Shading

CS425: Computer Graphics I

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Overview

- Shading models:
  - Flat
  - Gouraud
  - Phong

Shading

- How do we compute the color for the whole surface?
- Illumination models (e.g., Phong, Blinn-Phong) compute the color of sample points. How do we color the entire object?

Shading

- What we need in the shaders?

$$f_{Phong}(\mathbf{L}_{light}, \mathbf{l}, \mathbf{v}, \mathbf{n}) = k_{ambient}\mathbf{L}_{ambient} + \sum_{m \in lights} k_{diffuse}(\hat{\mathbf{l}}_{\boldsymbol{m}} \cdot \hat{\mathbf{n}})\mathbf{L}_{m,diffuse} + k_{specular}(\hat{\boldsymbol{h}}_{\boldsymbol{m}} \cdot \hat{\boldsymbol{n}})^{\boldsymbol{n}}\mathbf{L}_{m,specular}$$

  - Uniforms

Shading

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  - Uniforms
  - Normals

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  - Uniforms
  - Normals
  - Light position

Shading

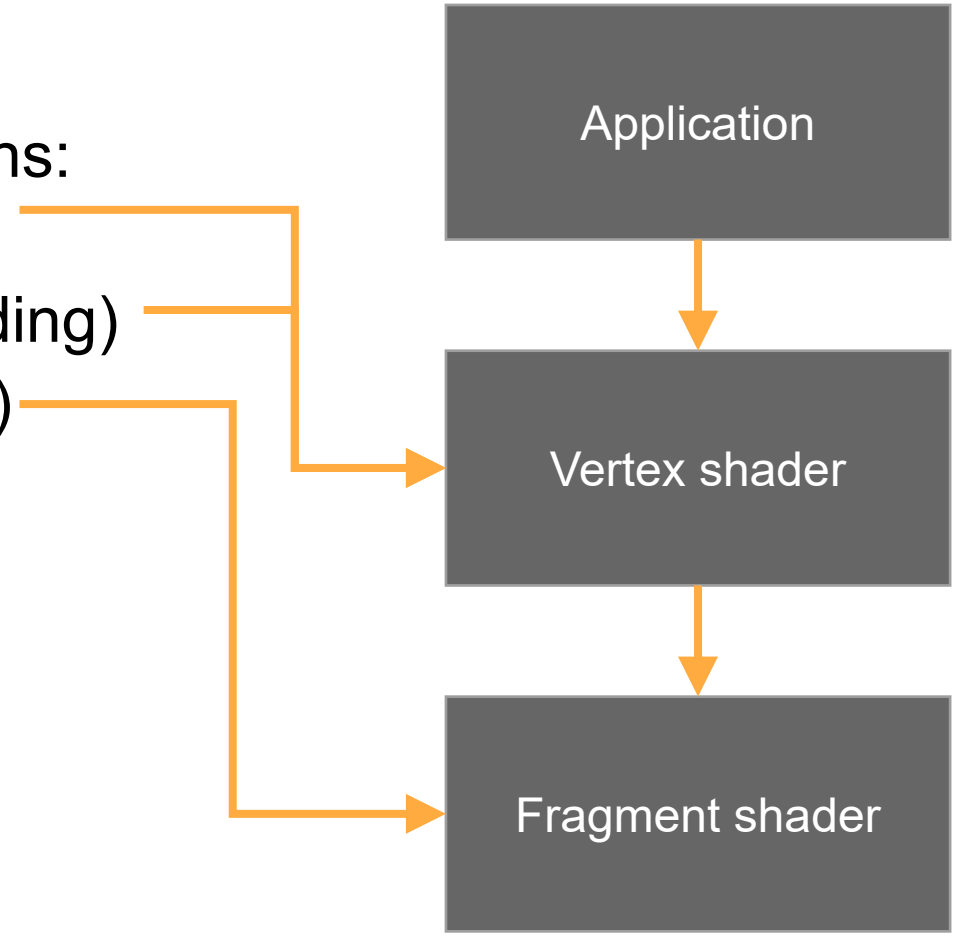
- What we need in the shaders?

$$f_{Phong}(\mathbf{L}_{light}, \mathbf{l}, \mathbf{v}, \mathbf{n}) = k_{ambient}\mathbf{L}_{ambient} + \sum_{m \in lights} k_{diffuse}(\hat{\mathbf{l}}_{\boldsymbol{m}} \cdot \hat{\mathbf{n}})\mathbf{L}_{m,diffuse} + k_{specular}(\hat{\boldsymbol{h}}_{\boldsymbol{m}} \cdot \hat{\boldsymbol{n}})^{\boldsymbol{n}}\mathbf{L}_{m,specular}$$

  - Uniforms
  - Normals
  - Light position
  - Half-vector: depends on $\mathbf{l}$ and $\mathbf{v}$
    - Do we really need to send $\mathbf{v}$? We can work on camera space!

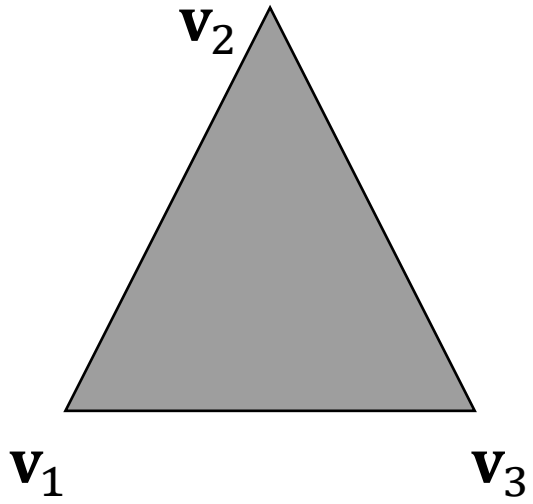
Shading: per-triangle, per-vertex, per-pixel

- We can compute shading operations:
  - Once per triangle (flat shading)
  - Once per vertex (Gouraud shading)
  - Once per pixel (Phong shading)

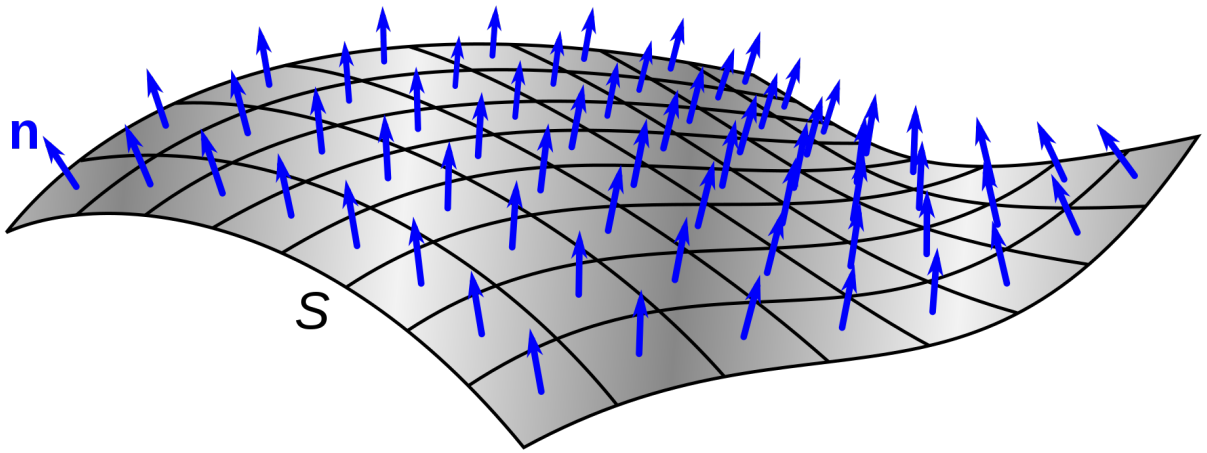


Computing normals

Triangle with vertices $\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3$:

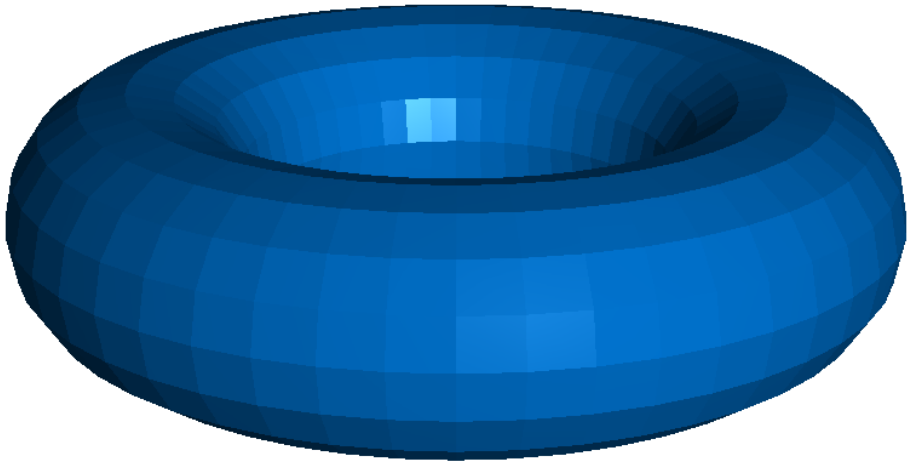


$$\mathbf{n} = (\mathbf{v}_2 - \mathbf{v}_1) \times (\mathbf{v}_3 - \mathbf{v}_1)$$



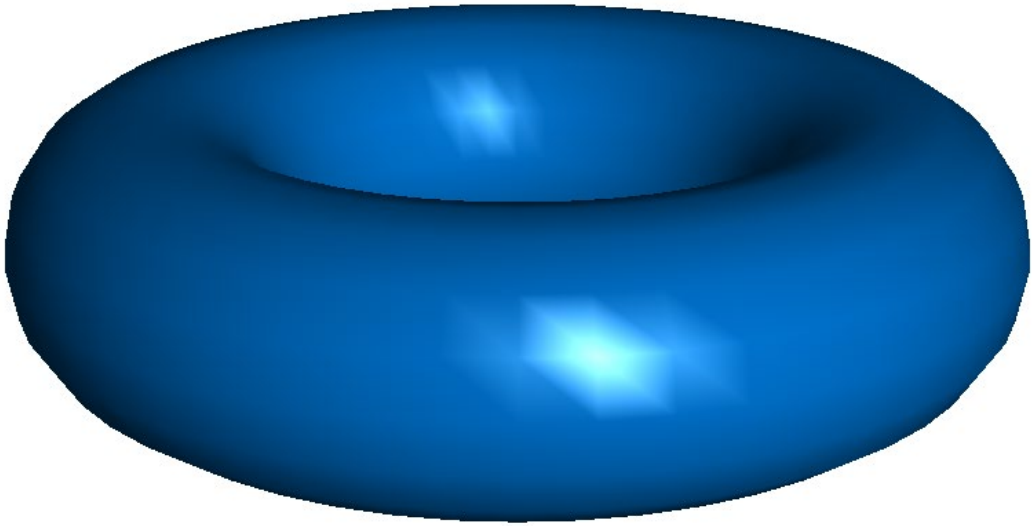
Flat shading

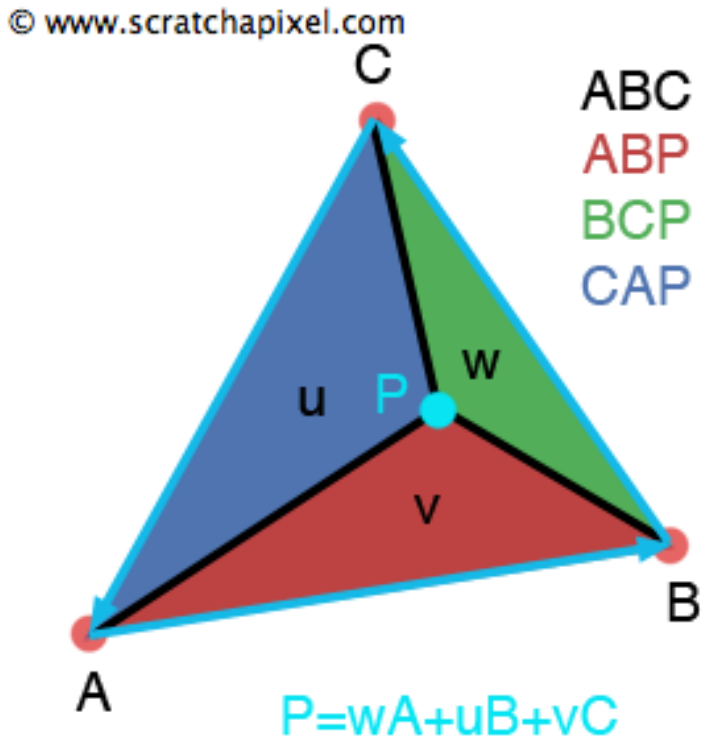
- Compute one color per polygon.
- All pixels in the same polygon are colored by the same color.



Gouraud shading

- Compute one color per vertex.
- Interpolate vertex **colors** across triangles.





Gouraud shading + WebGL

What uniforms in the vertex shader?

```
uniform float kAmbient;
uniform float kDiffuse;
uniform float kSpecular;
uniform float specExponent;
uniform vec3 colorAmbient;
uniform vec3 colorDiffuse;
uniform vec3 colorSpecular;
```

```
uniform vec3 lightPos; // or lightDir
```

What attributes in the vertex shader?

```
in vec3 pos;
in vec4 color;
in vec3 normal;
```

One normal per vertex.

Vertex shader:

- Blinn-Phong operations, send color result to fragment shader.

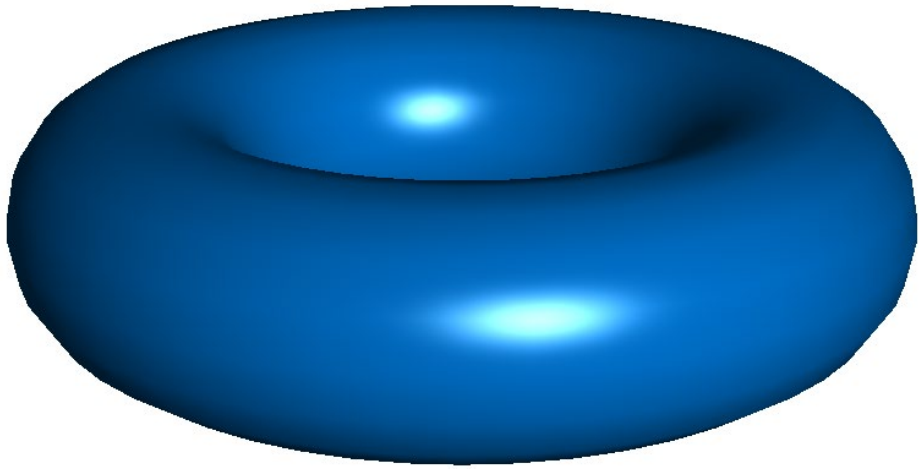
What about eye pos?

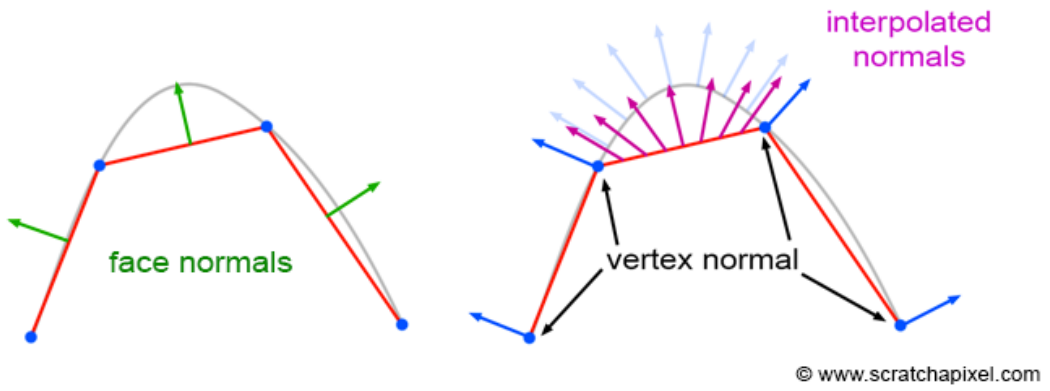
- No, if we perform everything in camera space.

```
posEyeSpace = modelViewMatrix * pos;
```

Phong shading

- One color per pixel.
- Interpolates vertex **normals** across triangles.
- Illumination model evaluated at each pixel.





Phong shading + WebGL

What uniforms in the frag shader?

```
uniform float kAmbient;
uniform float kDiffuse;
uniform float kSpecular;
uniform float specExponent;
uniform vec3 colorAmbient;
uniform vec3 colorDiffuse;
uniform vec3 colorSpecular;
```

```
uniform vec3 lightPos; // or lightDir
```

What varying in the frag shader?

```
in vec3 position;
in vec3 normal;
```

Fragment shader:

- Blinn-Phong operations, send color result to framebuffer.

Again: camera space.

```
posEyeSpace = modelViewMatrix * pos;
```

$$f_{Phong}(\mathbf{L}_{light}, \mathbf{l}, \mathbf{v}, \mathbf{n}) = k_{ambient}\mathbf{L}_{ambient} + \sum_{m \in lights} k_{diffuse}(\hat{\mathbf{l}}_{\boldsymbol{m}} \cdot \hat{\mathbf{n}})\mathbf{L}_{m,diffuse} + k_{specular}(\hat{\boldsymbol{h}}_{\boldsymbol{m}} \cdot \hat{\boldsymbol{n}})^{\boldsymbol{n}}\mathbf{L}_{m,specular}$$

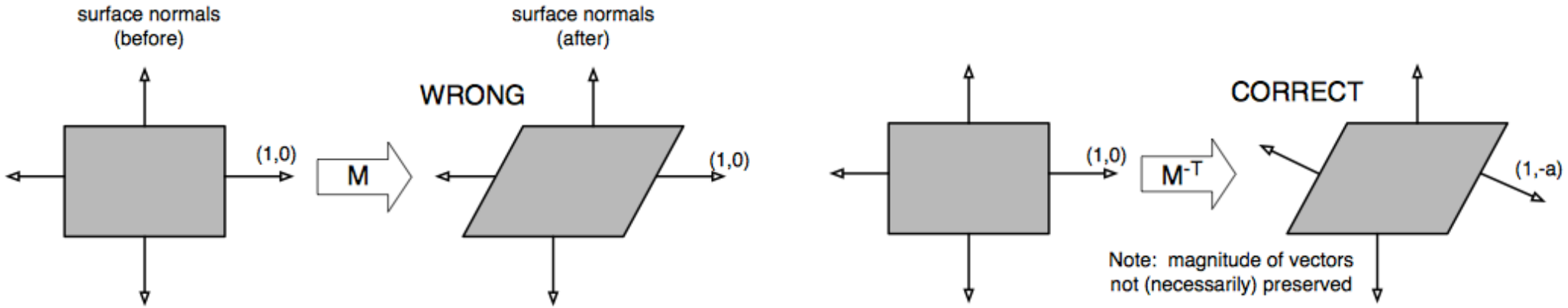
How can we transform normals?

- Vertex:

```
v = modelViewMatrix * vec4(position, 1);
```

- Normal:

```
n = uNormal * vec4(normal, 1);
```



$$\mathbf{NormalMatrix} = (\mathbf{ModelView}^{-1})^{\mathbf{T}}$$

How can we transform normals?

$\mathbf{t} = \mathbf{p_2} - \mathbf{p_1}$

$\mathbf{t} * \mathbf{M} = (\mathbf{p_2} - \mathbf{p_1}) * \mathbf{M}$

$\mathbf{t}' = \mathbf{p_2}' - \mathbf{p_1}'$

$\mathbf{n}$ and $\mathbf{t}$ are perpendicular

$\mathbf{n}'$and $\mathbf{t}'$must also be perpendicular

We find normal matrix by solving: $\mathbf{n}'.\mathbf{t}' = \mathbf{0}$

What is $\mathbf{n}'$? $\mathbf{G} * \mathbf{n}$

What is $\mathbf{t}'$? $\mathbf{M} * \mathbf{t}$

$(\mathbf{G} * \mathbf{n}).(\mathbf{M} * \mathbf{t}) = \mathbf{0}$

$\mathbf{G} = (\mathbf{M}^{-1})^{\mathbf{T}}$

Point and directional light

Directional Light

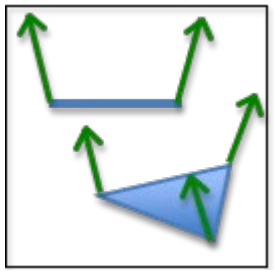
Point Light

```
uniform vec3 lightDir;
```

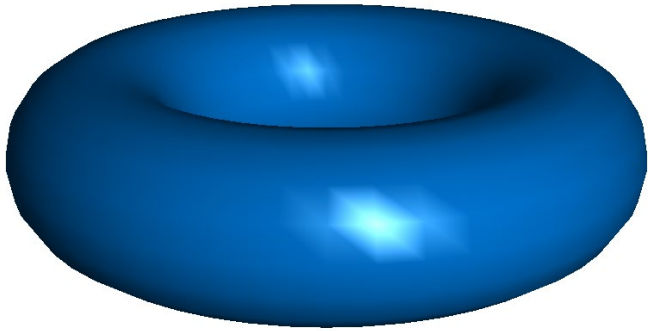
```
lightDir = normalize(lightPos - pos);
```

Comparison

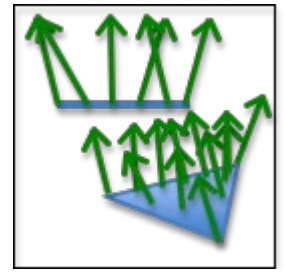
Gouraud shading



Vertex shader → color → Fragment shader



Phong shading



Vertex shader → normal position → Fragment shader