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Casting Shadows in OpenGL

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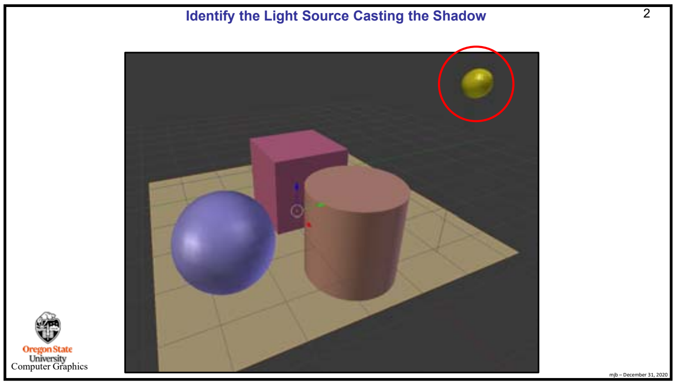

Identify the Light Source Casting the Shadow

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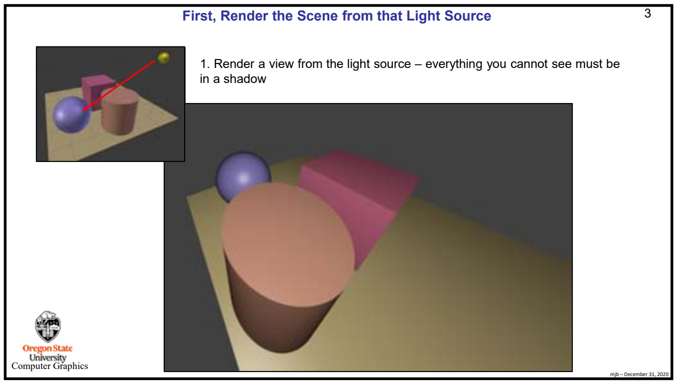
2



First, Render the Scene from that Light Source

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

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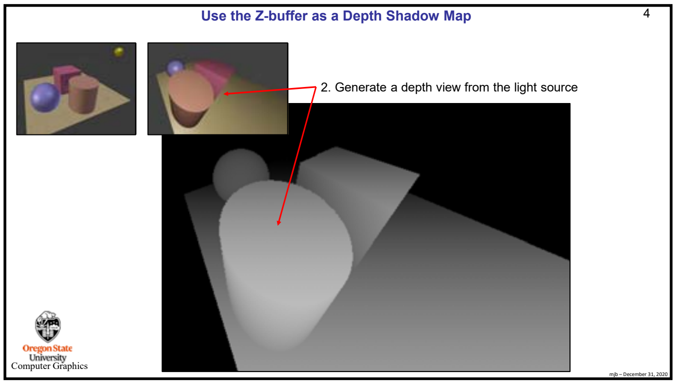

Use the Z-buffer as a Depth Shadow Map

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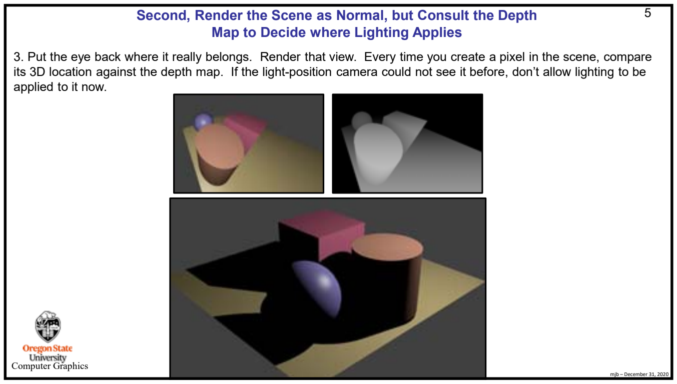
2. Generate a depth view from the light source

4



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

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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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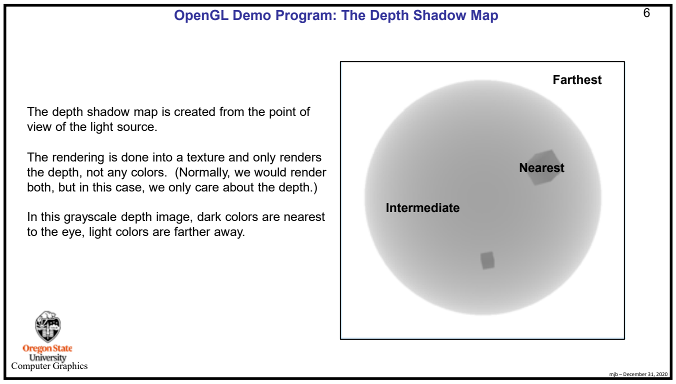

OpenGL Demo Program: The Depth Shadow Map

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

The rendering is done into a texture and only renders the depth, not any colors. (Normally, we would render both, but in this case, we only care about the depth.)

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

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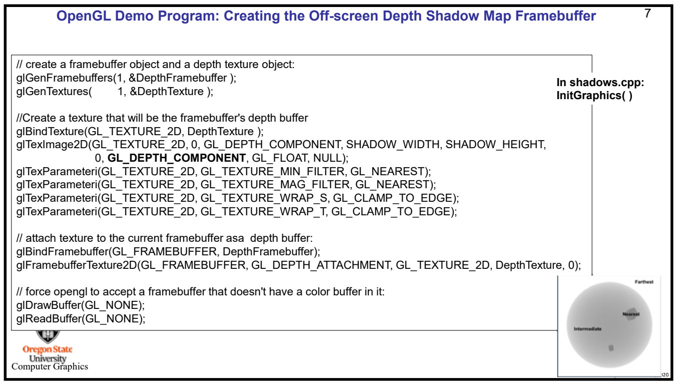
Farthest
Nearest
Intermediate

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

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```
// 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 the current framebuffer asa  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);
```

In shadows.cpp:
InitGraphics( )

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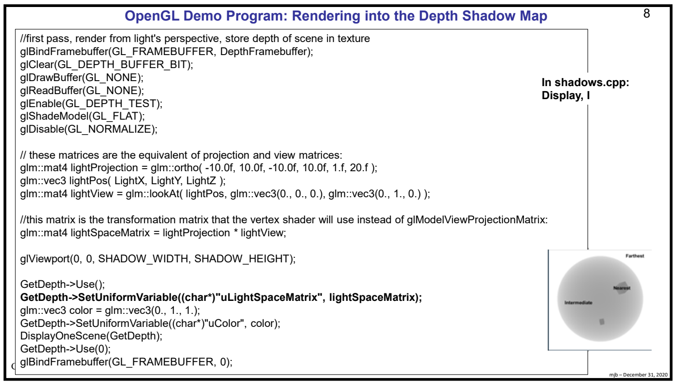
Farthest
Nearest
Intermediate

OpenGL Demo Program: Rendering into the Depth Shadow Map

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```
//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->Use(0);
glBindFramebuffer(GL_FRAMEBUFFER, 0);
```

In shadows.cpp:
Display, I

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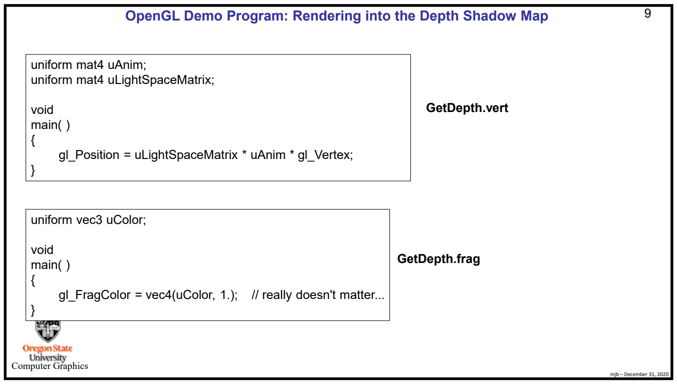

OpenGL Demo Program: Rendering into the Depth Shadow Map

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```
uniform mat4 uAnim;
uniform mat4 uLightSpaceMatrix;

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

GetDepth.vert

```
uniform vec3 uColor;

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

GetDepth.frag

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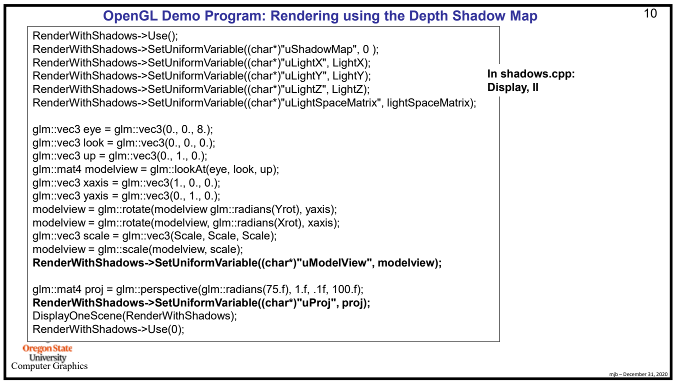

OpenGL Demo Program: Rendering using the Depth Shadow Map

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```
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);
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);
glm::vec3 scale = glm::vec3(Scale, Scale, Scale);
modelview = glm::scale(modelview, scale);
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->Use(0);
```

In shadows.cpp:
Display, II

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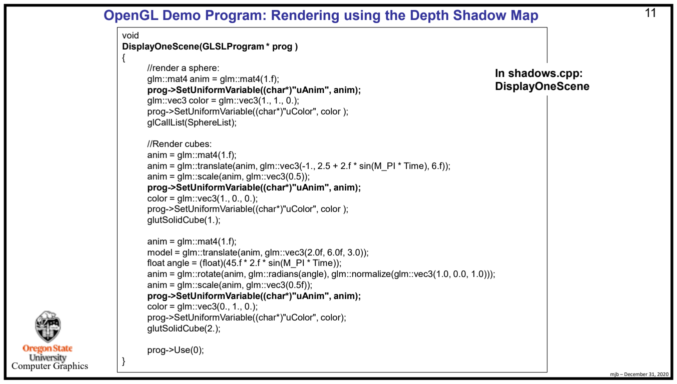

OpenGL Demo Program: Rendering using the Depth Shadow Map

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```
void
DisplayOneScene(GLSLProgram * prog )
{
        //render a sphere:
        glm::mat4 anim = glm::mat4(1.f);
        prog->SetUniformVariable((char*)"uAnim", anim);
        glm::vec3 color = glm::vec3(1., 1., 0.);
        prog->SetUniformVariable((char*)"uColor", color );
        glCallList(SphereList);

        //Render cubes:
        anim = glm::mat4(1.f);
        anim = glm::translate(anim, glm::vec3(-1., 2.5 + 2.f * sin(M_PI * Time), 6.f));
        anim = glm::scale(anim, glm::vec3(0.5));
        prog->SetUniformVariable((char*)"uAnim", anim);
        color = glm::vec3(1., 0., 0.);
        prog->SetUniformVariable((char*)"uColor", color );
        glutSolidCube(1.);

        anim = glm::mat4(1.f);
        model = glm::translate(anim, glm::vec3(2.0f, 6.0f, 3.0));
        float angle = (float)(45.f * 2.f * sin(M_PI * Time));
        anim = glm::rotate(anim, glm::radians(angle), glm::normalize(glm::vec3(1.0, 0.0, 1.0)));
        anim = glm::scale(anim, glm::vec3(0.5f));
        prog->SetUniformVariable((char*)"uAnim", anim);
        color = glm::vec3(0., 1., 0.);
        prog->SetUniformVariable((char*)"uColor", color);
        glutSolidCube(2.);

        prog->Use(0);
}
```

In shadows.cpp:
DisplayOneScene

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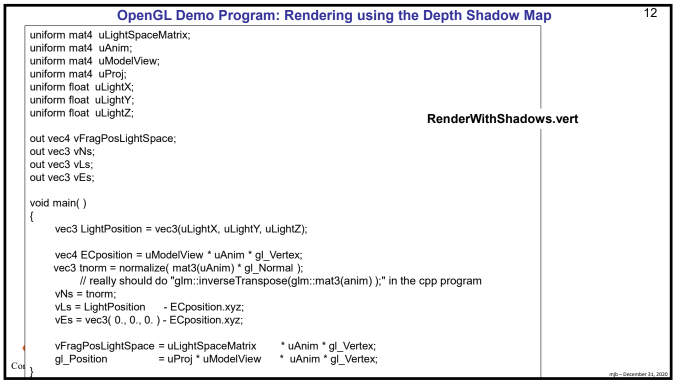

OpenGL Demo Program: Rendering using the Depth Shadow Map

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```
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 );
             // really should do "glm::inverseTranspose(glm::mat3(anim) );" in the cpp program
       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;
}
```

RenderWithShadows.vert

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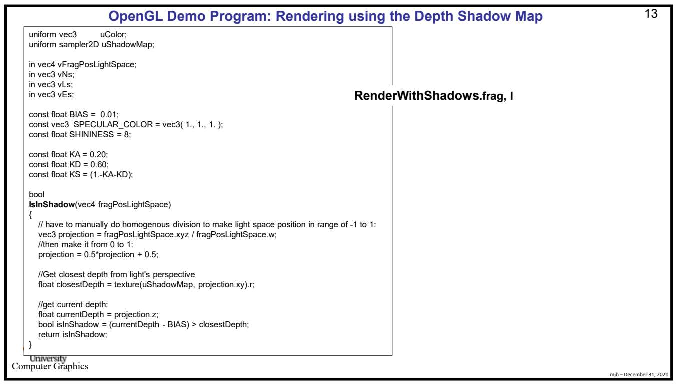

OpenGL Demo Program: Rendering using the Depth Shadow Map

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RenderWithShadows.frag, I

```
uniform vec3         uColor;
uniform sampler2D uShadowMap;

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;
}
```

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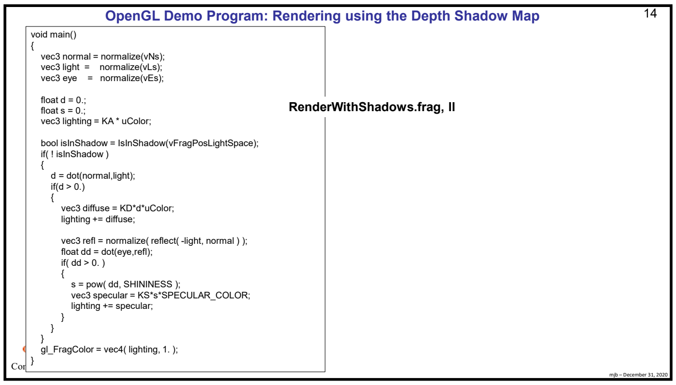

OpenGL Demo Program: Rendering using the Depth Shadow Map

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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( ! 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. );
}
```

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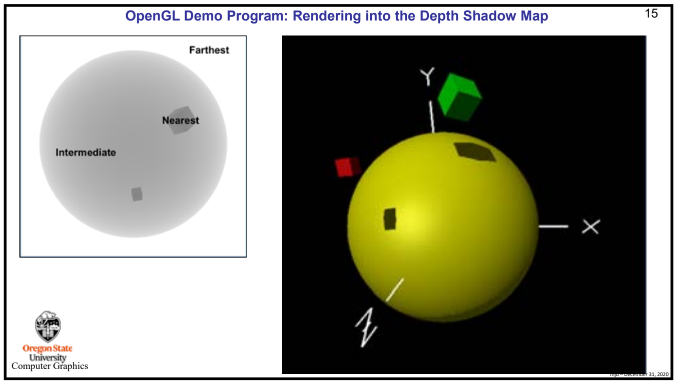

OpenGL Demo Program: Rendering into the Depth Shadow Map

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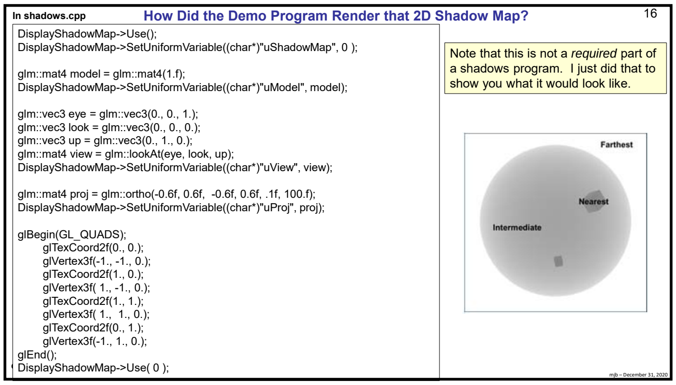

In shadows.cpp

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

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```
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->Use( 0 );
```

Note that this is not a *required* part of a shadows program. I just did that to show you what it would look like.

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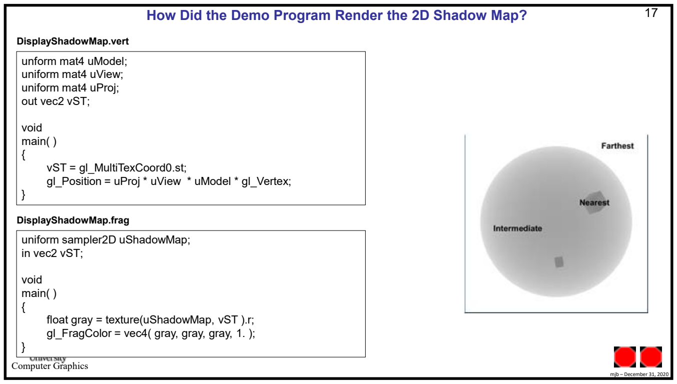

How Did the Demo Program Render the 2D Shadow Map?

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DisplayShadowMap.vert

```
unform 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

```
uniform sampler2D uShadowMap;
in vec2 vST;

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

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