26. Polygon Shading

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Source: Computer Graphics by Donald Hearn and M. Pauline Baker

Polygon Shading :-

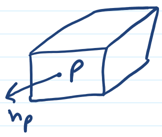
Process of applying illumination model to surface points.

approaches:-

1. Flat Shading
2. Gauraud Shading
3. Phong Shading

Flat Shading :-

One intensity for the whole polygon
constant shading for each face.



Select a point P on the face
Find normal to the face n_p.
Find intensity I at P
Fill the polygon with I.

→ Computationally Fast
→ Not smooth
→ Match Band effect

Polygon mesh approximation

Rendered with flat shading

Flat shading provides an accurate rendering if

① The object does not have a curved surface.

② All light sources illuminating the object are sufficiently far from the surface.

③ The viewing position is sufficiently far from the surface.

Gouraud Shading :— (Henri Gouraud, 1971)

Smooth Shading

Rendered with flat shading

Rendered with Gouraud Shading

INTERPOLATION :— Intensity values for each polygon are matched with the values of adjacent polygon.

STEPS :—

① Determine the average unit normal vector at each polygon vertex.

② Apply an illumination model to each vertex to calculate the vertex intensity.

③ Linearly interpolate the vertex intensities over the surface of the polygon.

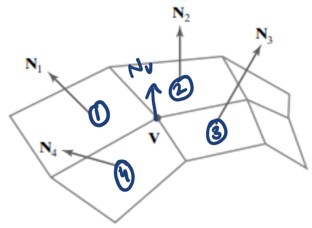


FIGURE 35
The normal vector at vertex **V** is calculated as the average of the surface normals for each polygon sharing that vertex.

Unit Normal at a vertex V is average of normals of the polygons incident at the vertex.

$$N_V = \sum_{k=1}^{n} N_k$$

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

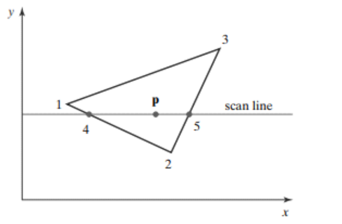
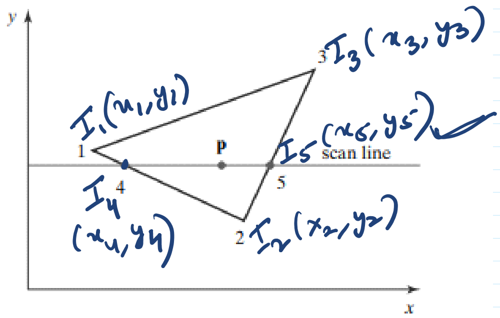


FIGURE 36
For Gouraud surface rendering, the intensity at point 4 is linearly interpolated from the intensities at vertices 1 and 2. The intensity at point 5 is linearly interpolated from intensities at vertices 2 and 3. An interior point **p** is then assigned an intensity value that is linearly interpolated from intensities at positions 4 and 5.

⇒ Now we have vertex normals N_1, N_2, N_3.
Compute the intensities at these vertices using these normals and some illumination model.

⇒ I_1, I_2, I_3



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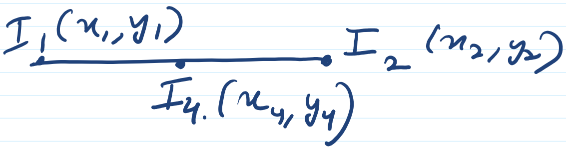
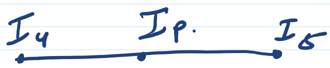


⇒ Fill the polygon using scan line conversion and interpolation.

$$I_4 = \frac{y_4 - y_2}{y_1 - y_2} I_1 + \frac{y_1 - y_4}{y_1 - y_2} I_2 \quad \text{—— (1)}$$

$$I_5 = \frac{y_5 - y_3}{y_2 - y_3} I_2 + \frac{y_2 - y_5}{y_2 - y_3} I_3 \quad \text{—— (2)}$$

using (1) and (2)



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

Calculation of intensities along incremental scan lines,

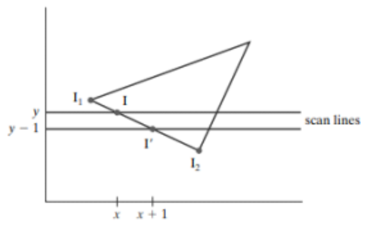


FIGURE 37
Incremental interpolation of intensity values along a polygon edge for successive scan lines.

$$I(x,y)$$

I_1 (x_1, y_1) $\qquad$ I_2 (x_2, y_2)

using equation ① / ②

$$\boxed{I = \frac{y - y_2}{y_1 - y_2} I_1 + \frac{y_1 - y}{y_1 - y_2} I_2} \quad \text{——— ③}$$

To obtain intensity I' for the next line

$\boxed{y = y - 1}$ in eq ②

$$I' = \frac{(y-1) - y_2}{y_1 - y_2} I_1 + \frac{y_1 - (y-1)}{y_1 - y_2} I_2$$

$$= \frac{(y - y_2 - 1) I_1}{y_1 - y_2} + \frac{(y_1 - y + 1) I_2}{y_1 - y_2}$$

$$= \frac{(y - y_2) I_1 - I_1}{y_1 - y_2} + \frac{(y_1 - y) I_2 + I_2}{y_1 - y_2}$$

$$= \frac{(y - y_2) I_1}{y_1 - y_2} + \frac{(y_1 - y) I_2}{y_1 - y_2} + \frac{I_2 - I_1}{y_1 - y_2}$$

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

$$\boxed{I' = I + \frac{I_2 - I_1}{y_1 - y_2}}$$

⇒ Successive intensity values down the edges is computed simply by adding constant term $\frac{I_2 - I_1}{y_1 - y_2}$ to the previous intensity value.

Drawbacks of Gouraud Shading :-

⇒ Highlights on the surface are sometimes diplayed with some shapes, and linear intensity intepolation causes bright / dark intensity streaks called Match Bands.

⇒ Can be reduced by dividing the surface into ↑ polygons

⇒ more precise intensity calculations.

Phong Shading :- "Phong Bui Tuong" 1973

Interpolation of normal vectors instead of the intensity values.

Then compute intensity at each point.

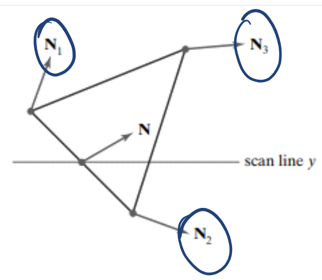


FIGURE 38
Interpolation of surface normals along a polygon edge.

STEPS :-

1. Determine the average unit normal vector at each vertex of the polygon.

2. Interpolate the vertex normals linearly over the projected area of the polygon.

3. Apply an illumination model at positions along scan lines to calculate pixel intensities using the interpolated normal vectors.

Normal vector N is intepolated vertically from the normal vectors at vertices 1 and 2

$$N = \frac{y - y_2}{y_1 - y_2} N_1 + \frac{y_1 - y}{y_1 - y_2} N_2$$

⇒ Apply incremental methods for obtaining normal vectors on successive scan lines and at successive pixel positions along scan lines.