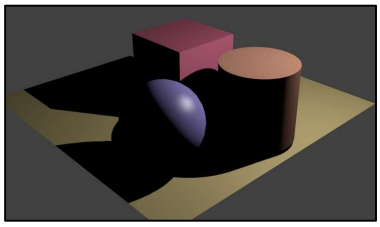
1

Casting Shadows in OpenGL



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Mike Bailey
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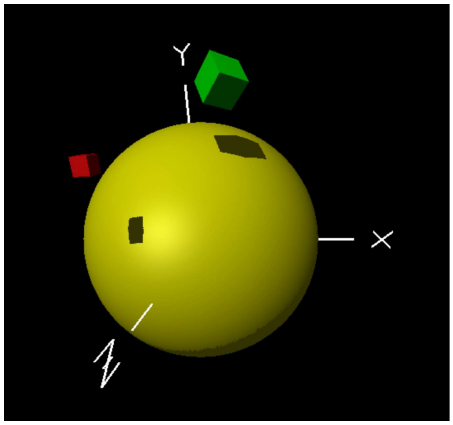

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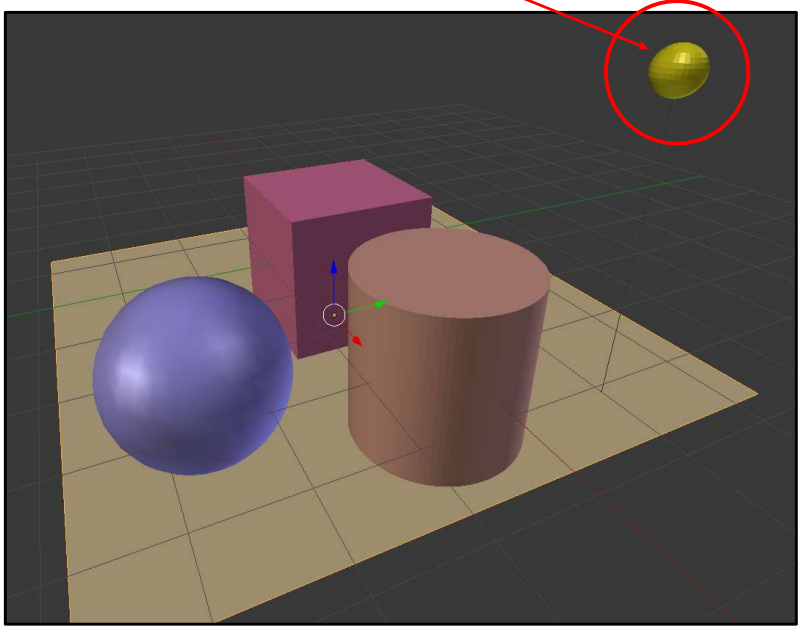
1

Identify the Light Source Casting the Shadow

2



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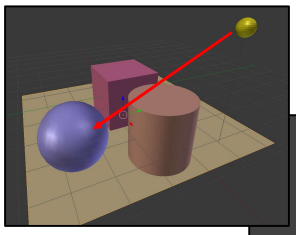
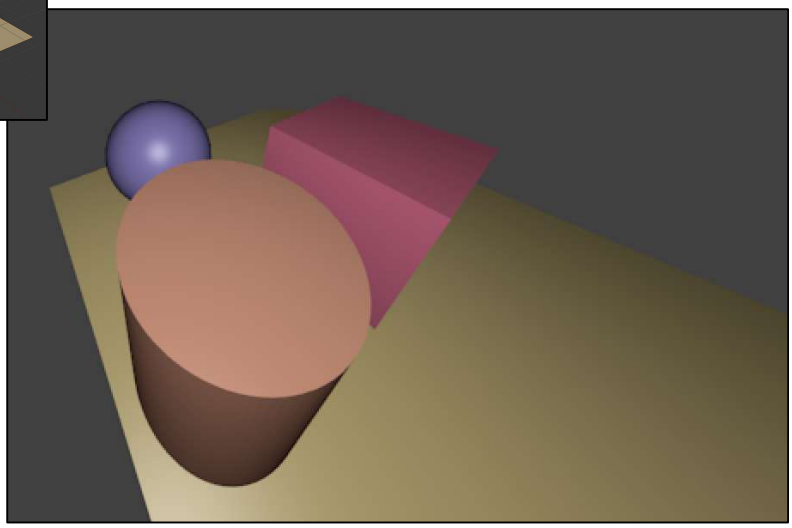
2

First, Render the Scene from the Point of View of that Light Source

3



1. Render a view from the light source – everything you cannot see must be in a shadow



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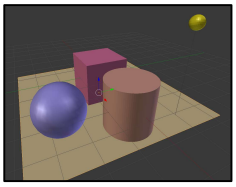
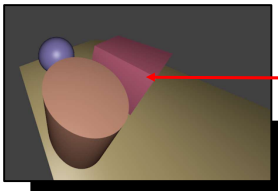
3

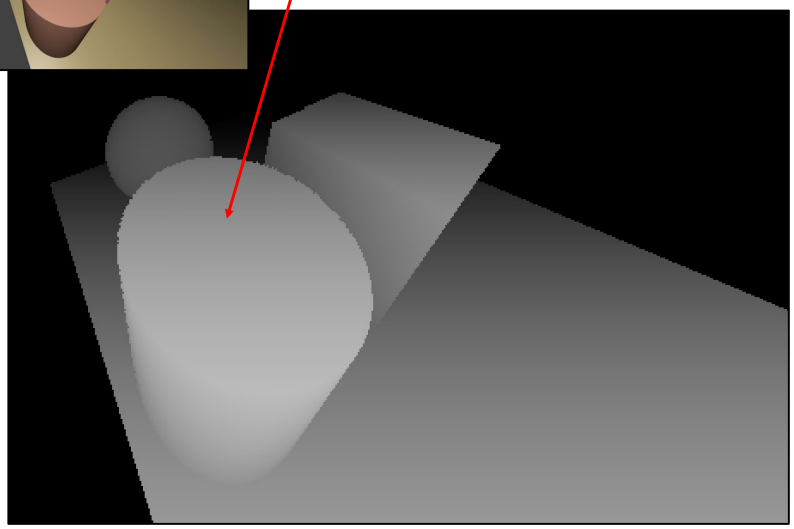
Second, use the Z-buffer as a Depth Shadow Map

4





2. Generate a depth view from the point of view of the light source (in OpenGL, this means extracting the z-buffer)



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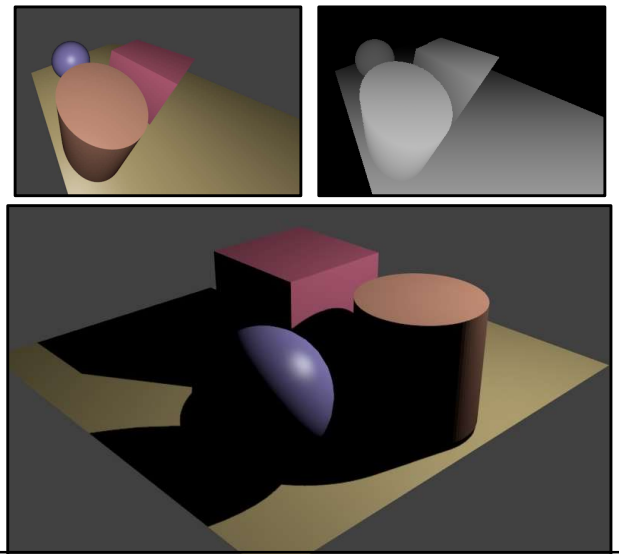
4

Third, Render the Scene as you Normally Would, but Consult the Depth Map to Decide where Lighting Can't Reach and Shouldn't Be Used

5

3. Put the eye back where it really belongs. Render that view. Every time you create a pixel in the scene, compare its 3D location against the depth map. If the light-position camera could not see it before, don't allow lighting to be applied to it now.



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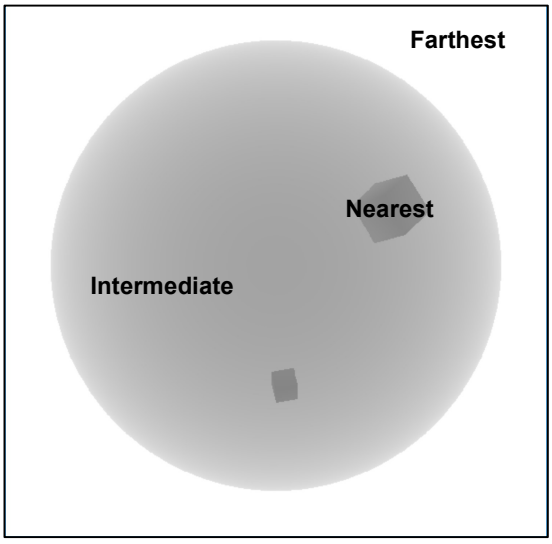
OpenGL Shadow Demo Program: The Depth (Z-buffer) Shadow Map

6

The depth shadow map is created from the point of view of the light source.

The rendering is done into an off-screen framebuffer and only renders the depth (z-buffer) , not any colors.

In this grayscale image, dark colors are nearest to the eye, light colors are farther away.



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OpenGL Demo Program: Creating the Off-screen Depth Shadow Map Framebuffer

7

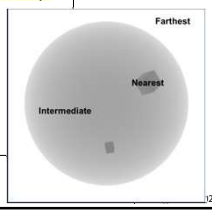
```
// create a framebuffer object and a depth texture object:
glGenFramebuffers(1, &DepthFramebuffer );
glGenTextures(       1, &DepthTexture );

//Create a texture that will be the framebuffer's depth buffer
glBindTexture(GL_TEXTURE_2D, DepthTexture );
glTexImage2D(GL_TEXTURE_2D, 0, GL_DEPTH_COMPONENT, SHADOW_WIDTH, SHADOW_HEIGHT,
                    0, GL_DEPTH_COMPONENT, GL_FLOAT, NULL);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_CLAMP_TO_EDGE);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_T, GL_CLAMP_TO_EDGE);

// attach texture to framebuffer as depth buffer:
glBindFramebuffer(GL_FRAMEBUFFER, DepthFramebuffer);
glFramebufferTexture2D(GL_FRAMEBUFFER, GL_DEPTH_ATTACHMENT, GL_TEXTURE_2D, DepthTexture, 0);

// force opengl to accept a framebuffer that doesn't have a color buffer in it:
glDrawBuffer(GL_NONE);
glReadBuffer(GL_NONE);
glBindFramebuffer(GL_FRAMEBUFFER, 0);
```

In shadows.cpp:
InitGraphics( )



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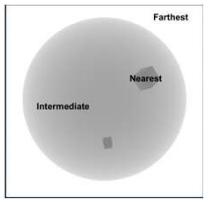
7

OpenGL Demo Program: Rendering into the Depth Shadow Map

8

```
//first pass, render from light's perspective, store depth of scene in texture
glBindFramebuffer(GL_FRAMEBUFFER, DepthFramebuffer);
glClear(GL_DEPTH_BUFFER_BIT);
glDrawBuffer(GL_NONE);
glReadBuffer(GL_NONE);
glEnable(GL_DEPTH_TEST);
glShadeModel(GL_FLAT);
glDisable(GL_NORMALIZE);

// these matrices are the equivalent of projection and view matrices
glm::mat4 lightProjection = glm::ortho(-10.0f, 10.0f, -10.0f, 10.0f, 1.f, 20.f);
glm::vec3 lightPos(LightX, LightY, LightZ);
glm::mat4 lightView = glm::lookAt(lightPos, glm::vec3(0., 0., 0.), glm::vec3(0., 1., 0.));

//this matrix is the transformation matrix that the vertex shader will use instead of glModelViewProjectionMatrix:
glm::mat4 lightSpaceMatrix = lightProjection * lightView;

glViewport(0, 0, SHADOW_WIDTH, SHADOW_HEIGHT);

GetDepth.Use( );
GetDepth.SetUniformVariable((char*)"uLightSpaceMatrix", lightSpaceMatrix);
glm::vec3 color = glm::vec3(0., 1., 1.);
GetDepth.SetUniformVariable((char*)"uColor", color);
DisplayOneScene(GetDepth);
GetDepth.UnUse( );
glBindFramebuffer(GL_FRAMEBUFFER, 0);
```

In shadows.cpp:
Display( ), l



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8

OpenGL Demo Program: Rendering using the Depth Shadow Map

9

```
RenderWithShadows.Use();
RenderWithShadows.SetUniformVariable((char*)"uShadowMap", 0 );
RenderWithShadows.SetUniformVariable((char*)"uLightX", LightX);
RenderWithShadows.SetUniformVariable((char*)"uLightY", LightY);
RenderWithShadows.SetUniformVariable((char*)"uLightZ", LightZ);
RenderWithShadows.SetUniformVariable((char*)"uLightSpaceMatrix", lightSpaceMatrix);

glm::vec3 eye = glm::vec3(0., 0., 8.);
glm::vec3 look = glm::vec3(0., 0., 0.);
glm::vec3 up = glm::vec3(0., 1., 0.);
glm::mat4 modelview = glm::lookAt(eye, look, up);

if (Scale < MINSCALE)            Scale = MINSCALE;
glm::vec3 scale = glm::vec3(Scale, Scale, Scale);
modelview = glm::scale(modelview, scale);
glm::vec3 xaxis = glm::vec3(1., 0., 0.);
glm::vec3 yaxis = glm::vec3(0., 1., 0.);
modelview = glm::rotate(modelview, glm::radians(Yrot), yaxis);
modelview = glm::rotate(modelview, glm::radians(Xrot), xaxis);
RenderWithShadows.SetUniformVariable((char*)"uModelView", modelview);

glm::mat4 proj = glm::perspective(glm::radians(75.f), 1.f, .1f, 100.f);
RenderWithShadows.SetUniformVariable((char*)"uProj", proj);
DisplayOneScene(RenderWithShadows);
RenderWithShadows.UnUse( );
```

In shadows.cpp:
Display( ), II

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9

OpenGL Shadows Demo Program Shaders: Rendering using the Depth Shadow Map

10

GetDepth.vert

```
#version 330 compatibility

uniform mat4 uLightSpaceMatrix;
uniform mat4 uAnim;

void
main()
{
    gl_Position = uLightSpaceMatrix * uAnim * gl_Vertex;
}
```

GetDepth.frag

```
#version 330 compatibility

uniform vec3 uColor;

void main()
{
    gl_FragColor = vec4(uColor, 1.);    // really doesn't matter...
}
```

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10

OpenGL Shadows Demo Program Shaders: Rendering using the Depth Shadow Map

RenderWithShadows.vert

```
#version 330 compatibility

uniform mat4  uLightSpaceMatrix;
uniform mat4  uAnim;
uniform mat4  uModelView;
uniform mat4  uProj;
uniform float   uLightX;
uniform float   uLightY;
uniform float   uLightZ;

out vec4 vFragPosLightSpace;
out vec3 vNs;
out vec3 vLs;
out vec3 vEs;

void
main()
{
        vec3 LightPosition = vec3(uLightX, uLightY, uLightZ);

        vec4 ECposition = uModelView * uAnim * gl_Vertex;
        vec3 tnorm = normalize( mat3(uAnim) * gl_Normal );
        vNs = tnorm;
        vLs = LightPosition      - ECposition.xyz;
        vEs = vec3( 0., 0., 0. ) - ECposition.xyz;

        vFragPosLightSpace = uLightSpaceMatrix       *   uAnim * gl_Vertex;
        gl_Position                = uProj * uModelView      * uAnim * gl_Vertex;
}
```


OpenGL Shadows Demo Program Shaders: Rendering using the Depth Shadow Map

RenderWithShadows.frag, I

```
#version 330 compatibility

uniform vec3        uColor;
uniform sampler2D uShadowMap;
uniform int           uShadowsOn;

in vec4 vFragPosLightSpace;
in vec3 vNs;
in vec3 vLs;
in vec3 vEs;

const float   BIAS =  0.01;
const vec3  SPECULAR_COLOR = vec3( 1., 1., 1. );
const float   SHININESS = 8.;

const float KA = 0.20;
const float KD = 0.60;
const float KS = (1.-KA-KD);

bool    IsInShadow(vec4 fragPosLightSpace)
{
   // have to manually do homogenous division to make light space position in range of -1 to 1:
   vec3 projection = fragPosLightSpace.xyz / fragPosLightSpace.w;
   //then make it from 0 to 1:
   projection = 0.5*projection + 0.5;

   //get closest depth from light's perspective
   float closestDepth = texture(uShadowMap, projection.xy).r;

   //get current depth:
   float currentDepth = projection.z;
   bool isInShadow = (currentDepth - BIAS) > closestDepth;
   return isInShadow;
}
```

OpenGL Shadows Demo Program Shaders: Rendering using the Depth Shadow Map

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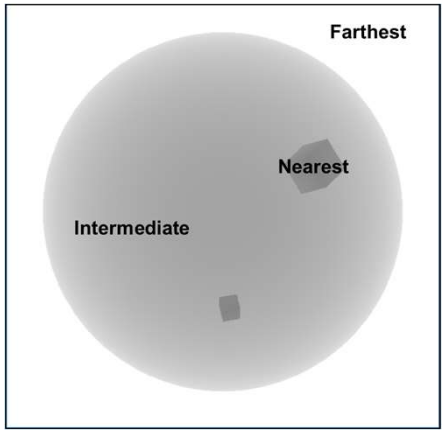
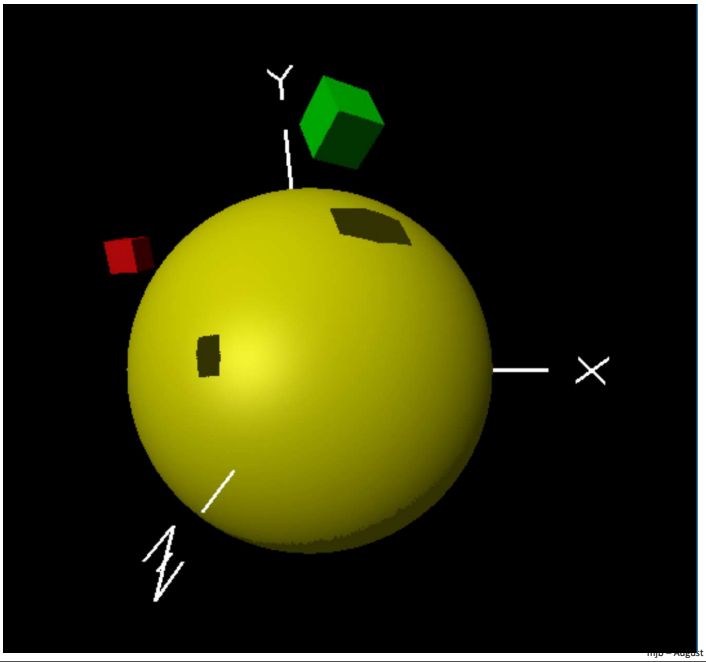
RenderWithShadows.frag, II

```
void    main( )
{
    vec3 normal  = normalize(vNs);
    vec3 light   = normalize(vLs);
    vec3 eye     = normalize(vEs);

    float d = 0.;
    float s = 0.;
    vec3 lighting = KA * uColor;

    bool isInShadow = IsInShadow(vFragPosLightSpace);
    if( uShadowsOn != 0 )
        isInShadow = false;     // if in ShadowOff mode, nothing should be cnsidered in a shadow
    if( ! isInShadow )
    {
        d = dot(normal,light);
        if(d > 0.)
        {
            vec3 diffuse = KD*d*uColor;
            lighting += diffuse;

            vec3 refl = normalize( reflect( -light, normal ) );
            float dd = dot(eye,refl);
            if( dd > 0. )
            {
                s = pow( dd, SHININESS );
                vec3 specular = KS*s*SPECULAR_COLOR;
                lighting += specular;
            }
        }
    }
    gl_FragColor = vec4( lighting, 1. );
}
```


OpenGL Shadows Demo Program: Rendering using the Depth Shadow Map

14

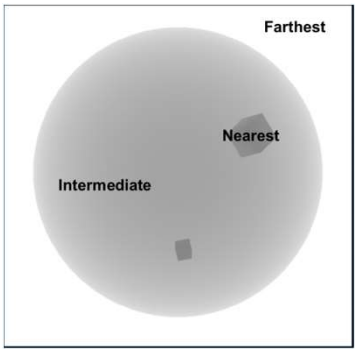




How Did the Demo Program Render that 2D Shadow Map?

In shadows.cpp

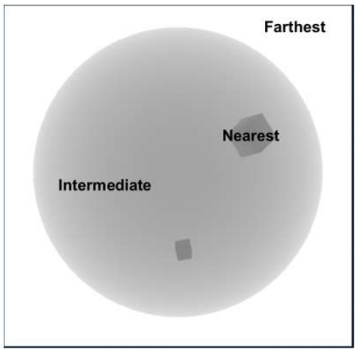
```
DisplayShadowMap.Use();
DisplayShadowMap.SetUniformVariable((char*)"uShadowMap", 0 );

glm::mat4 model = glm::mat4(1.f);
DisplayShadowMap.SetUniformVariable((char*)"uModel", model);

glm::vec3 eye = glm::vec3(0., 0., 1.);
glm::vec3 look = glm::vec3(0., 0., 0.);
glm::vec3 up = glm::vec3(0., 1., 0.);
glm::mat4 view = glm::lookAt(eye, look, up);
DisplayShadowMap.SetUniformVariable((char*)"uView", view);

glm::mat4 proj = glm::ortho(-0.6f, 0.6f,  -0.6f, 0.6f, .1f, 100.f);
DisplayShadowMap.SetUniformVariable((char*)"uProj", proj);

glBegin(GL_QUADS);
glTexCoord2f(0., 0.);
glVertex3f(-1., -1., 0.);
glTexCoord2f(1., 0.);
glVertex3f( 1., -1., 0.);
glTexCoord2f(1., 1.);
glVertex3f( 1.,  1., 0.);
glTexCoord2f(0., 1.);
glVertex3f(-1., 1., 0.);
glEnd();

DisplayShadowMap.UnUse( );
```



How Did the Demo Program Render the 2D Shadow Map?

DisplayShadowMap.vert

```
#version 330 compatibility

uniform mat4 uModel;
uniform mat4 uView;
uniform mat4 uProj;

out vec2 vST;

void
main()
{
	vST = gl_MultiTexCoord0.st;
	gl_Position = uProj * uView  * uModel * gl_Vertex;
}
```



DisplayShadowMap.frag

```
#version 330 compatibility

uniform sampler2D uShadowMap;

in vec2 vST;

void
main( )
{
	float gray = texture(uShadowMap, vST ).r;
	gl_FragColor = vec4( gray, gray, gray, 1. );
}
```