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Different Shading Algorithms for Image Processing

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Abstract: Nowadays the role of images is becoming popular in the field of graphics and helpful for various researchers to carry out their research through the use of computer graphics. In this paper, we have discussed and compared the different methods used for shading an object. Shading can be applied to an object to view the different areas of the object with lighter and darker shades.

Keywords: Flat shading, Gouraud, Illumination model, Interpolation, Phong shading.

I. INTRODUCTION

Today the position of images in the life of people is very important so the researchers will have more realistic significance [1]. Shading is used in most of graphics drawing to analyze the depth of a 3D object by varying various levels of darkness. Shading can be done by applying different shading algorithms to analyze the darker areas and lighter areas of an object.
Computer graphics deals with reasonable depiction of 3-d objects. There are many rendering algorithms used. The different shading algorithms used for shading are: Gouraud shading, Phong shading, flat shading (constant shading).Two of the most famous algorithms are Gouraud Shading Algorithm and Phong Shading Algorithm. These algorithms handle location of light source, location of the camera, and surface reflection properties in different manners and produce different results. Their computational complexities are also very different.Phong Shading being very complex as compared to Gouraud Shading [2].
Computer image generation systems often represent curved surfaces as a mesh of planar polygons that are shaded to restore a smooth appearance. Two of the most famous graphics techniques, derived from shading algorithms by Henri Gouraud and Bui Tuong Phong, have been implemented in hardware and software worldwide. Both methods use various steps to smooth out the shading of a polygonal surface and a smooth-shaded model seems smoother. The sharp creases between polygons are gone, replaced by a continuous change in tone or color. Phong normal interpolation is the process of computing a point's surface normal by linear interpolation of the components of two normals at either end of a line containing that point. This normal may then be used as part of a shading equation that takes into account specular highlights in an empirical manner, Phong illumination.Gouraud shading means the process of interpolating a color component to find intermediate color values across a polygon. Phong shading means interpolating surface normals to find intermediate normals that we can then evaluate with respect to the light source to find a color for that point [3].
The different shading methods are:

- Gouraud shading
- Phong shading
- Flat (constant shading)

II. GOURARD SHADING

Gouraud shading**,** named after Henri Gouraud, also called as 'intensity interpolation shading' or 'color interpolation shading' is a method of interpolation used for shading surfaces represented by different polygons. Gourard shading explains the concept of interpolation which is applied to individual polygon vertices. The Gouraud shading process requires that the normal be known for each vertex of the polygonal mesh. This algorithm computes the intensities at each vertex of polygonal mesh and then interpolates the intensities across the polygon. The gouraud shading computes the intensity calculations down and then across each scan lines thus eliminating the sharp edges. The main purpose of Gouraud shading is to eliminate the discontinuities in intensity along polygon edges [4].

The algorithm for gourard shading is as follows:

- Calculate intensities at each vertex of polygon (N_v).
- Interpolates these vertex intensities along the edges of polygon.

- Interpolate these edge intensities along the scan line in the interior of the polygon.

To calculate the intensity at each vertex, we need to calculate unit normal vector at the vertex –

$$N_v = \frac{\sum_{k=1}^{n} N_k}{\left| \sum_{k=1}^{n} N_k \right|}$$

The following Fig. 1 shows the vertex normals of an 3D object [5] for gouraud shading.

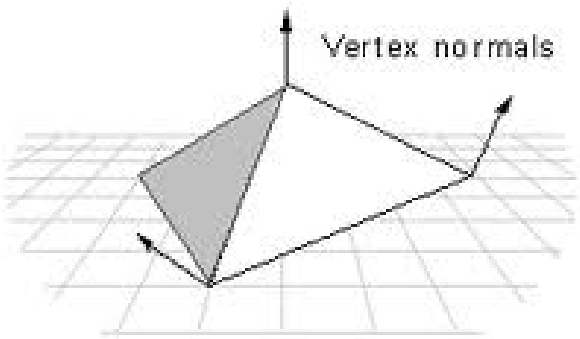
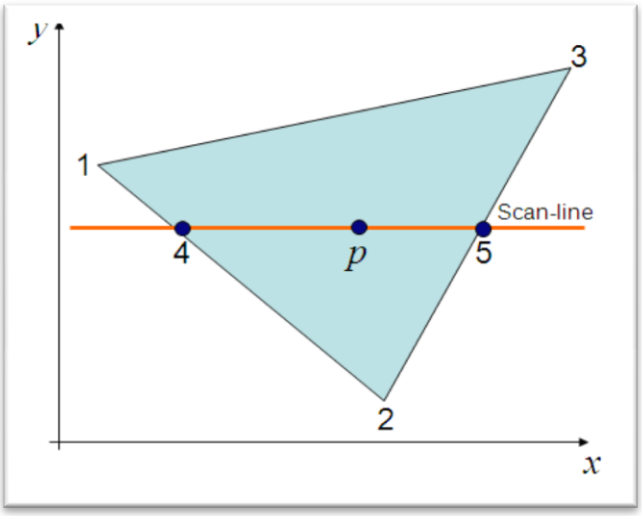


Fig 1: vertex unit normals for Gouraud shading

Illumination values are linearly interpolated across each scan line as shown in Fig.2



$$I_4 = \frac{y_4 - y_2}{y_1 - y_2} I_1 + \frac{y_1 - y_4}{y_1 - y_2} I_2$$

$$I_5 = \frac{y_5 - y_2}{y_3 - y_2} I_3 + \frac{y_3 - y_5}{y_3 - y_2} I_2$$

$$I_p = \frac{x_5 - x_p}{x_5 - x_4} I_4 + \frac{x_p - x_4}{x_5 - x_4} I_5$$

14

Fig 2. Calculating intensity values across scan line

III. FLAT SHADING

Flat shading is the fastest and simple method of shading but does not god quality of images. Flat shading (constant shading) requires calculation of intensities for each polygon surfaces [6]. Flat surface rendering or constant shading is the simplest rendering format that involves some basic surface properties such as color distinctions and reflectivity. This method produces a rendering that does not smooth over the faces which make up the surface. The resulting visualization shows an object that appears to have surfaces faceted like a diamond. The disadvantage of flat shading is that it gives low-polygon models a faceted look. Sometimes this look can be advantageous though, such as in modeling boxy objects. Artists sometimes use flat shading to look at the polygons of a solid model they are creating.

Rendering only requires the computation of a color for each visible face. The whole face is filled with this color. This approach is fast and very simple, but it gives quite unrealistic results and non-smooth surfaces. This is highlighted by the Mach effect: the intensity at the vicinities of the edges is overestimated for light values and underestimated for dark values. Fig. 3 shows and object shaded using flat shading.

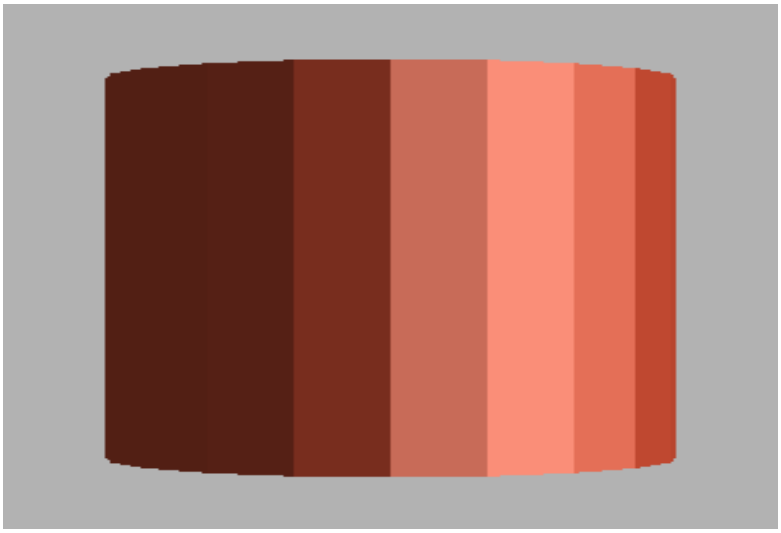


Fig 3: Flat shading

In flat shading each polygon is drawn with the same color. We just need to know one normal for the entire surface. 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 colour.But in gouraud shading we need to know the normal at each vertex of the polygon and this method is slower than flat shading. Fig.4 shows the comparison of flat and gouraud shading.

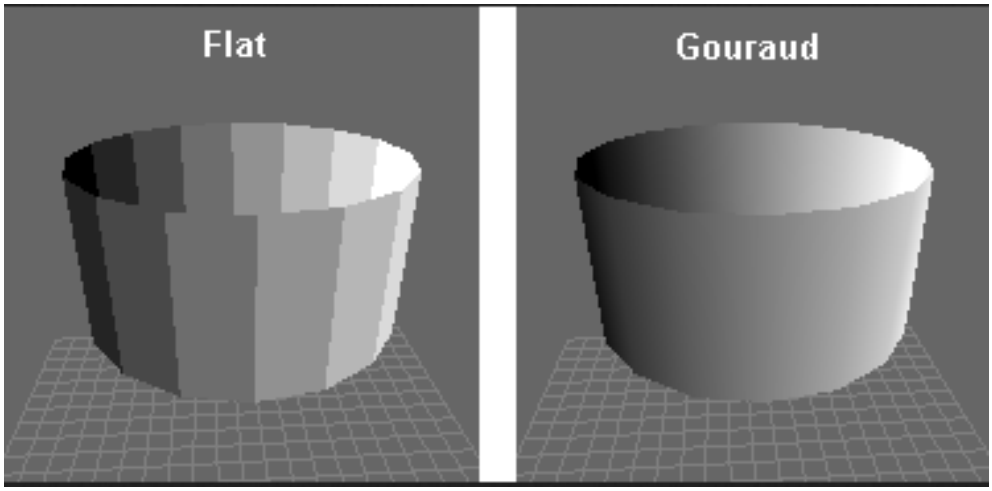


Fig 4: Flat and Gouraud shading

IV. PHONG SHADING

Phong shading is one of the most useful shading algorithms in computer generated images as it provides high degree of practicality. It is slowest but provides best quality of images. The first stage in the process is the same as for the Gouraud Shading - for any polygon we evaluate the vertex normals [9]. For each scan line in the polygon we evaluate by linear interpolation the normal vectors at the end of each line. These two vectors N_a and N_b are then used to interpolate N_s. We thus derive a normal vector for each point or pixel on the polygon that is an approximation to the real normal on the curved surface approximated by the polygon. Ns, the interpolated normal vector, is then used in the intensity calculation. The vector interpolation tends to restore the curvature of the original surface that has been approximated by a polygon mesh. Phong shading species how to calculate color on every point of surface. But calculating of color at every point may be slow therefore phong shading employs calculating intensities at vertices only and then apply interpolation to calculate in between points(between pixels) [7].

The algorithm is as follows:

1) Compute a normal N for each vertex of the polygon.
2) From bi-linear interpolation compute a normal, Ni for each pixel.
3) From Ni compute intensity Ii for each pixel of the polygon.
4) Paint pixel to shade corresponding to Ii.

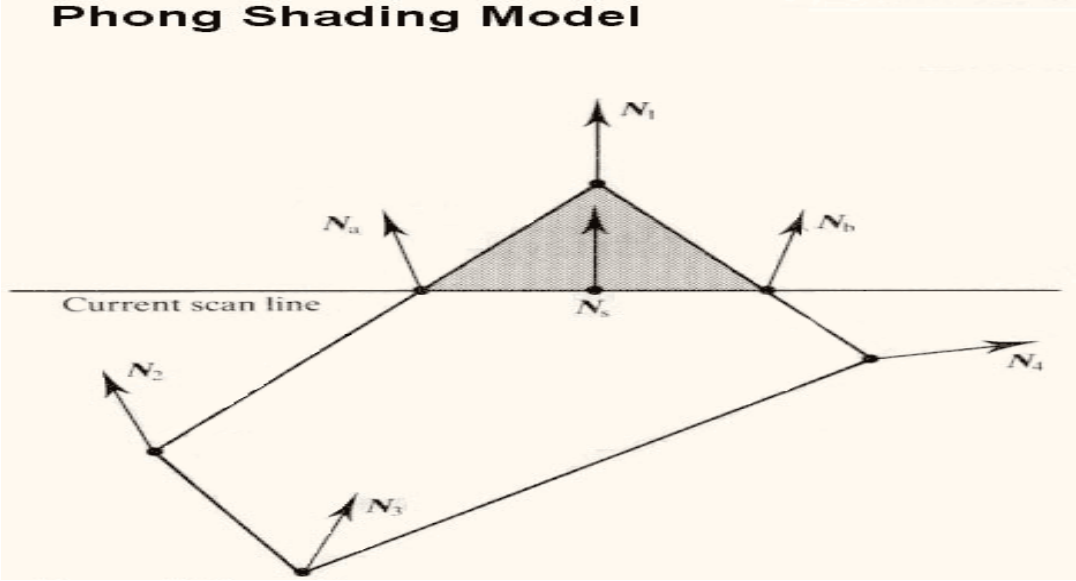


Fig 5 : Phong shading model

This makes the Phong Shading interpolation phase three times as expensive as Gouraud Shading. In addition there is an application of the Phong model intensity equation at every pixel.[8]

V. COMPARISON OF SHADING METHODS

Flat shading	**Gouraud shading**	**Phong shading**
Also called constant shading. Computes illumination once per polygon and apply it to whole polygon	Computes illumination at border(vertices) and interpolates.	Also called accurate shading.Applies illumination at every point of polygon surface.
Creates discontinuities in color.	Interpolates colors along edges and scanline.	Interpolates normals instead of colors.
Problem of machbands .	Handles machbands problem found in flat shading.	Removes machbands completely
Low cost.	Not so Expensive.	More Expensive than gouraud shading.
Requires very less processing and is fast in time.	Requires moderate processing and time.	Requires complex processing and is slower but is more efficient as compared to other shading methods.
Lighting equation used once for polygon.	Lighting equation used at each vertex.	Lighting equation used at each pixel.

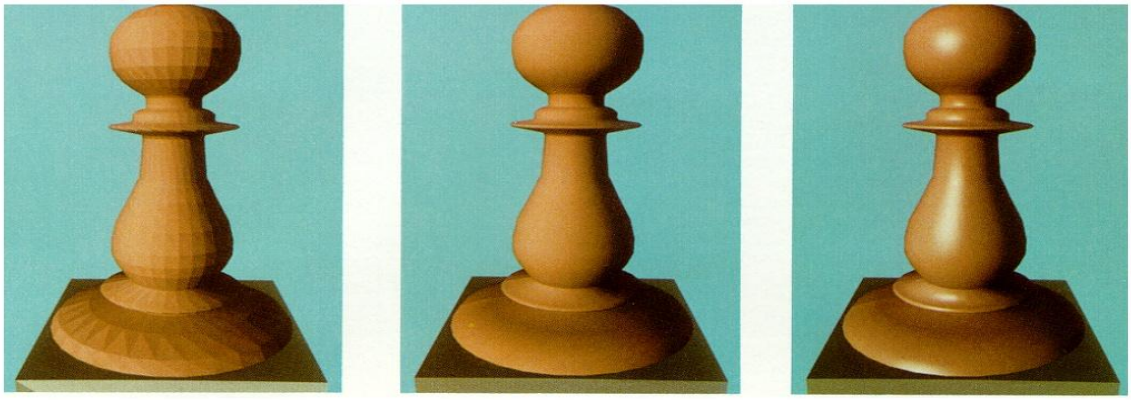


Figure 1: Flat shading. **Figure 2: Gouraud shading.** **Figure 3: Phong shading.**

Fig 5: Comparison of flat, gourard and phong shading

VI. CONCLUSION

In this paper, we have described the various shading methods used in todays life and compared them with each other. We have also stated the algorithm used for phong shading and gouraud shading. From the comparison of these shading methods described here, we can conclude that phong shading is much more superior to flat and gouraud shading but requires lot of time for processing and results in better outputs.

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