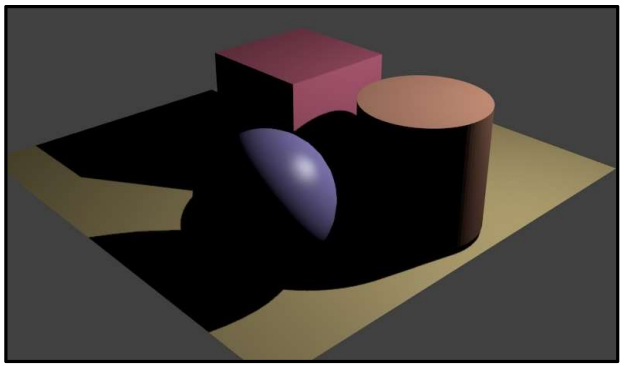
Casting Shadows in OpenGL



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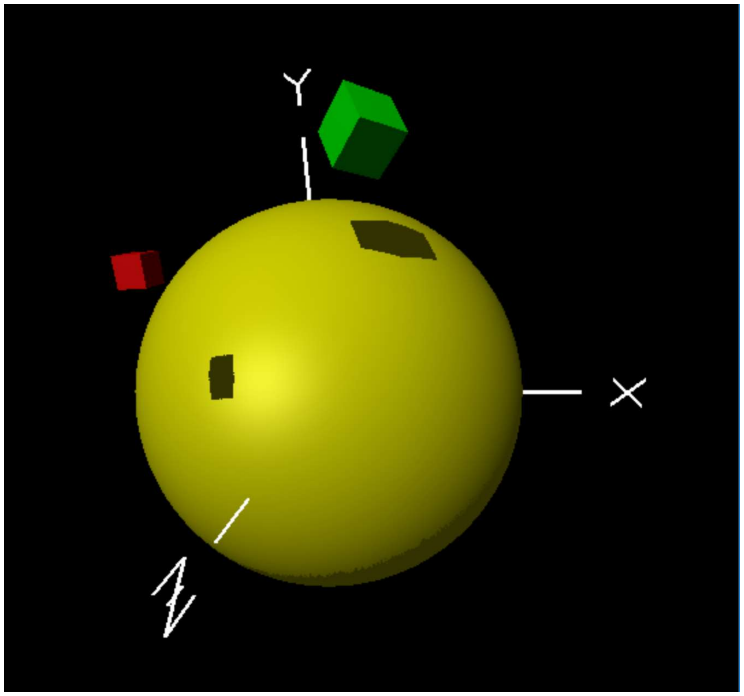
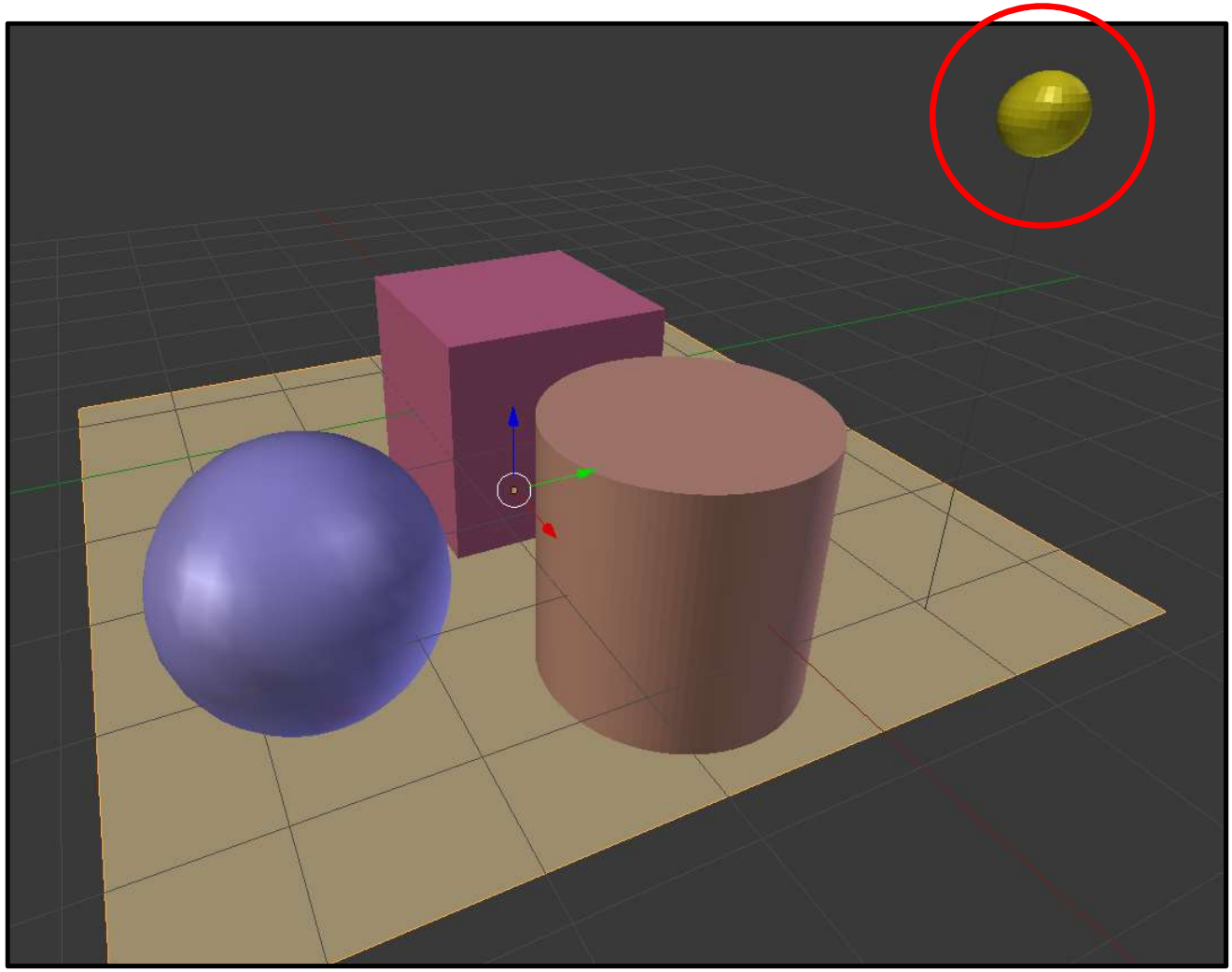
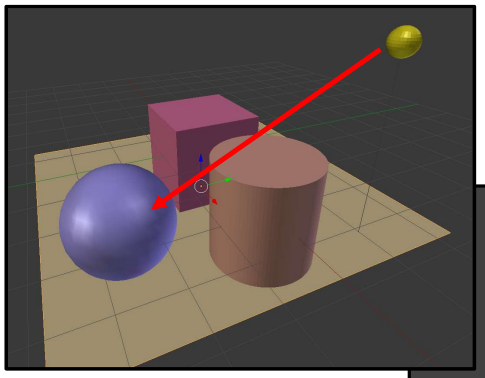


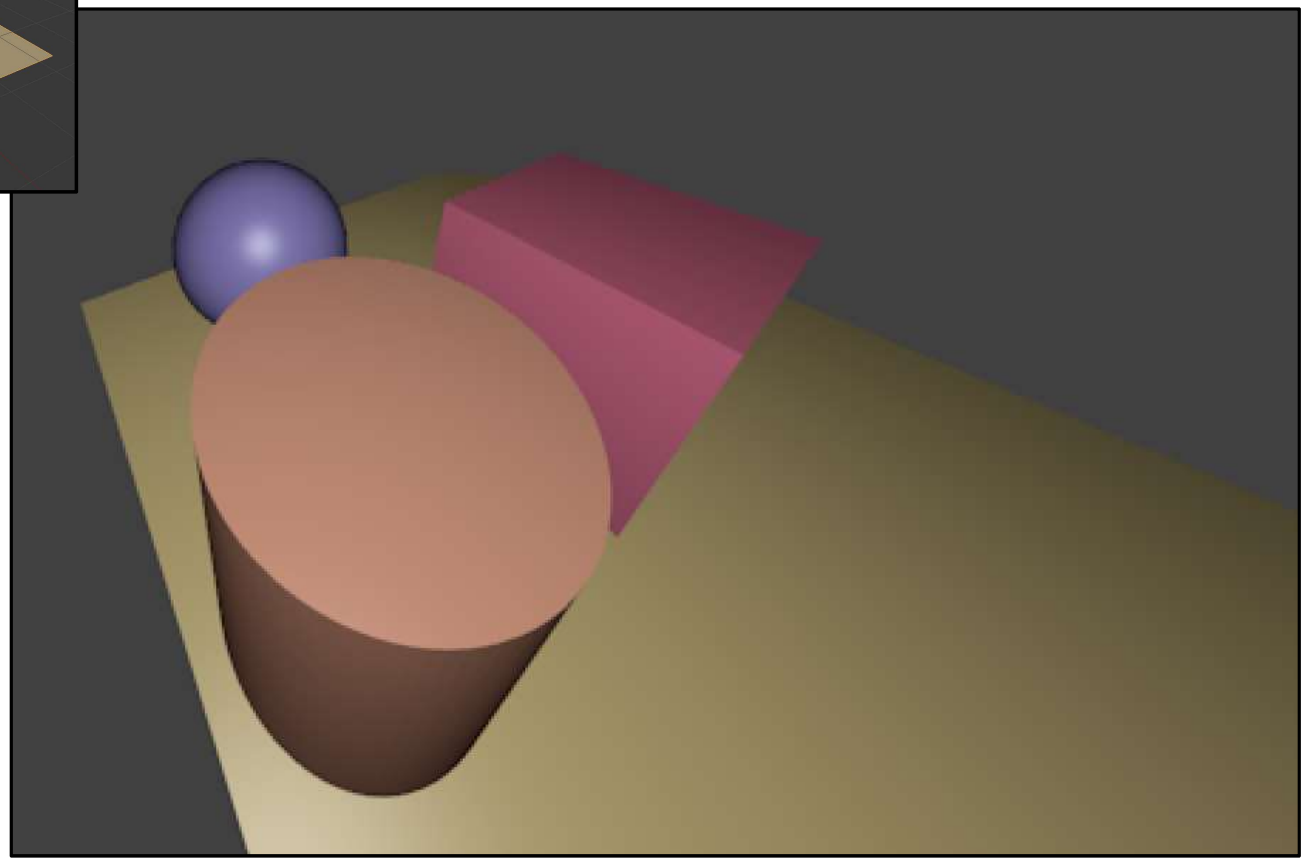
Identify the Light Source Casting the Shadow



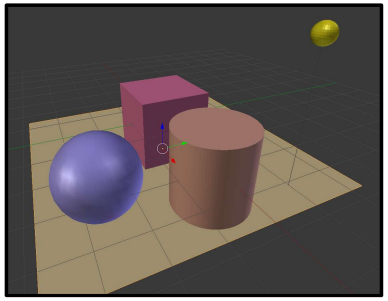
First, Render the Scene from that Light Source

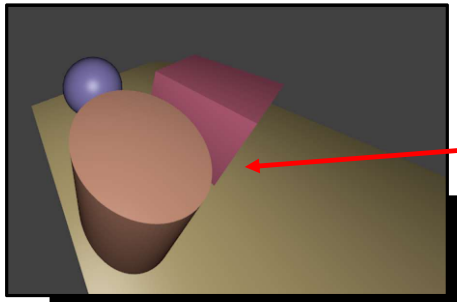


1. Render a view from the light source – everything you cannot see must be in a shadow

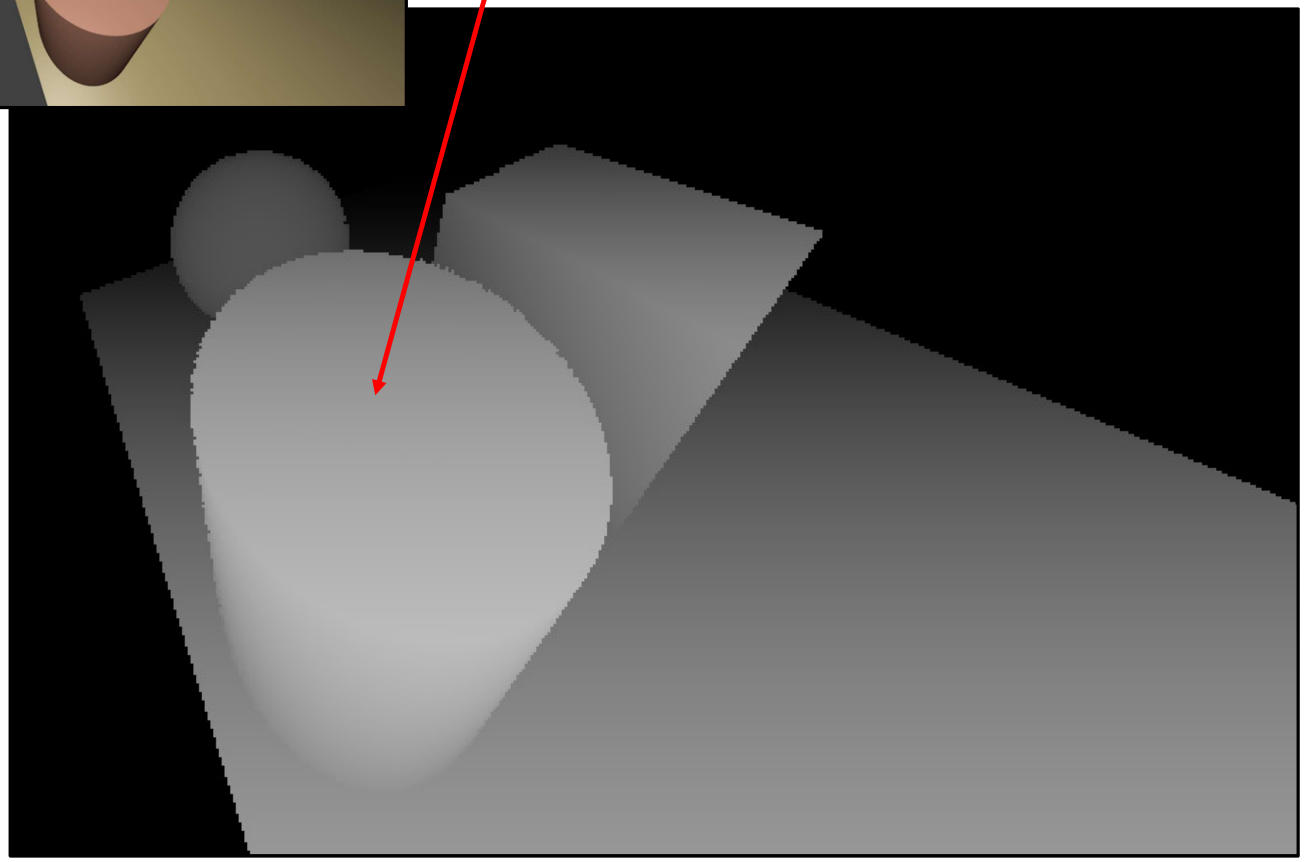


Use the Z-buffer as a Depth Shadow Map



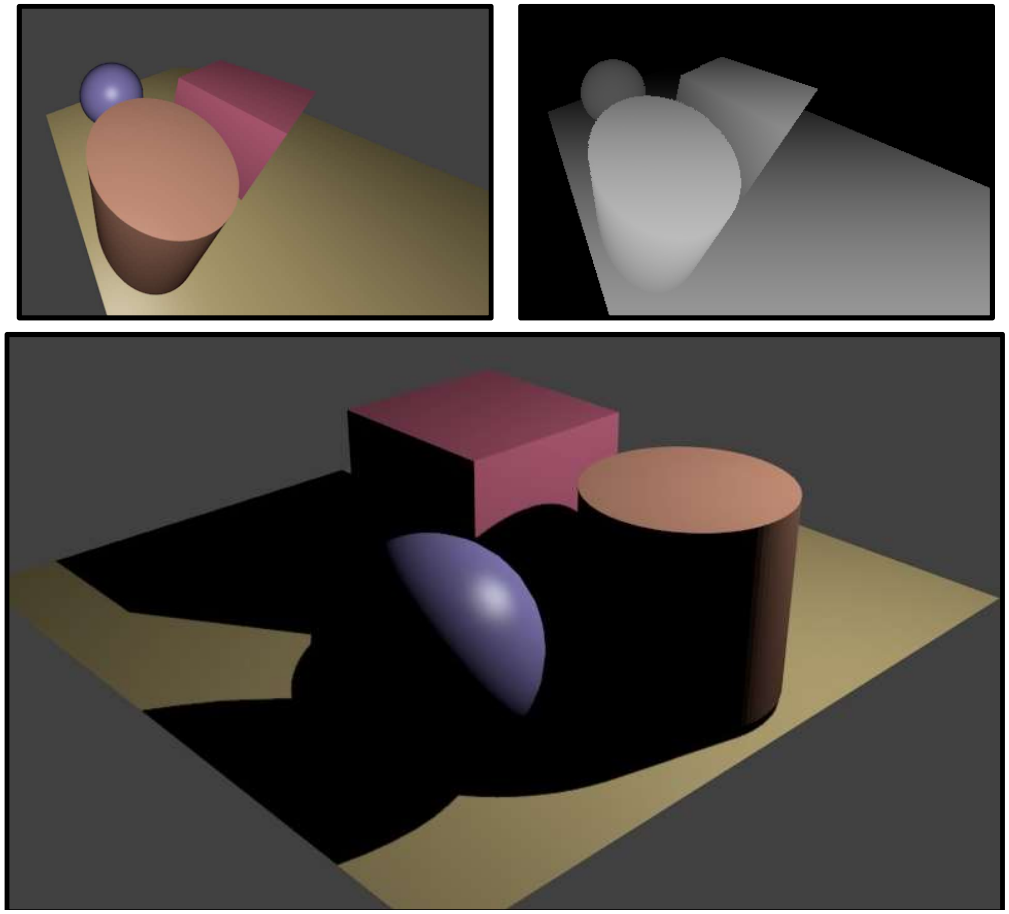


2. Generate a depth view from the light source



Second, Render the Scene as Normal, but Consult the Depth Map to Decide where Lighting Applies

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.

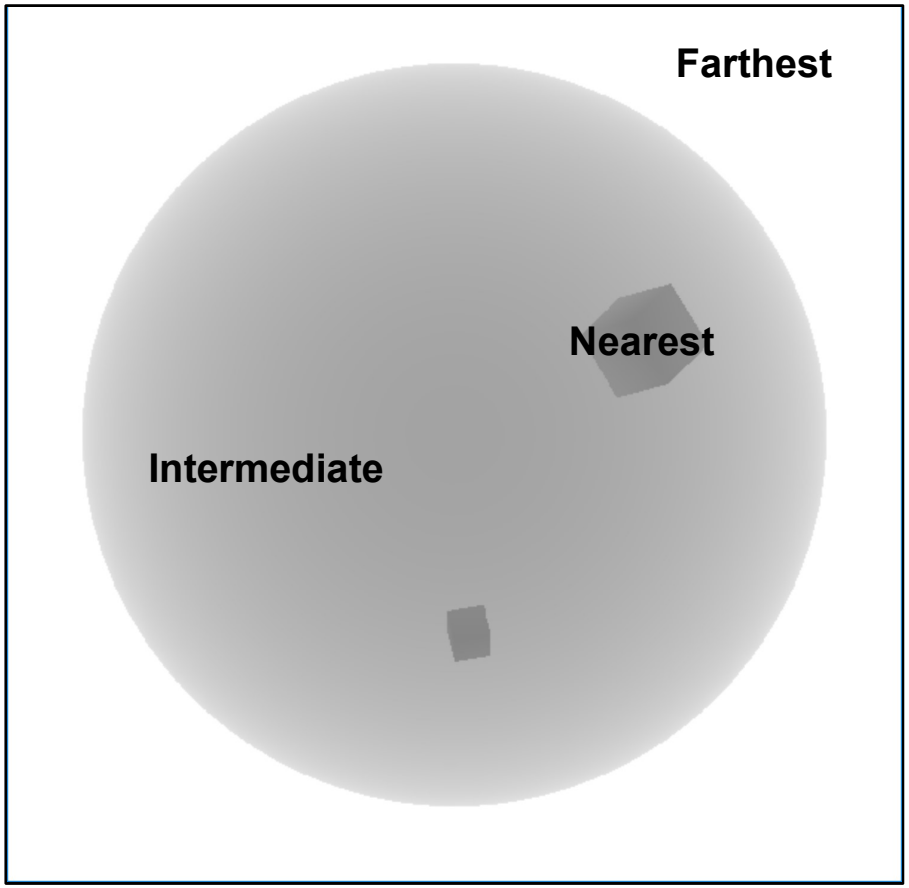


OpenGL Demo Program: The Depth Shadow Map

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, not any colors.

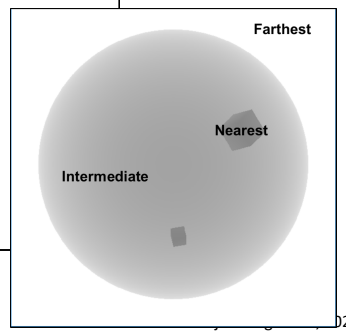
In this grayscale image, dark colors are nearest to the eye, light colors are farther away.



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

In shadows.cpp:
InitGraphics( )

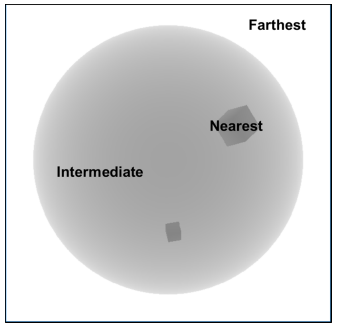
```
// create a framebuffer object and a depth texture object:
glGenFramebuffers(1, &DepthFramebuffer );
glGenTextures(       1, &DepthTexture );

//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_NEAREST);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
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);
```



OpenGL Demo Program: Rendering into the Depth Shadow Map


```
//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);

//this matrix is the transformation matrix that the vertex shader will use instead of glViewProjectionMatrix:
glm::mat4 lightView = glm::lookAt(lightPos, glm::vec3(0., 0., 0.), glm::vec3(0., 1., 0.));
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->Use(0);
glBindFramebuffer(GL_FRAMEBUFFER, 0);
```

In shadows.cpp:
Display, I



OpenGL Demo Program: Rendering using the Depth Shadow Map


```
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 view = glm::lookAt(eye, look, up);
glm::vec3 scale = glm::vec3(Scale, Scale, Scale);
view = glm::scale(view, scale);
glm::vec3 xaxis = glm::vec3(1., 0., 0.);
glm::vec3 yaxis = glm::vec3(0., 1., 0.);
view = glm::rotate(view, glm::radians(Yrot), yaxis);
view = glm::rotate(view, glm::radians(Xrot), xaxis);

RenderWithShadows->SetUniformVariable((char*)"uView", view);
glm::mat4 proj = glm::perspective(glm::radians(75.f), 1.f, .1f, 100.f);
RenderWithShadows->SetUniformVariable((char*)"uProj", proj);
DisplayOneScene(RenderWithShadows);
RenderWithShadows->Use(0);
```

In shadows.cpp: Display, II

OpenGL Demo Program: Rendering using the Depth Shadow Map


```
uniform mat4 uLightSpaceMatrix;
uniform mat4 uModel;

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

GetDepth.vert

```
uniform vec3 uColor;

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

GetDepth.frag

Oregon State University
Computer Graphics

OpenGL Demo Program: Rendering using the Depth Shadow Map

RenderWithShadows.vert

```
uniform mat4  uLightSpaceMatrix;
uniform mat4  uModel;
uniform mat4  uView;
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 = uView * uModel * gl_Vertex;
	vec3 tnorm = normalize( mat3(uModel) * gl_Normal );
	vNs = tnorm;
	vLs = LightPosition      - ECposition.xyz;
	vEs = vec3( 0., 0., 0. ) - ECposition.xyz;

	vFragPosLightSpace = uLightSpaceMatrix  * uModel * gl_Vertex;
	gl_Position        = uProj * uView      * uModel * gl_Vertex;
}
```

OpenGL Demo Program: Rendering using the Depth Shadow Map

RenderWithShadows.frag, I

```
uniform vec3          uColor;
uniform sampler2D uShadowMap;

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

out vec4 fFragColor;

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;
}
```

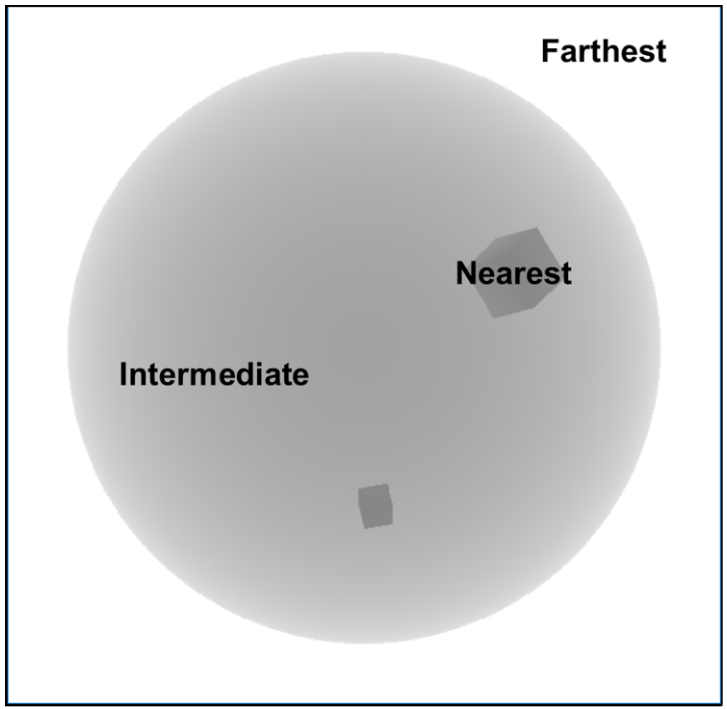
Co

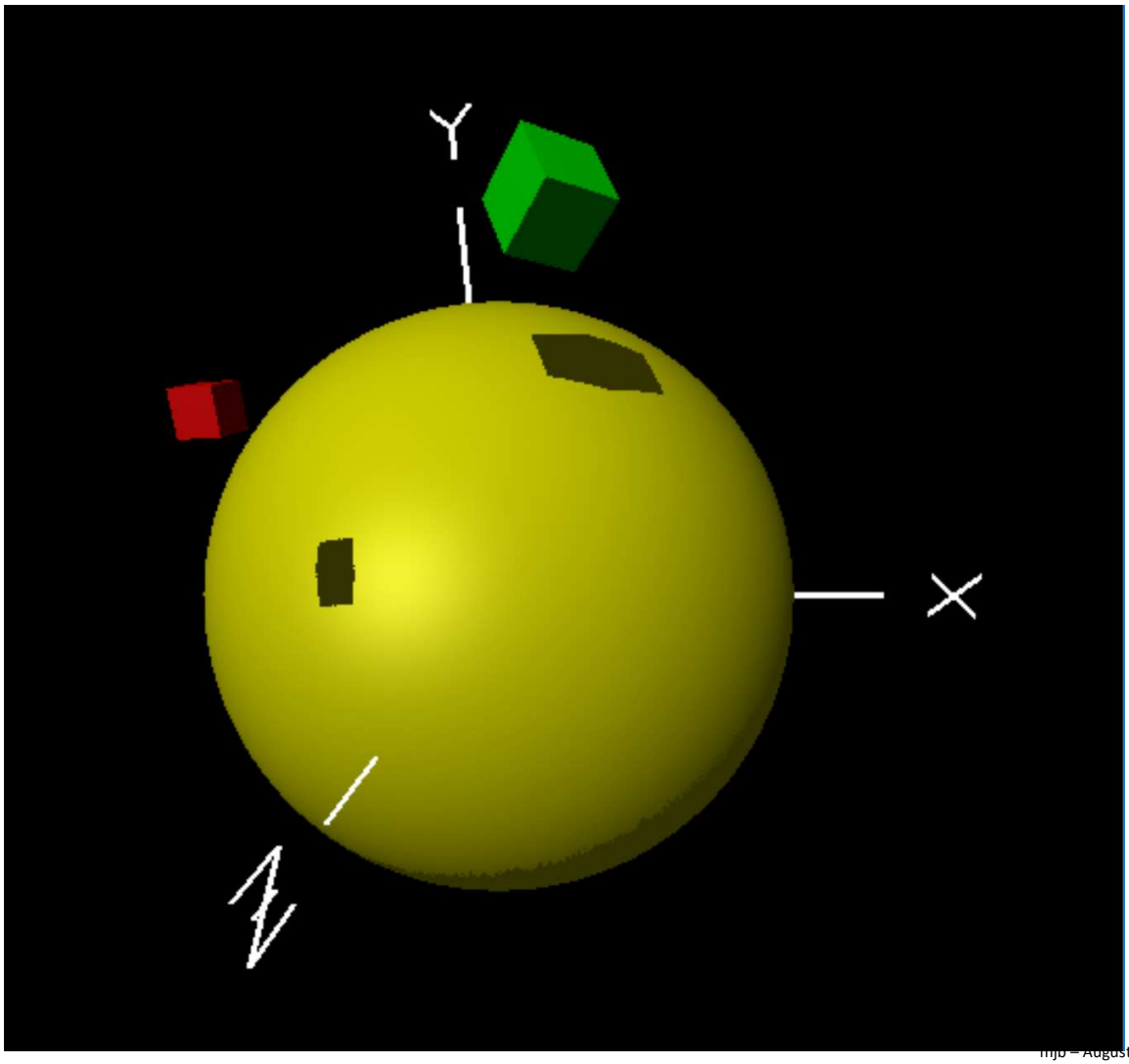
OpenGL Demo Program: Rendering using the Depth Shadow Map


```
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( ! 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;
            }
        }
    }
    fFragColor = vec4( lighting, 1. );
}
```

RenderWithShadows.frag, II

OpenGL Demo Program: Rendering into the Depth Shadow Map

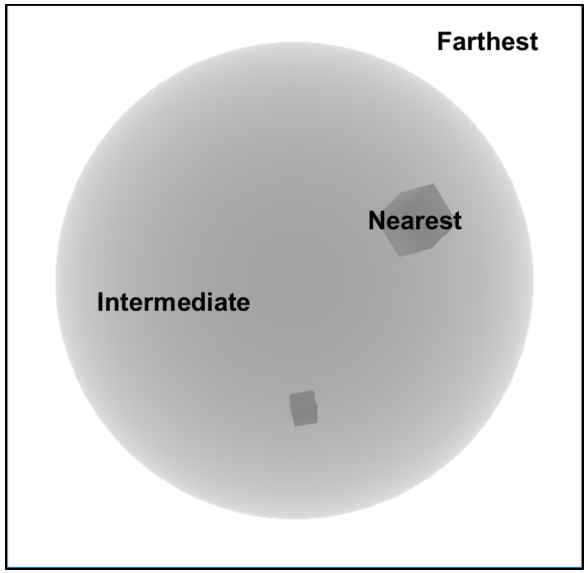




How Did the Demo Program Render the 2D Shadow Map?

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();
```



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

DisplayShadowMap.vert

```
out vec2 vST;

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

DisplayShadowMap.frag

```
uniform sampler2D uShadowMap;

in vec2 vST;

out vec4 fFragColor;

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