Using Shaders for Lighting

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Lighting Definitions

N = Normal vector
L = Vector from Point to the Light
R = Light reflection vector
E = Vector from the Point to the eye

Ambient = Light intensity that is “everywhere”
Diffuse = Light intensity proportional to \( \cos(\Theta) \)
Specular = Light intensity proportional to \( \cos^S(\Phi) \)
A-D-S = Lighting model that includes Ambient, Diffuse, and Specular

Flat Interpolation = Use a single polygon normal to compute one A-D-S for the entire polygon
Smooth Interpolation = Use a normal at each vertex to compute one A-D-S at each vertex

Per-fragment lighting = Interpolate the vectors across the entire polygon and then compute A-D-S at each fragment
A-D-S Lighting

Ambient: $K_a$

Diffuse: $K_d \cdot \text{cos} \theta$

Specular: $K_s \cdot \text{cos}^s \phi$
Ambient-only

Diffuse-only

Specular-only

ADS – Shininess=50

ADS – Shininess=1000

ADS – Shininess=1000 -- Flat
The Difference Between Per-Vertex Lighting and Per-Fragment Lighting

Per-vertex

Per-fragment
The Difference Between Per-Vertex Lighting and Per-Fragment Lighting

Per-vertex

Per-fragment
Vertex shader:

```cpp
#version 330 compatibility
out vec2 vST;       // texture coords
out vec3 vN;        // normal vector
out vec3 vL;        // vector from point to light
out vec3 vE;        // vector from point to eye

const vec3 LIGHTPOSITION = vec3( 5., 5., 0. );

void main( )
{
    vST = gl_MultiTexCoord0.st;
    vec4 ECposition = gl_ModelViewMatrix * gl_Vertex;  // eye coordinate position
    vN = normalize( gl_NormalMatrix * gl_Normal );  // normal vector
    vL = LIGHTPOSITION - ECposition.xyz;            // vector from the point to the light position
    vE = vec3( 0., 0., 0. ) - ECposition.xyz;       // vector from the point to the eye position
    gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
}
```

Applying Per-Fragment Lighting
Applying Per-Fragment Lighting

Fragment shader:

```glsl
#version 330 compatibility
uniform float uKa, uKd, uKs; // coefficients of each type of lighting
uniform float uShininess; // specular exponent
in vec2 vST; // texture cords
in vec3 vN; // normal vector
in vec3 vL; // vector from point to light
in vec3 vE; // vector from point to eye
void main( )
{
    vec3 Normal = normalize(vN);
    vec3 Light = normalize(vL);
    vec3 Eye = normalize(vE);

    vec3 myColor = vec3( 1.0, 0.5, 0.0 ); // default color
    vec3 mySpecularColor = vec3( 1.0, 1.0, 1.0 ); // specular highlight color

    vec3 ambient = uKa * myColor;
    float d = 0.;
    float s = 0.
    if( dot(Normal,Light) > 0. ) // only do specular if the light can see the point
    {
        d = dot(Normal,Light);
        vec3 ref = normalize( reflect( -Light, Normal ) ); // reflection vector
        s = pow( max( dot(Eye,ref),0. ), uShininess );
    }
    vec3 diffuse = uKd * d * myColor;
    vec3 specular = uKs * s * mySpecularColor;
    gl_FragColor = vec4( ambient + diffuse + specular, 1. );
}
```

Here’s where we figure out what color this fragment will be

Here’s where we apply lighting to that color
Applying Per-Fragment Lighting
Per-fragment A-D-S Lighting with Flat Interpolation

Each polygon has a single lighting value applied to every pixel within it.
Per-fragment A-D-S Lighting with Flat Interpolation

**Vertex shader:**

```glsl
...  
flat out vec2 vST; // texture coords  
flat out vec3 vN; // normal vector  
flat out vec3 vL; // vector from point to light  
flat out vec3 vE; // vector from point to eye  
...  
```

**Fragment shader:**

```glsl
...  
flat in vec2 vST; // texture cords  
flat in vec3 vN; // normal vector  
flat in vec3 vL; // vector from point to light  
flat in vec3 vE; // vector from point to eye  
...  
```
Flat Shading

Smooth Shading
What you see depends on the light color and the material color

\[ E_R = L_R \cdot M_R \]
\[ E_G = L_G \cdot M_G \]
\[ E_B = L_B \cdot M_B \]

This is how you implement subtractive coloring.
A-D-S Anisotropic Lighting with Normal Interpolation

Note: The bright spot is not circular because the material has different properties in different directions. Materials such as fur, hair, and brushed metal behave this way.

Summary

Flat

Smooth

Anisotropic
Besides Hair, Other Real World Examples of Anisotropic Lighting Behavior

Information Desk

Elevator Doors