Shading
(Part 2)

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Reading

Required:

- Angel chapter 5.

Optional:

- OpenGL red book, chapter 5.

Gouraud vs. Phong interpolation

Now we know how to compute the color at a point on a surface using the Blinn-Phong lighting model.

Does graphics hardware do this calculation at every point? Not by default...

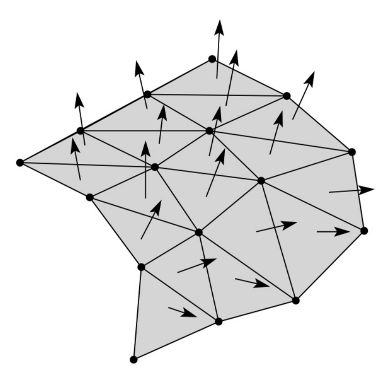
Smooth surfaces are often approximated by polygonal facets, because:

- Graphics hardware generally wants polygons (esp. triangles).
- Sometimes it easier to write ray-surface intersection algorithms for polygonal models.

How do we compute the shading for such a surface?

Faceted shading

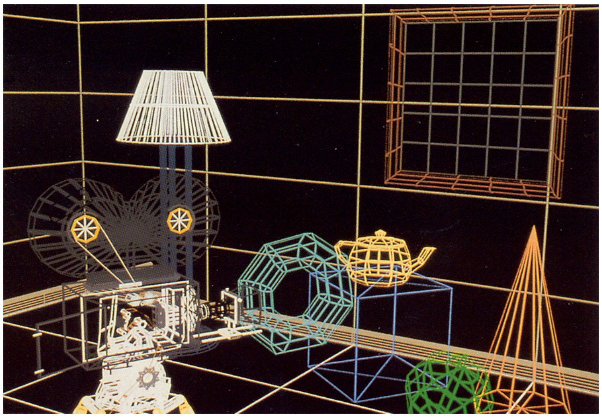
Assume each face has a constant normal:

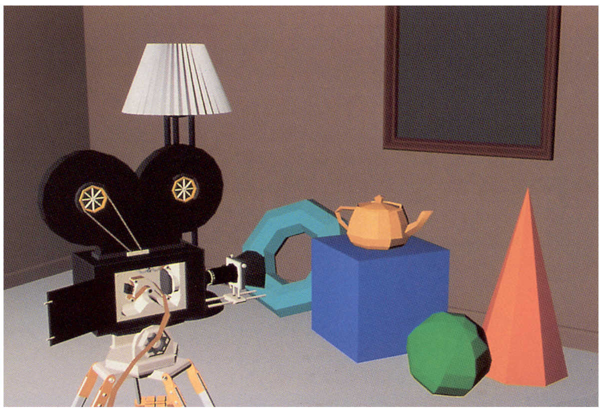


For a distant viewer and a distant light source and constant material properties over the surface, how will the color of each triangle vary?

Result: faceted, not smooth, appearance.

Faceted shading (cont'd)





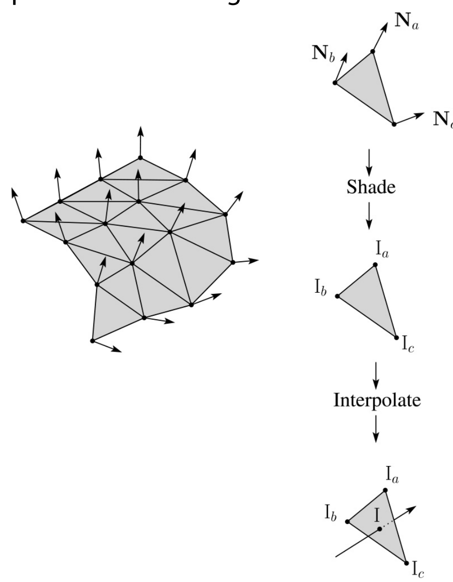
[Williams and Siegel 1990]

Gouraud interpolation

To get a smoother result that is easily performed in hardware, we can do **Gouraud interpolation**.

Here's how it works:

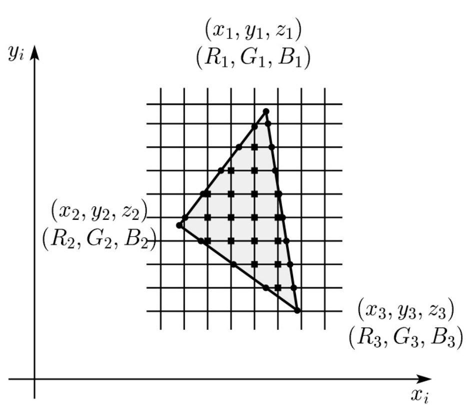
1. Compute normals at the vertices.
2. Shade only the vertices.
3. Interpolate the resulting vertex colors.



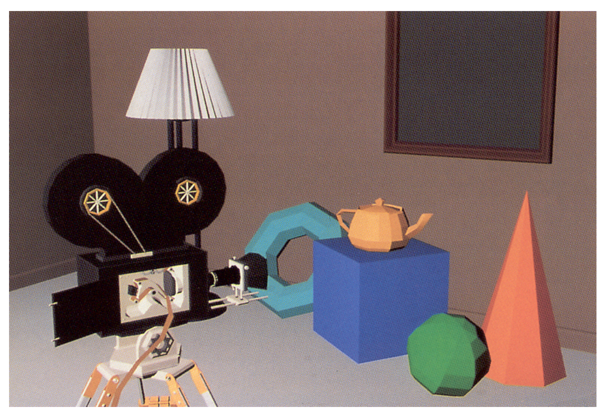
Rasterization with color

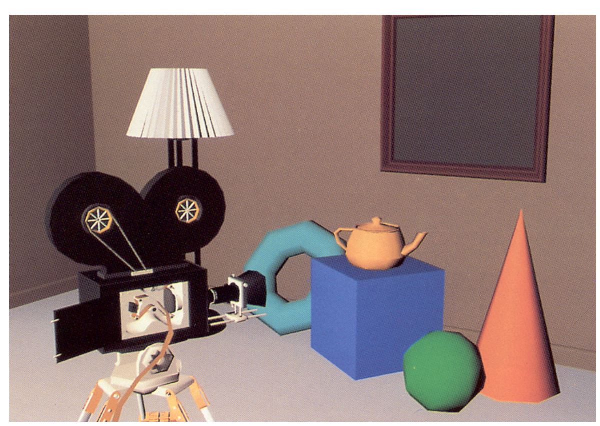
Recall that the z-buffer works by interpolating z-values across a triangle that has been projected into image space, a process called rasterization.

During rasterization, colors can be smeared across a triangle as well:



Facted shading vs. Gouraud interpolation



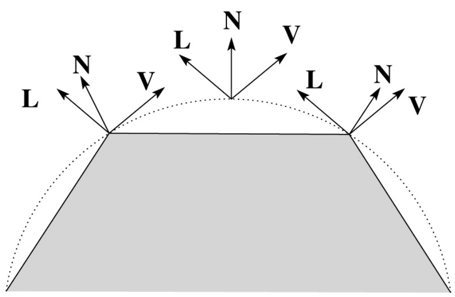


[Williams and Siegel 1990]

Gouraud interpolation artifacts

Gouraud interpolation has significant limitations.

1. If the polygonal approximation is too coarse, we can miss specular highlights.



2. We will encounter **Mach banding** (derivative discontinuity enhanced by human eye).

This is what graphics hardware does by default.

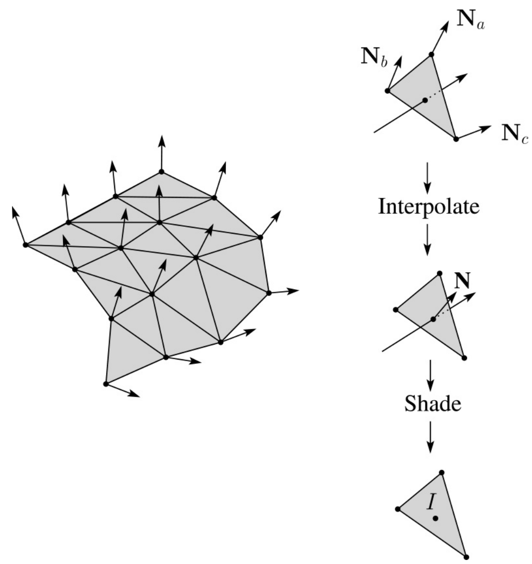
A substantial improvement is to do…

Phong interpolation

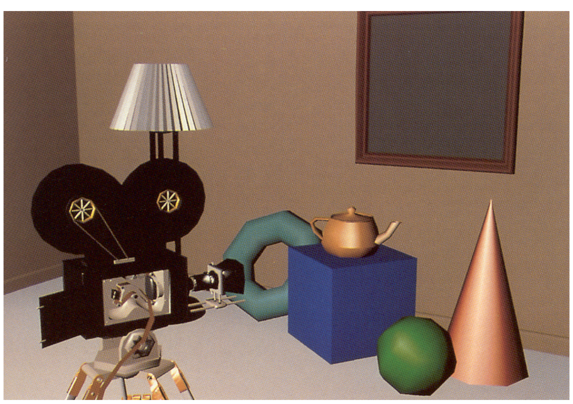
To get an even smoother result with fewer artifacts, we can perform **Phong *interpolation***.

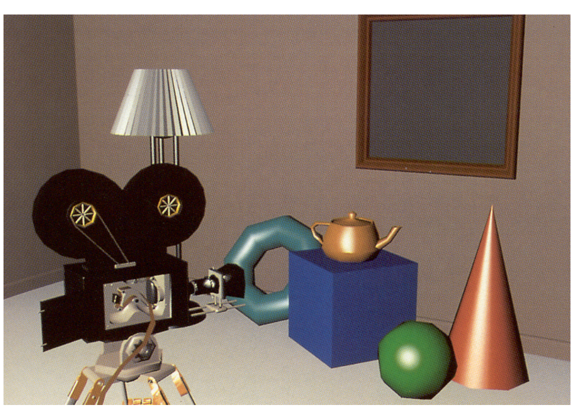
Here's how it works:

1. Compute normals at the vertices.
2. Interpolate normals and normalize.
3. Shade using the interpolated normals.



Gouraud vs. Phong interpolation





[Williams and Siegel 1990]

Default pipeline: Gouraud interpolation

Vertex processor

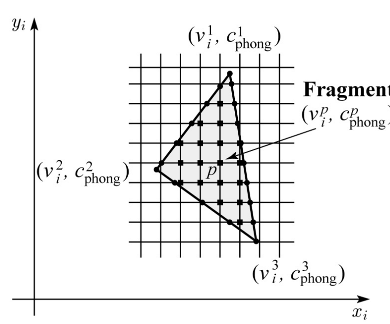
Default vertex processing:

$L \leftarrow$ determine lighting direction
$V \leftarrow$ determine viewing direction
$N \leftarrow$ normalize(n_e)
$c_{\text{phong}} \leftarrow$ shade with L, V, N, k_d, k_s, n_s
attach c_{phong} to vertex as "varying"
$v_i \leftarrow$ project v to image

Primitive assembler

$v_i^1, v_i^2, v_i^3 \rightarrow$ triangle

Rasterizer



Fragment processor

Default fragment processing:

color $\leftarrow c_{\text{phong}}^p$

Programmable pipeline: Phong-interpolated normals!

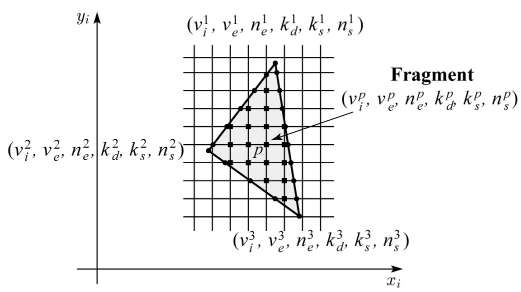
Vertex processor

Vertex shader:
attach n_e to vertex as "varying"
attach v_e to vertex as "varying"
$v_i \leftarrow$ project v to image

Primitive assembler

$v_i^1, v_i^2, v_i^3 \rightarrow$ triangle

Rasterizer

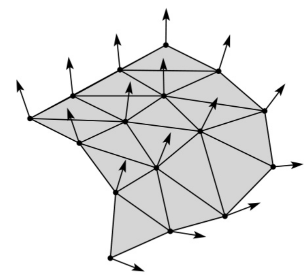


Fragment processor

Fragment shader:
$L \leftarrow$ determine lighting direction
$V \leftarrow$ determine viewing direction
$N \leftarrow$ normalize(n_e^p)
color $\leftarrow$ shade with $L, V, N, k_d^p, k_s^p, n_s^p$

Surface normals

How can we compute the normal to a surface at a given point?



Tangent vectors and tangent planes

Normals on a surface of revolution

Summary

You should understand the equation for the Blinn-Phong lighting model described in the "Iteration Four" slide:

- What is the physical meaning of each variable?
- How are the terms computed?
- What effect does each term contribute to the image?
- What does varying the parameters do?

You should also understand the differences between faceted, Gouraud, and Phong *interpolated* shading.

And you should understand how to compute the normal to a surface of revolution.