CS 543: Computer Graphics

Shading II

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(with lots of help from Prof. Emmanuel Agu :-)

Recall: Setting Light Properties

- Define colors and position a light

```
var light_ambient[]  = { 0.0, 0.0, 0.0, 1.0 };
var light_diffuse[]  = { 1.0, 1.0, 1.0, 1.0 };
var light_specular[] = { 1.0, 1.0, 1.0, 1.0 };
var light_position[] = { 0.0, 0.0, 1.0, 1.0 };
```

Colors

Position

Recall: Setting Material Properties

- Define ambient/diffuse/specular reflection and shininess

```
Var mat_amb_diff[] = { 1.0, 0.5, 0.8, 1.0 };
Var mat_specular[] = { 1.0, 1.0, 1.0, 1.0 };
Var shininess[] = { 5.0 };

Pass values to shader…see book code
```

Refl. coeff.

Range: dull 0 – very shiny 128

Recall: Calculating Color at Vertices

- Illumination from a light

Illum = ambient + diffuse + specular

$$= K_a \times I + K_d \times I \times \cos(\theta) + K_s \times I \times \cos^f(\phi)$$

- If there are N lights

Total illumination for a point P = Σ **(Illum)**

- Sometimes lights or surfaces are colored
- Treat R, G, and B components separately
  - *i.e.*, can specify different RGB values for either light or material

$$Illum_r = K_{ar} \times I_r + K_{dr} \times I_r \times \cos(\theta) + K_{sr} \times I_r \times \cos^f(\phi)$$

$$Illum_g = K_{ag} \times I_g + K_{dg} \times I_g \times \cos(\theta) + K_{sg} \times I_g \times \cos^f(\phi)$$

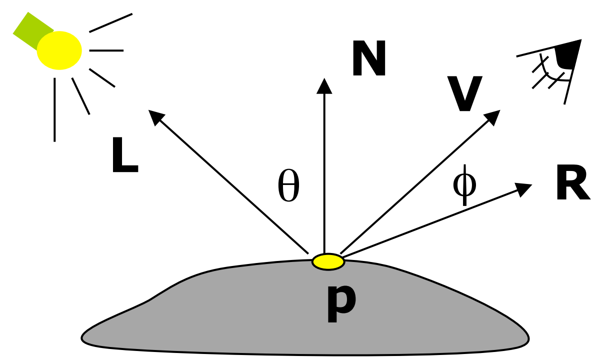
$$Illum_b = K_{ab} \times I_b + K_{db} \times I_b \times \cos(\theta) + K_{sb} \times I_b \times \cos^f(\phi)$$

Recall: Calculating Color at Vertices (cont.)

Illum = ambient + diffuse + specular

$$= K_a \times I + K_d \times I \times \cos(\theta) + K_s \times I \times \cos^f(\phi)$$

- $\cos(\theta)$ and $\cos^f(\phi)$ are calculated as dot products of *Light vector* L, *Normal* N, and *Mirror-direction vector* R



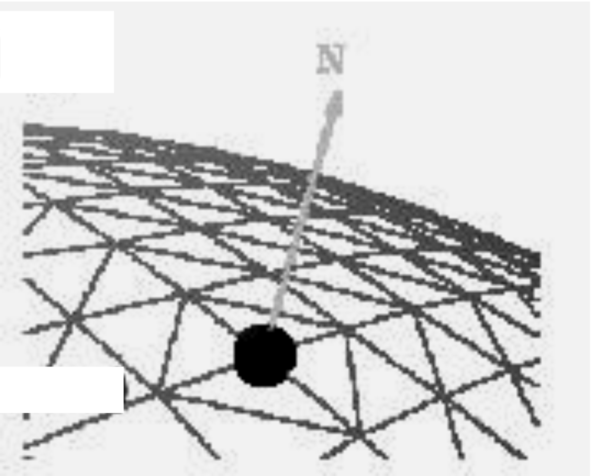
- To give

$$\text{Illum} = K_a \times I + K_d \times I \times (N.L) + K_s \times I \times (R.V)$$

Importance of Surface Normals

- Correct normals are essential for correct lighting
- Associate a normal with each vertex

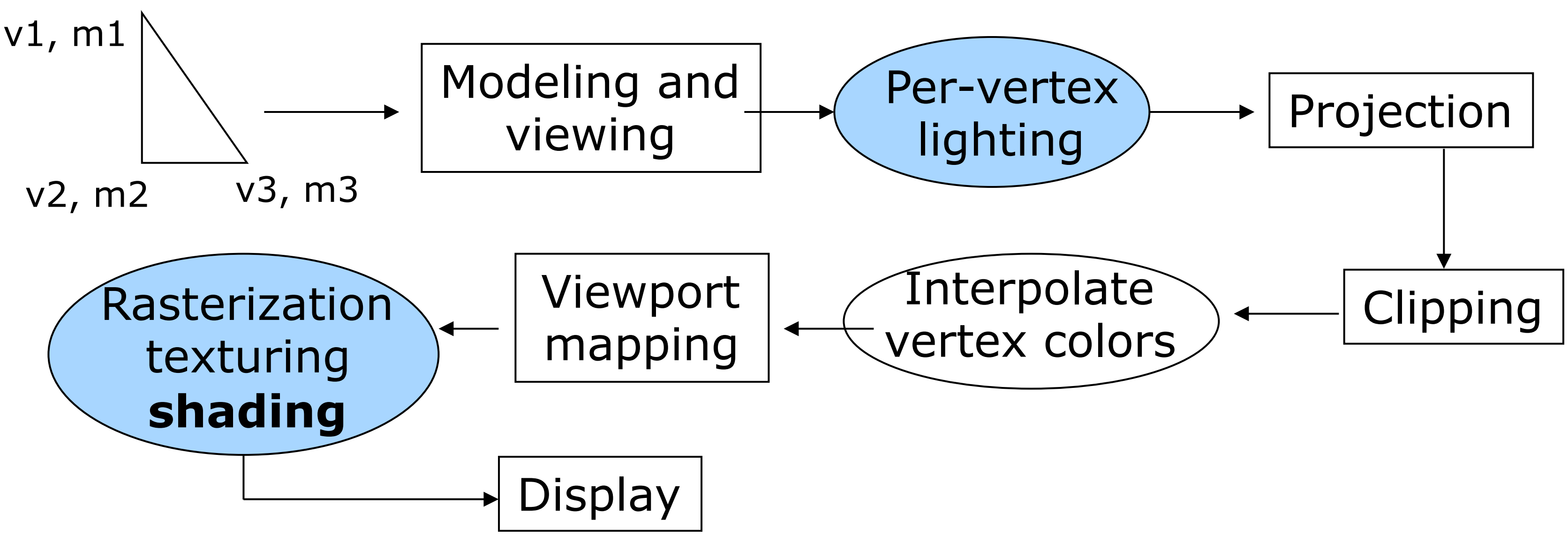
```
normalsArray.push( u, v, n );
pointsArray.push( x, y, z );
...
```



- All normals must be specified in unit length
  - Do in shader: ***vec4 NN = vec4(vNormal, 0);***

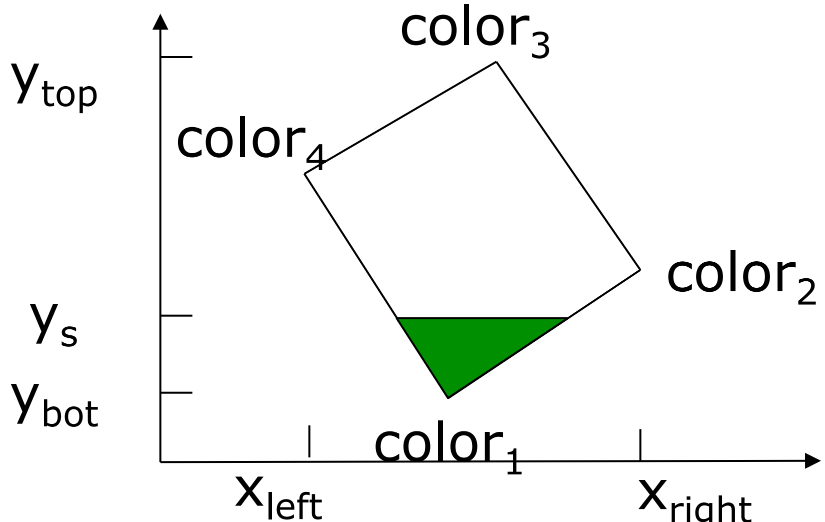
Lighting Revisited

- Light calculation so far is at vertices
- Pixel may not fall right on vertex
- **Shading**
  - Calculates color of interior pixels
- Where are **lighting** & **shading** performed in the pipeline?



Example Shading Function

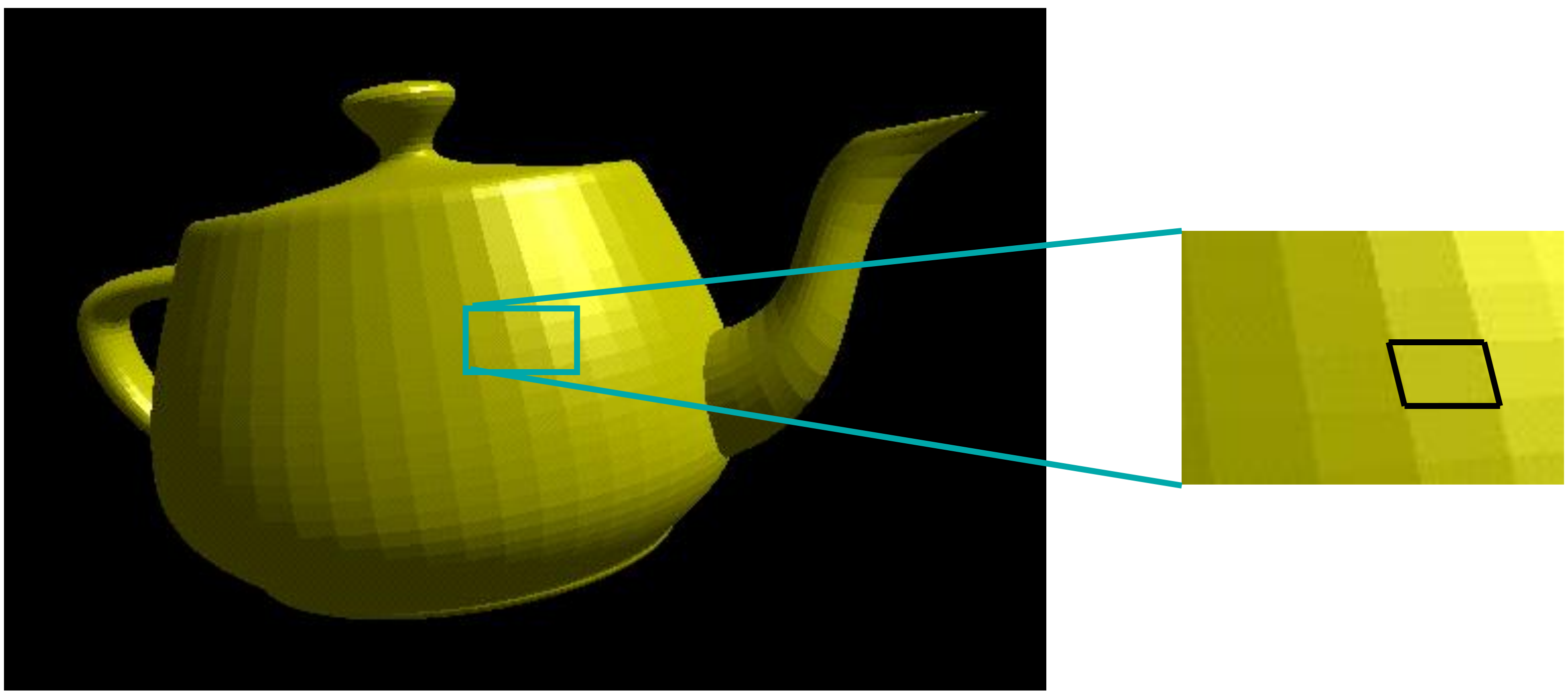
```
for( int y = y_bot; y <= y_top; y++ )  {
  find x_left and x_right
  for( int x = x_left; x < x_right; x++ )  {
    find the color c for this pixel
    put c into the pixel at (x, y)
  }
}
```



- Scans pixels, row by row, calculating color for each pixel

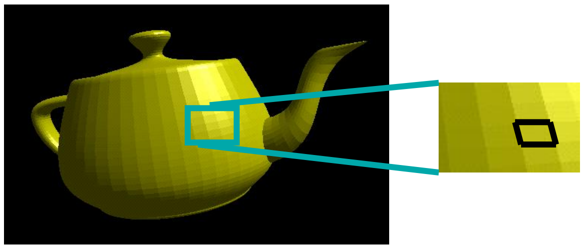
Polygon Shading Models

- Flat shading
  - Compute lighting once and assign the color to the whole polygon (or mesh)



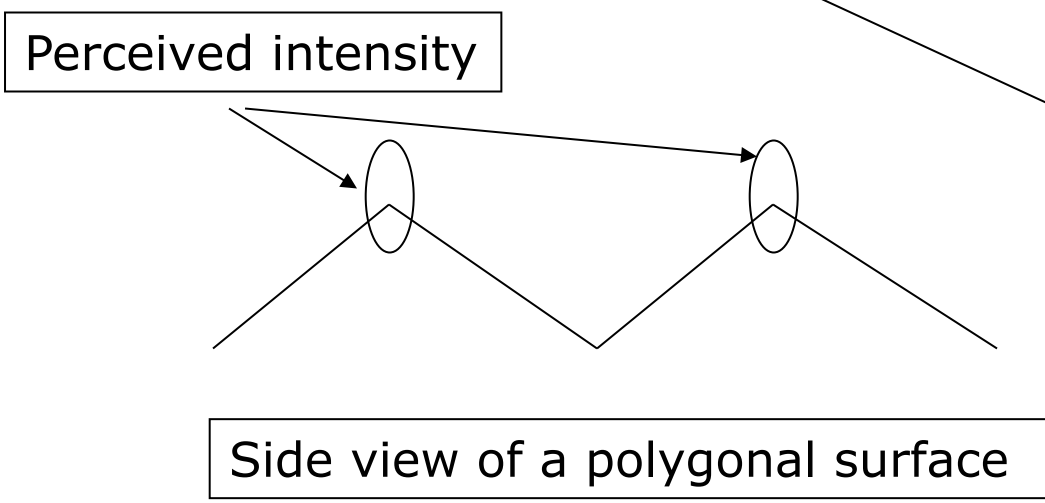
Flat Shading

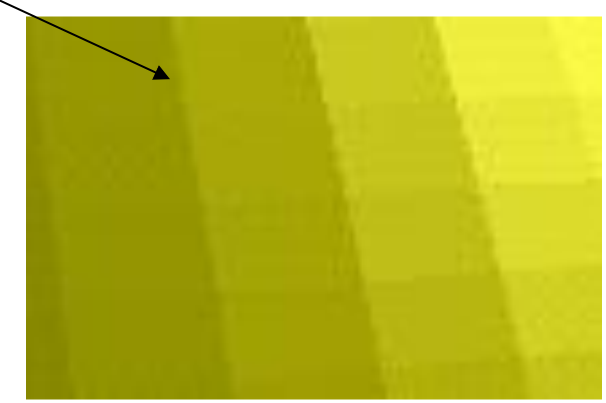
- Only use one vertex normal and material property to compute the color for the polygon
- Benefit: fast to compute
- Used when
  - Polygon is small enough
  - Light source is far away (why?)
  - Eye is very far away (why?)



Mach-Band Effect

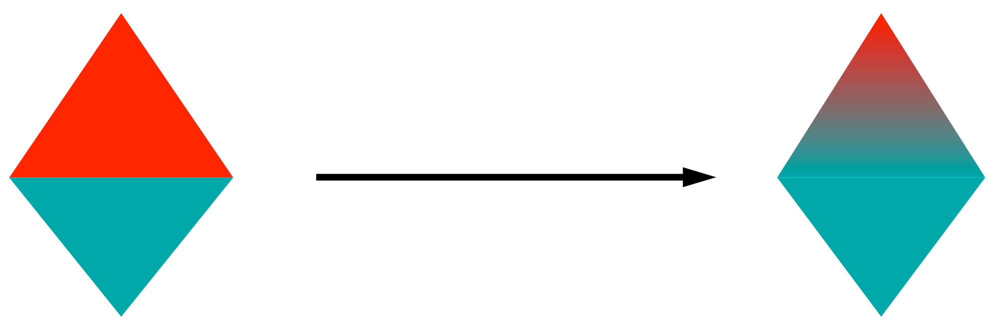
- Flat shading suffers from "mach banding"
  - Human eyes accentuate discontinuities at boundaries





Smooth Shading

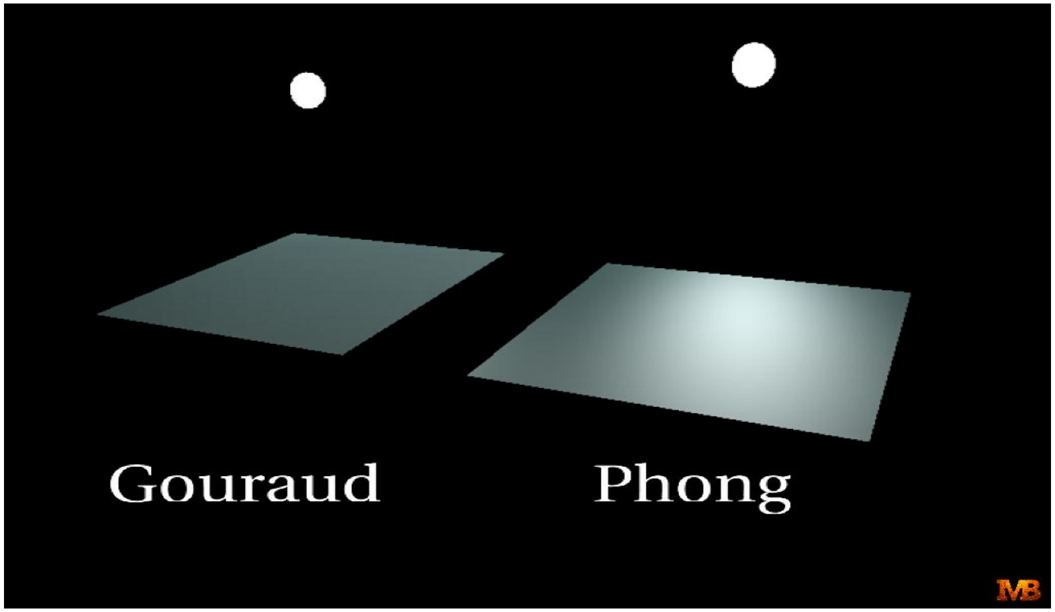
- Fix the mach banding
  - Remove edge discontinuities
- Compute lighting for more points on each face



Flat shading **Smooth shading**

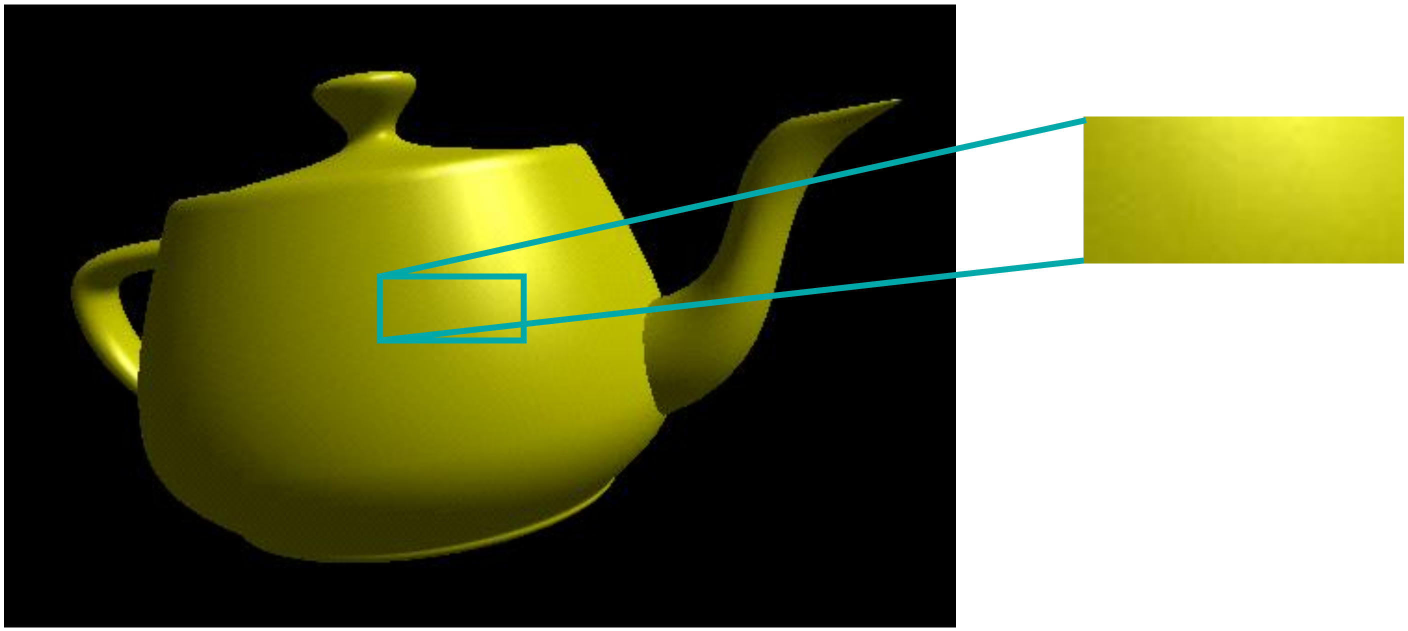
Smooth Shading (cont.)

- Two popular methods
  - Gouraud shading (used by OpenGL)
  - Phong shading (better specular highlight, not in OpenGL)



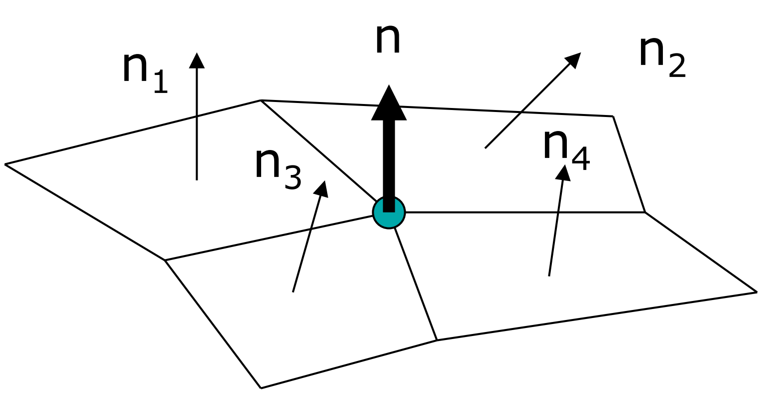
Gouraud Shading

- Lighting is calculated for each of the polygon vertices
- Colors are interpolated for interior pixels



Gouraud Shading (cont.)

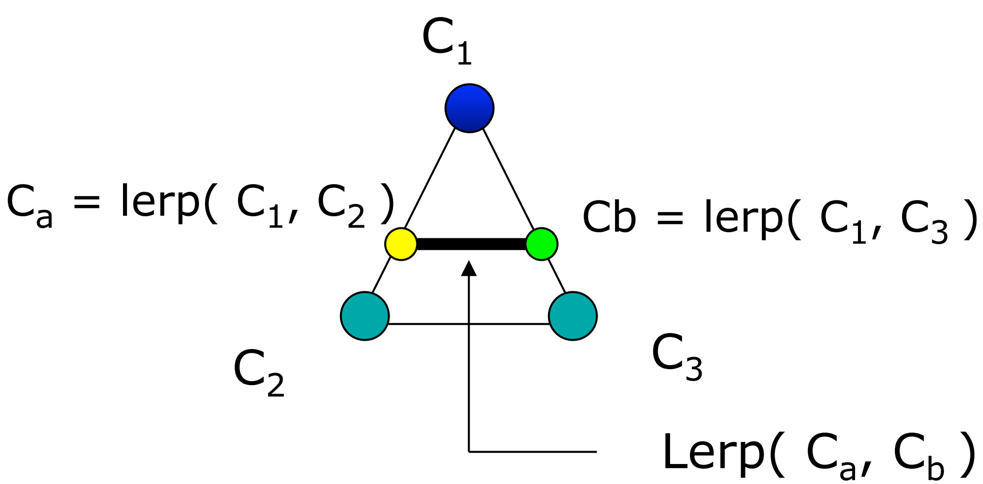
- Per-vertex lighting calculation
- Normal is needed for each vertex
- Per-vertex normal can be computed by averaging the adjacent face normals



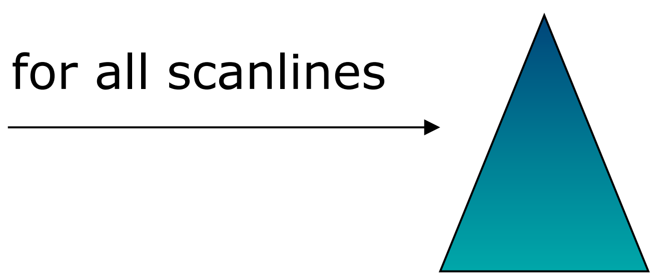
$$n = (n_1 + n_2 + n_3 + n_4) / 4.0$$

Gouraud Shading (cont.)

- Compute vertex illumination (color) before the projection transformation
- Shade interior pixels: color interpolation (normals are not needed for interior)



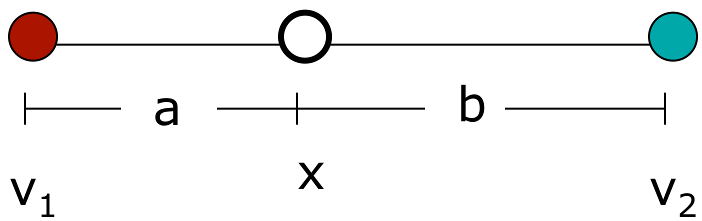
for all scanlines



* lerp: linear interpolation

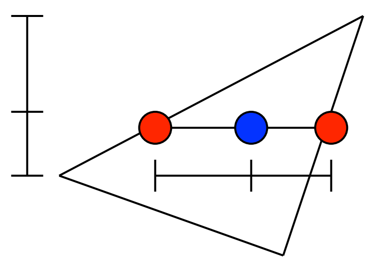
Gouraud Shading (cont.)

- Linear interpolation



x = b / (a+b) * v1 + a/(a+b) * v2

- Interpolate triangle color: use y distance to interpolate the two end points in the scanline, and use x distance to interpolate interior pixel colors

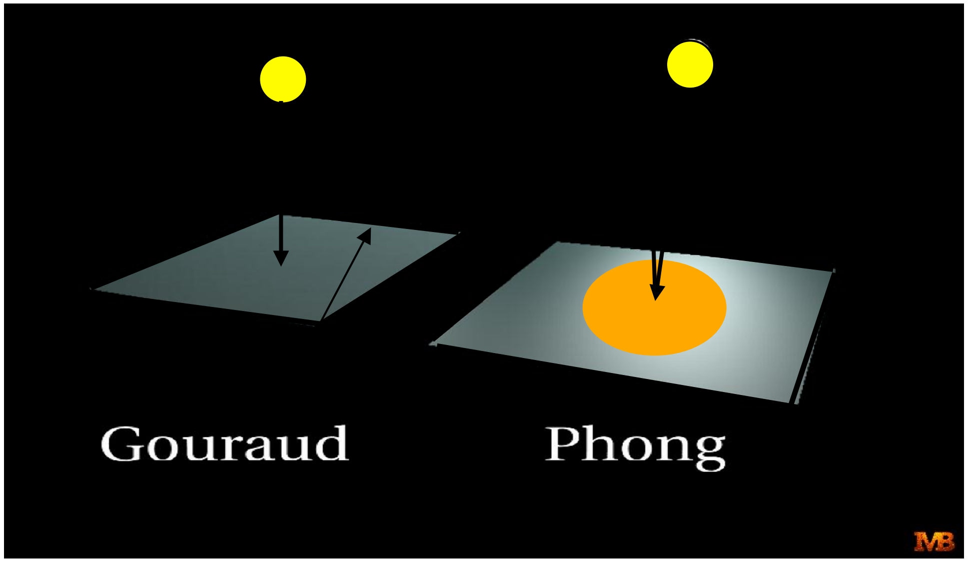


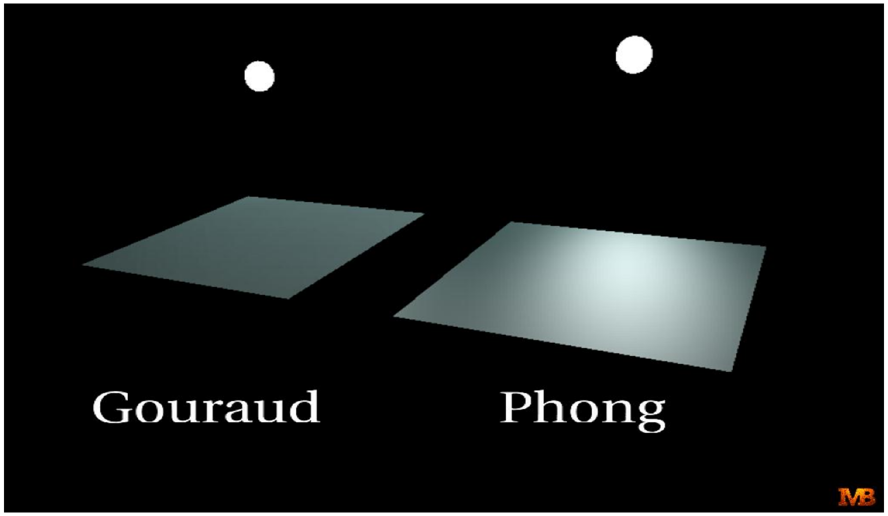
Gouraud Shading Function

```
// for each scan line
for( int y = y_bot; y <= y_top; y++ )  {
  find x_left and x_right
  find color_left and color_right
  color_inc = (color_right - color_left) /
               (x_right - x_left)
  for( int x = x_left, c = color_left;
         x < x_right; x++, c += color_inc )  {
    put c into the pixel at (x, y)
  }
}
```

Gouraud Shading Problem

- Lighting in the polygon interior can be inaccurate



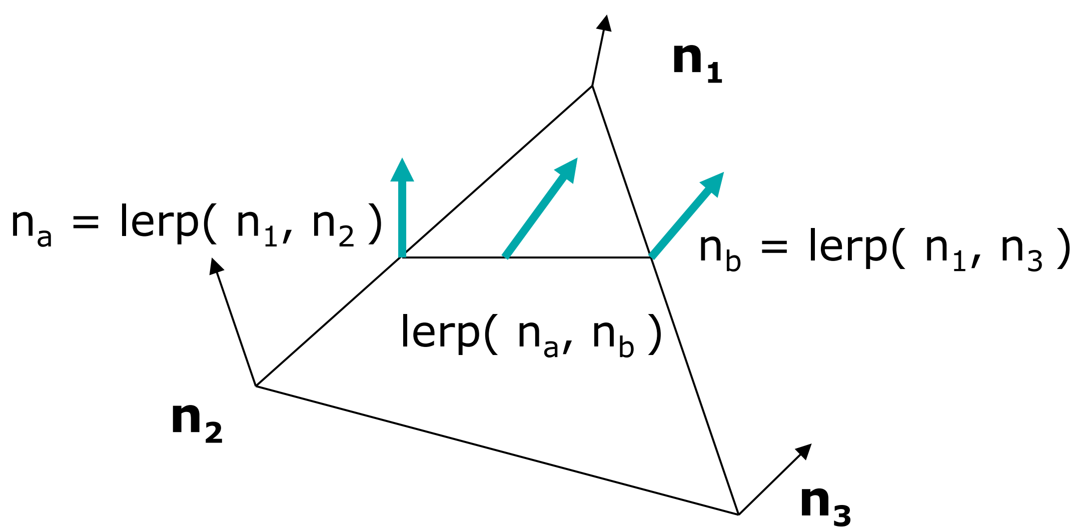


Phong Shading

- Instead of interpolation, we calculate lighting for each pixel inside the polygon (per-pixel lighting)
- Need normals for all the pixels
  - Not provided by user!
- Phong shading algorithm
  - Interpolate the normals across polygon
  - Compute lighting during rasterization
    - Need to map the normal back to world or eye space though

Phong Shading (cont.)

- Normal interpolation



- Slow
  - Not supported by OpenGL, but now graphics cards have pixel shaders that can be used to do this quickly