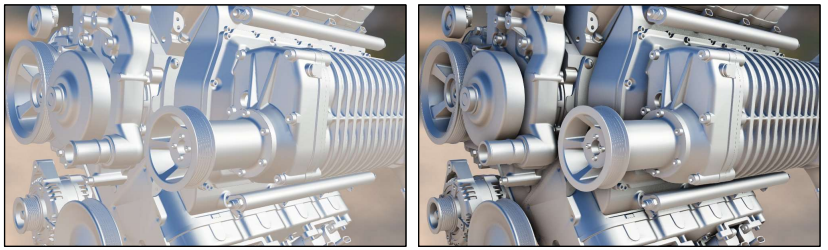
Screen Space Ambient Occlusion (SSAO)

Oregon State University
Mike Bailey
mjb@cs.oregonstate.edu

Oregon State University
Computer Graphics

1

A Neat Global Illumination-ish Trick: Screen Space Ambient Occlusion (SSAO)



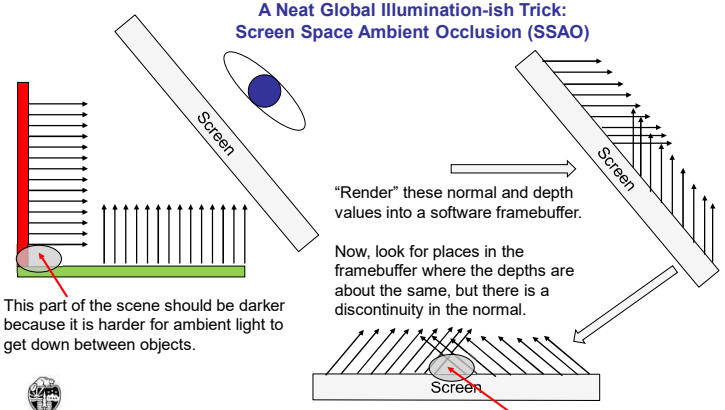
Kitware

The idea is to imitate the darkness that appears in crevices that light has a hard time getting to.

Oregon State University
Computer Graphics

2

A Neat Global Illumination-ish Trick: Screen Space Ambient Occlusion (SSAO)



This part of the scene should be darker because it is harder for ambient light to get down between objects.

"Render" these normal and depth values into a software framebuffer.

Now, look for places in the framebuffer where the depths are about the same, but there is a discontinuity in the normal.

Make that part of the scene darker.

Oregon State University
Computer Graphics

3

First, Create a GPU Memory Framebuffer

```
// create a framebuffer object and a depth texture object:
glGenFramebuffers(1, &NZFramebuffer);
glGenTextures(1, &NZTexture);
glGenTextures(1, &NZDepth);

glBindFramebuffer(GL_FRAMEBUFFER, NZFramebuffer);

// create a texture that will be the framebuffer's color buffer (to store normal and z):
glBindTexture(GL_TEXTURE_2D, NZTexture);
glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA32F, SSAO_WIDTH, SSAO_HEIGHT, 0, GL_RGBA, 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);
glFramebufferTexture2D(GL_FRAMEBUFFER, GL_COLOR_ATTACHMENT0, GL_TEXTURE_2D, NZTexture, 0);

// create a texture that will be the framebuffer's depth buffer:
glBindTexture(GL_TEXTURE_2D, NZDepth);
glTexImage2D(GL_TEXTURE_2D, 0, GL_DEPTH_COMPONENT, SSAO_WIDTH, SSAO_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);
glFramebufferTexture2D(GL_FRAMEBUFFER, GL_DEPTH_ATTACHMENT, GL_TEXTURE_2D, NZDepth, 0);

glBindFramebuffer(GL_FRAMEBUFFER, 0);
```

Oregon State University
Computer Graphics

4

SSAO is a Two-pass Algorithm:
Pass #1: Render the Surface Normals and Depths into a GPU Memory Framebuffer

5

GetNZ.vert

```
#version 330 compatibility

// note: in this pass, we are not rendering any colors, so no lighting info is necessary
// however, transformation matrix info is necessary so that the scene is in the right orientation to get the normal and z

uniform mat4  uAnim;
uniform mat4  uModelView;
uniform mat4  uProj;

out vec3  vN;
out vec4  vP;

void
main( )
{
	vN = normalize( vec3( uAnim * vec4(gl_Normal,0.) ) );
		// we want the normal in model coordinates, not world coords or eye coords
	vP = uProj * uModelView  * uAnim * gl_Vertex;
		// we want the z in eye coordinates because we need to divide by the .w
	gl_Position = vP;
}
```

Oregon State University Computer Graphics

mjb – January 20, 2022

5

SSAO is a Two-pass Algorithm:
Pass #1: Render the Surface Normals and Depths into a GPU Memory Framebuffer

6

GetNZ.frag

```
#version 330 compatibility

// note: in this pass, we are not rendering any colors, so no lighting info is necessary

in vec3   vN;
in vec4   vP;

void main()
{
	vec3 N = normalize(vN);		// in the range  0. to +1.
	float Z = vP.z / vP.w;		// in the range -1. to +1.
	gl_FragColor = vec4(N, Z);	// this gets written into the uNZMap texture
}
```

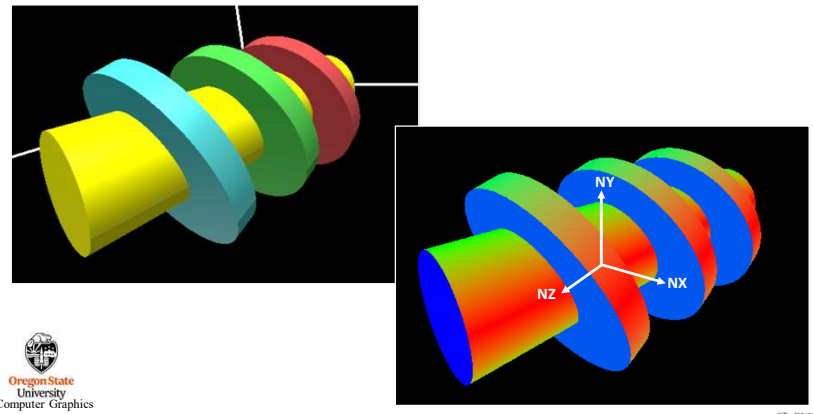
Oregon State University Computer Graphics

mjb – January 20, 2022

6

Here is the Scene and What the Normal Vectors Look Like, Rendered as Colors

7



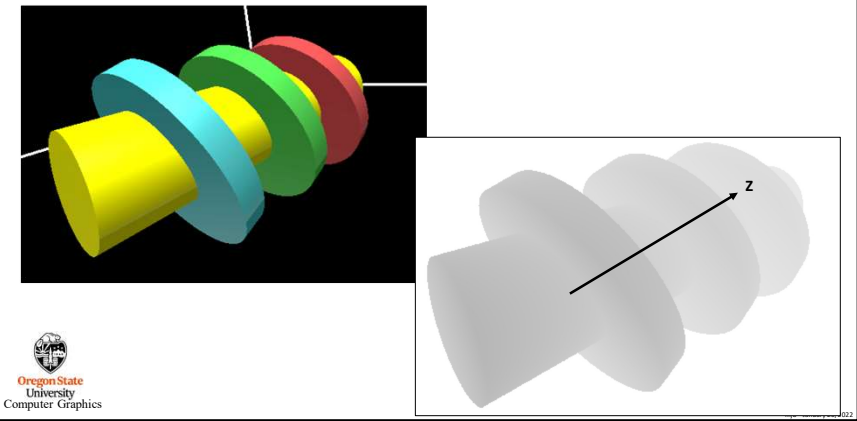
Oregon State University Computer Graphics

mjb – January 20, 2022

7

Here is the Scene and What the Z Values Look Like, Rendered as Grayscale

8



Oregon State University Computer Graphics

8

Pass #2: Render the 3D Scene and Adjust the Lighting Anywhere the SSAO Conditions are Right

RenderWithNZ.vert

```
#version 330 compatibility

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

out vec3 vNs;
out vec3 vLs;
out vec3 vEs;
out vec4 vP;

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

	vP = uProj * uModelView   * uAnim * gl_Vertex;  // need the projection matrix to put z values in the proper range
	gl_Position = vP;
}
```


9

Pass #2: Render the 3D Scene and Adjust the Lighting Anywhere the SSAO Conditions are Right

RenderWithNZ.frag, I

```
#version 330 compatibility

uniform vec3      uColor;
uniform sampler2D uNZMap;
uniform int       uSSAOOn;

in vec3 vNs;
in vec3 vLs;
in vec3 vEs;
in vec4 vP;

const float uDelta =  0.0050;
const float uZTol  =  0.0010;
const float uNTol  = -0.00001;

float Ds, Dt;          // change in s and t to get tothe next texel
int Nums = 15;         // must be an odd number
int Numt = 15;         // must be an odd number

const float MININTEN = 0.50;

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);
```


10

Pass #2: Render the 3D Scene and Adjust the Lighting Anywhere the SSAO Conditions are Right

RenderWithNZ.frag, II

```
float
IsInACrevice( vec2 st )
{
	float inten = 1.;
	// get the normal's and z's:
	vec4  rgba00 = texture(uNZMap, st );
	vec3  n00    = normalize(rgba00.rgb);
	float z00    = rgba00.a;
	for( int it = -Numt/2; it <= Numt/2; it++ )
	{
		vec2 newst;
		newst.t = st.t + Dt * float(it);
		for( int is = -Nums/2; is <= Nums/2; is++ )
		{
			if( is==0  &&  it==0 )		continue;
			newst.s = st.s + Ds * float(is);
			vec4  rgba = texture(uNZMap, newst );
			vec3  n    = normalize(rgba.rgb);
			float z    = rgba.a;
			// we are in a crevice if:
			// 1. the surrounding z values are approximately the same, and,
			// 2. the surrounding normals are approximately different

			if( abs(z00-z) < uZTol  && dot( n00, n ) < uNTol  )
			{
				float i = 1. - MININTEN * float( abs(is) + abs(it) ) / float( Nums/2 + Numt/2 );
				if( i < inten )
					inten = i;     // keep the minimum
			}
		}
	}
	return inten;
}
```

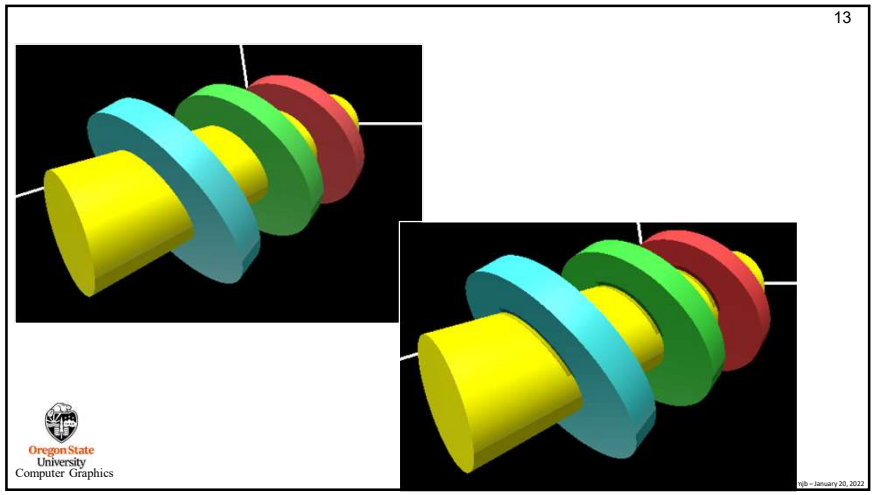

11

Pass #2: Render the 3D Scene and Adjust the Lighting Anywhere the SSAO Conditions are Right

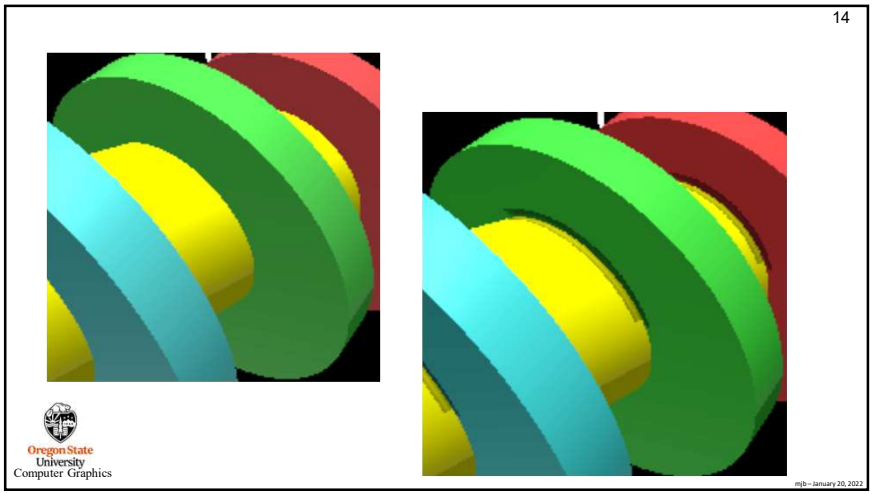
RenderWithNZ.frag, III

```
void
main()
{
	vec2 numtexels = textureSize( uNZMap, 0 );
	Ds = 1. / numtexels.s;
	Dt = 1. / numtexels.t;
	vec3 normal = normalize(vNs);
	vec3 light  = normalize(vLs);
	vec3 eye    = normalize(vEs);

	// have to manually do homogenous division to make position in range of -1 to 1:
	vec2 st = vP.xy / vP.w;// in the range -1. to 1.
	st = vec2(0.5,0.5) * ( st + vec2(1.,1.) );// now in the range 0. to 1. so can use as a texture lookup

	// get the normal and z at the uNZMap texture coords (st.s,st.t)

	float Inten = 1.;
	if( uSSAOOn != 0 )
		Inten = IsInACrevice( st );

	vec3 lighting = KA * uColor;
	float d = dot(normal,light);

	. . . Lighting . . .

	gl_FragColor = vec4( Inten * lighting, 1. );
}
```

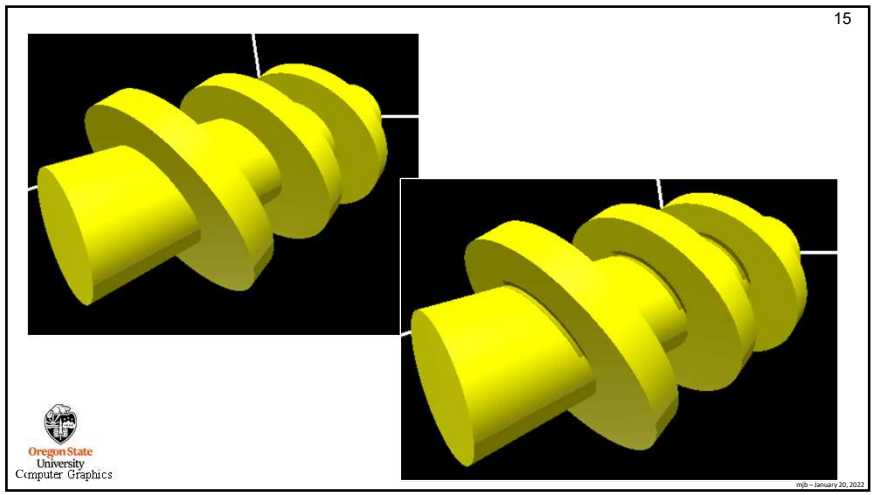

12



13



14



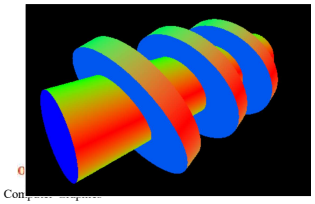
15

16

How to Display the Colored Normal Vectors

DisplayNMap.vert

```
#version 330 compatibility

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

out vec4 vP;

void
main()
{
        vP = uProj * uView  * uModel * gl_Vertex;
        gl_Position = vP;
}
```



DisplayNMap.frag

```
#version 330 compatibility

uniform sampler2D uNZMap;
in vec4 vP;

void
main( )
{
        vec2 st = vP.xy / vP.w;// in the range -1. to 1.
        st = vec2(0.5,0.5) * ( st + vec2(1.,1.) );
                // now in the range 0. to 1. so can use it for a texture lookup

        // get the normal at the uNZMap texture coords (st.s,st.t)
        vec3 n = texture( uNZMap, st ).rgb;// in the range -1. to +1.
        n = abs(n);// in the range 0. to +1.
        gl_FragColor = vec4( n, 1. );// display normal components as rgb
}
```

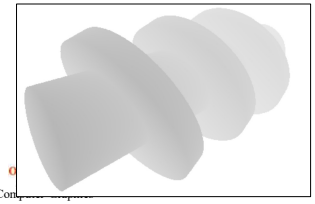
mjb – January 20, 2022

16

How to Display the Grayscale Depth Values

DisplayZMap.vert

```
#version 330 compatibility

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

out vec4 vP;

void
main()
{
	vP = uProj * uView  * uModel * gl_Vertex;
	gl_Position = vP;
}
```



DisplayZMap.frag

```
#version 330 compatibility

uniform sampler2D uNZMap;
in vec4 vP;

void
main( )
{
	vec2 st = vP.xy / vP.w;// in the range -1. to 1.
	st = vec2(0.5,0.5) * ( st + vec2(1.,1.) );
		// now in the range 0. to 1. so can use in a texture lookup

	// get the z at the uNZMap texture coords (st.s,st.t)
	float Z = texture( uNZMap, st ).a;
	Z = 0.5 * ( Z + 1. );	// now in the range 0. to 1.
	gl_FragColor = vec4( Z, Z, Z, 1. );// greyscale
}
```

mjb – January 20, 2022