts of the ship illuminated by direct starlight are very bright, while parts that are in the shade are completely dark. The result is the ship mostly looked in black and white, with few grays or colors. A realistic shading model should therefore consider light reflection from other objects and from nearby walls.

## II. THE LIGHT SOURCES

The object is illuminated by light which is to follow rays of light from light-emitting on the object surfaces called light sources. According to [2] has described the light sources on the scene as the following:

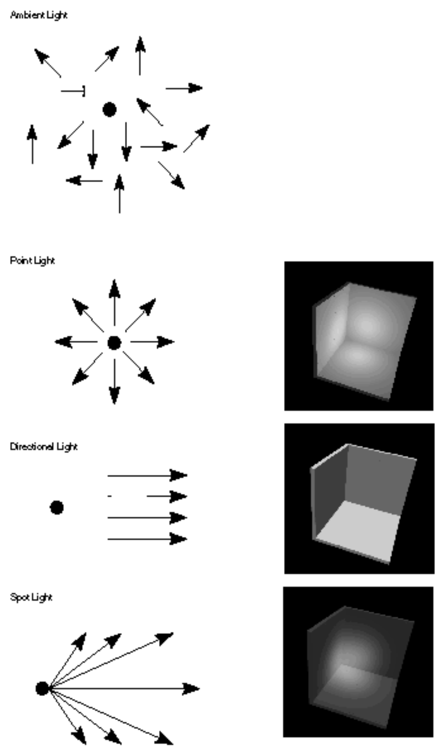


**Fig.1** The different of light sources[3].

### 1) *Ambient light.*

This light is non-directional light source in which the light is come from all direction. The intensity is not affected by anything else such as position or orientation.

### 2) *Point light.*

The light source that does not give equal amount of light in all direction in which the object will gain brighter when it is closer to the light. The intensity of the light source is depended on the distance. The angle function is affected to light ray. It is characterized by color, intensity, location and falloff function.

*3) Directional light.*

This kind of light source is produced a light source from infinite distance from the scene. All of the light rays illuminate in a form of a single parallel direction and with equal intensity everywhere. It is characterized by color, intensity and direction.

*4) Spotlight.*

The light is radiated in a cone with more light in the center of the cone. This light is attached by the primary axis of direction with a restricted on it. It is characterized as a point light, an axis of direction, a radius about that axis and possibly a radial falloff function.

## III. A Reflection Model

The one of shading entities is the surface object which is affected by light ray reflection on it to produce the acceptable result. The reflection model can be discuss as the following

*1) Diffuse reflection.*

This reflection model spreads all light in all direction equally. According to the Lambert's law stated that the diffuse reflection is proportional to the cosine of the angle $\theta$ between the normal $n$ and the direction of the source $l$

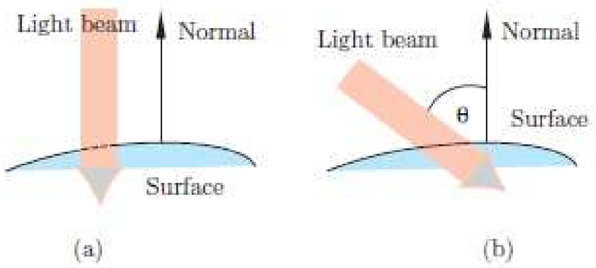


**Fig. 2** Diffuse Reflection at an Angle [1].

Since

$$cos\theta = l \cdot n$$

And adding a reflection coefficient $k_d$, $0 \leq k_d \leq 1$, we have

$$R_d = k_d(l \cdot n)$$

If the light attenuation is needed to account as it travels a distance *d*, so the quadratic attenuation term is

$$Rd = \frac{Kd}{A + BD + C(D \cdot D)}(l \cdot n)$$

And also

$$Id = \frac{kd}{A + AD + C(D \cdot D)}(l \cdot n)$$

*2) Specular reflection.*

The reflection model produces to the highlight reflection on the object surfaces.

**Fig. 3** Specular reflection[4].

The angle $\emptyset$ between the reflection direction $r$ and the direction $v$ of the viewer is affected the amount of specular light. The Phong model sets

$$R_s = k_s \cos^n\emptyset$$

for some coefficient $k_s$, $0 \leq k_s \leq 1$. The exponent $n$ is a shininess coefficient. As $n$ increases, the reacted light is concentrated in a narrower region, centered around r. Values of between 100 and 500 correspond to metallic surfaces, smaller values correspond to broader highlights. Assuming $v$ and $r$ have unit length. Therefore

$$R_s = k_s\,(r \,.\, v)^n$$

A distance term is multiplied similar to diffuse reflections. The combination the three type of reflection gives

$$I = \frac{1}{A + BD + C(D \cdot D)}\left(Kd(l \cdot n)Ld + Ks(r \cdot v)nLs\right) + KaLa$$

The direction of reflection r is easy to compute from n and l, assuming that n has unit length, therefore it is noticing that

$$\frac{l + r}{2} = (l \cdot n)n$$

Implies that

$$r = 2(l \cdot n)n - l$$

## IV. The Shading Models

Shading models are import in order to have desired illumination model [5]. The efficient shading models for surface defined by polygon can be described as below

*1) Constant shading*

This model is the simplest shading model also known as faceted shading or flat shading[5]. The same color is applied on each entire polygon and fast rendering. The lighting equitation uses once per polygon. Given a single normal to the plane the lighting equations and the material properties are used to generate a single color. The polygon is filled with that color.

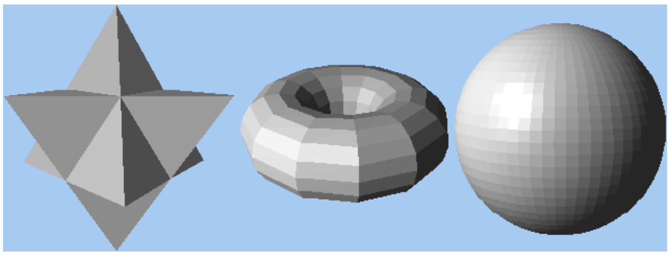

**Fig.4** Constant shading or Flat shading Model[6].

*2) Gouraud Shading*

This shading is also called intensity interpolation shading or color interpolation shading. The colors are interpolated across the polygon and each vertex of polygon is needed to identify. The render process is slower than flat shading. The light equitation is applied at each vertex and also the color is determined from lighting quantitation along with the material properties. Scan-line interpolation is used to assign a color at each point of a projected polygon as a weighted average of given vertex colors.

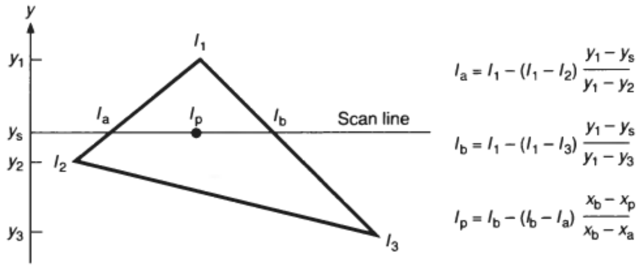


**Fig. 5** Intensity interpolation along polygon edges and scan lines[5].

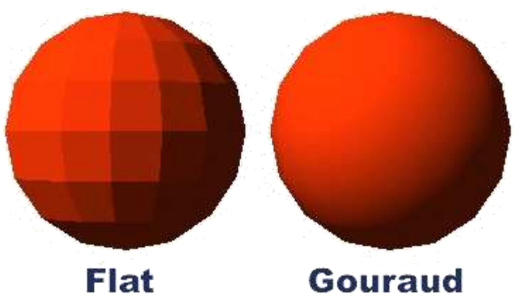


**Fig. 6** The same object with flat and Gouraud shading applied.[7]

*3) Phong Shading*

The shading model is more realistic than others because the shading algorithm needs to blend the vertex normal at each point of polygon to give a local normal. Furthermore, the calculation is applied to have full lighting of rendering. The vertex normal can be blended in the same way as vertex colors: scan-line by scan-line.

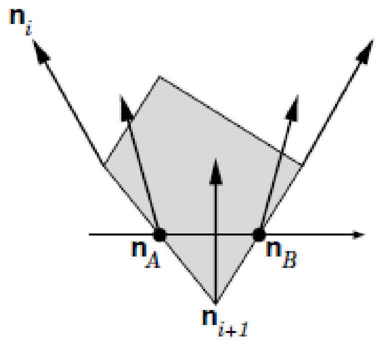


**Fig.7** Normal vector interpolation[4].

For example, if the scan line in the fig.7 crosses the edge [$c_i$, $c_{i+1}$] at the point

$$cA = (1-\alpha)c_i + \alpha c_{i+1}$$

Then we define the normal there to be

$$nA = \frac{(1-\alpha)Ni + \alpha Ni + 1}{(1-\alpha)Ni + \alpha Ni + 1}$$

and similarly for nB. Then nA and nB are linearly interpolated and normalized to find a surface normal at each point along the scan-line [4].

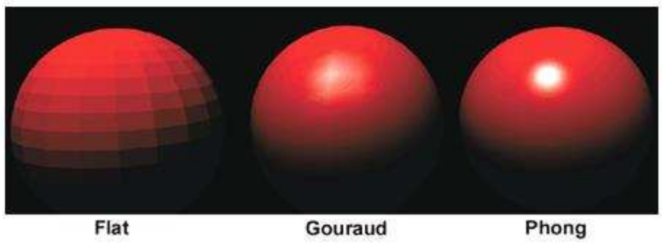


**Fig. 8** Types of Shading Flat, Gouraud and Phong shading are the three most common types of shading used on 3D objects. (Image courtesy of Intergraph Computer Systems.) [8]

## V. Conclusion

The lighting and shading is used to have interrelation with each other in order to produce realistic rendering. However, shading modeling can also enhance the realistic looking on the image by combining more than one model. Different purposes are used to applied with shading such as fast rendering is for gaming, slow rendering with quality of output for realistic object and soon. Moreover, the several techniques that have mentioned in this work can enhance in other purposes.

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