Using the Stencil Buffer

Oregon State University

Mike Bailey

mjb@cs.oregonstate.edu
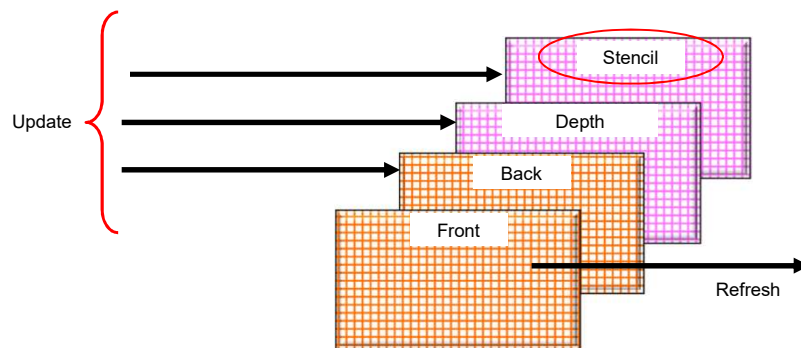
Oregon State
University
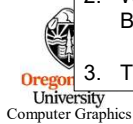Computer Graphics

stencilbuffer.pptx

mjb – August 30, 2022

The Framebuffers

Here's what the Stencil Buffer can do for you:

1. While drawing into the Back Buffer, you can write values into the Stencil Buffer at the same time.

2. While drawing into the Back Buffer, you can do arithmetic on values in the Stencil Buffer at the same time.

3. The Stencil Buffer can be used to write-protect certain parts of the Back Buffer.

Oregon State
University
Computer Graphics

mjb – August 30, 2022

You Can Think of the Stencil Buffer as a Separate Framebuffer, or, You Can Think of it as being Per-Pixel

Both are correct, but I like thinking of it "per-pixel" better.

One pixel

Oregon State University
Computer Graphics

mjb – August 30, 2022

The Stencil Buffer is Tested Per-Pixel, Very Much Like the Depth Buffer is

glStencilFunc(func, ref, mask)

This specifies the comparison test that is to be done per-pixel.

func can be any of GL_NEVER, GL_ALWAYS, GL_EQUAL, GL_NOTEQUAL, GL_LESS, GL_LEQUAL, GL_GREATER, GL_GEQUAL

ref is an integer reference value that is used to test the pixel's existing stencil value against using the chosen **func**

mask is set to 1 in all these examples

The stencil test produces a *true* or *false* value at each pixel where drawing is to be done.

```
if( ref <func>  S_existing is true )
{
        Allow the color write to the existing pixel to take place;
        Modify the pixel's existing stencil value depending on what the glStencilOp says to do;
}
```

Oregon State University
Computer Graphics

mjb – August 30, 2022

This Tells You What to Do with the *true* or *false* Value from the Stencil Test

glStencilOp(sfail, zfail, zpass)

This specifies how a pixel's stencil value is modified when a fragment passes or fails the stencil test depending on what combinations of *true* and *false* the stencil test and the depth buffer test produce. If the stencil test fails, then *sfail* happens. If the stencil test succeeds, then either *zfail* or *zpass* happen depending on if the depth-buffer test failed or succeeded.

The three values can be any of:

GL_KEEP	Retain the existing stencil value
GL_ZERO	Set the stencil value to zero
GL_REPLACE	Replace the stencil value with **ref** from the Stencil Func
GL_INCR	Increment the stencil value, with clamping
GL_INCR_WRAP	Increment the stencil value, without clamping
GL_DECR	Decrement the stencil value, with clamping
GL_DECR_WRAP	Decrement the stencil value, without clamping
GL_INVERT	Bitwise toggle the stencil bits: 0's → 1's, 1's → 0's

```
if( ref  <func>  S_existing is true )
{
        Allow the color write to the existing pixel to take place;
        Modify the pixel's existing stencil value depending on what the glStencilOp says to do;
}
```

Oregon State
University
Computer Graphics

mjb – August 30, 2022

Setting Up the Stencil Buffer

```
// at the top of the program:

const int STENCILBIT = 1;
const int DEFAULT_STENCIL = 0;
const float BIGX = 2.;
const float BIGY = BIGX;
const float CLOSEZ = -1.;
float Xlens, Ylens;
float Box = 0.40f;

// in InitGraphics( ):

glutInitDisplayMode( GLUT_RGBA | GLUT_DOUBLE | GLUT_DEPTH | GLUT_STENCIL );

glClearColor( BACKGROUND_COLOR );
glClearStencil( DEFAULT_STENCIL );


// in Display( ):
. . .
glClear( GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT | GL_STENCIL_BUFFER_BIT );
. . .
glEnable( GL_STENCIL_TEST );
. . .
```
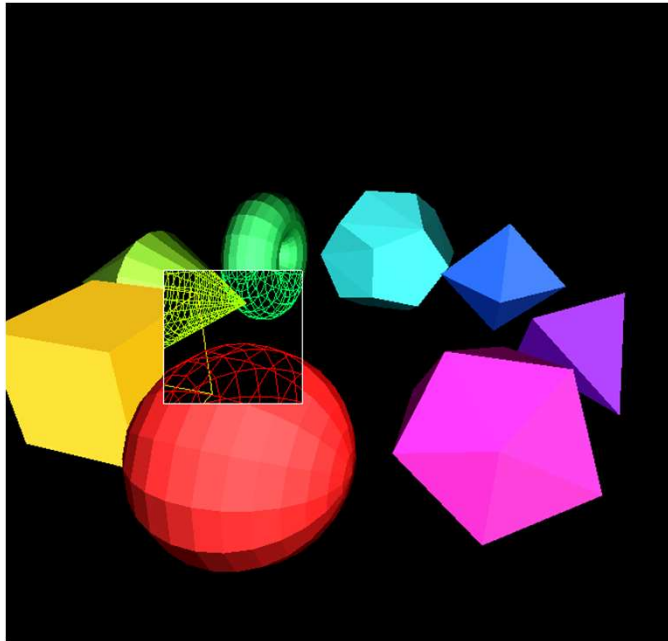
University
Computer Graphics

mjb – August 30, 2022

Using the Stencil Buffer to Create a *Magic Lens*

mjb – August 30, 2022

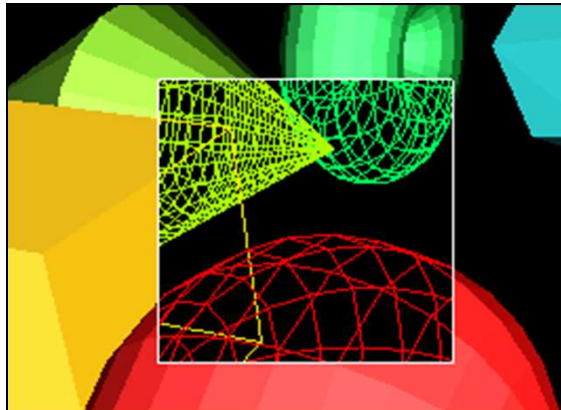## Using the Stencil Buffer to Create a *Magic Lens*

1. Clear the SB = 0
2. Enable the SB
3. Write protect the color buffer and depth buffer
4. Draw a filled square, while setting SB = 1
5. Write-enable the color buffer and depth buffer
6. Draw the solids wherever SB == 0
7. Draw the wireframes wherever SB == 1
8. Disable the SB

mjb – August 30, 2022

Moving the Magic Lens with the Middle Mouse Button

```
// in MouseMotion( ):

 if( ActiveButton & MIDDLE )
{
    if( Stencil == LENS )
    {
        int w = glutGet( GLUT_WINDOW_WIDTH );
        int h = glutGet( GLUT_WINDOW_HEIGHT );
        Xlens =  2.*(float)x/(float)w  - 1.;
        Ylens = -2.*(float)y/(float)h  + 1.;
    }
    else
    {
        Scale += SCLFACT * (float) ( dx - dy );
    }
}
```

x/w ranges from 0. to 1.
y/h ranges from 1. to 0
Xlens and Ylens range from -1. to 1. (NDC)

Oregon State
University
Computer Graphics

mjb – August 30, 2022

Using the Stencil Buffer to Create a *Magic Lens*

```
glMatrixMode( GL_PROJECTION );
glLoadIdentity( );

glMatrixMode( GL_MODELVIEW );
glLoadIdentity( );
```

These two identity transformation matrices cause
the drawing to take place in NDC (-1 to 1.), which
is what Xlens, Ylens, and Box are defined in

```
glDepthMask( GL_FALSE );
glColorMask( GL_FALSE, GL_FALSE, GL_FALSE, GL_FALSE );
```

Write protect the depth and color buffers

```
glStencilFunc( GL_ALWAYS, 1, STENCILBIT );
glStencilOp( GL_REPLACE, GL_REPLACE, GL_REPLACE );
```

Everywhere we draw, always
replace the stencil value with a **1**

```
glBegin( GL_QUADS );
    glVertex2f( Xlens-Box/2.,  Ylens-Box/2. );
    glVertex2f( Xlens+Box/2., Ylens-Box/2. );
    glVertex2f( Xlens+Box/2., Ylens+Box/2. );
    glVertex2f( Xlens-Box/2.,  Ylens+Box/2. );
glEnd( );
```

Draw a filled-in box

```
glColorMask( GL_TRUE, GL_TRUE, GL_TRUE, GL_TRUE );
glDepthMask( GL_TRUE );
```

Write-enable the depth and color buffers

Oregon State
University
Computer Graphics

mjb – August 30, 2022

Using the Stencil Buffer to Create a *Magic Lens*

```
<< set the GL_PROJECTION and GL_MODELVIEW matrices as normal >>

glEnable( GL_LIGHTING );
glStencilFunc( GL_EQUAL, 0, STENCILBIT );
glStencilOp( GL_KEEP, GL_KEEP, GL_KEEP );
glShadeModel( GL_SMOOTH );
for( int i = 0; i < 8; i++ )
{
        glCallList( SolidLists[ i ] );
}
```

Draw the solids everywhere *except* inside the lens

```
glDisable( GL_LIGHTING );
glStencilFunc( GL_EQUAL, 1, STENCILBIT );
glStencilOp( GL_KEEP, GL_KEEP, GL_KEEP );
glShadeModel( GL_FLAT );
for( int i = 0; i < 8; i++ )
{
        glCallList( WireLists[ i ] );
}
```

Draw the wireframes *only* inside the lens

```
<< set the GL_PROJECTION and GL_MODELVIEW matrices to identity again >>

glDisable( GL_LIGHTING );
glShadeModel( GL_FLAT );
glDisable( GL_DEPTH_TEST );
glColor3f( 1., 1., 1. );
glBegin( GL_LINE_LOOP );
        glVertex2f( Xlens-Box/2.,  Ylens-Box/2. );
        glVertex2f( Xlens+Box/2., Ylens-Box/2. );
        glVertex2f( Xlens+Box/2., Ylens+Box/2. );
        glVertex2f( Xlens-Box/2.,  Ylens+Box/2. );
glEnd( );
glEnable( GL_DEPTH_TEST );
```

Draw the boundary of the lens

Oregon State University
Computer Graphics

mjb – August 30, 2022

I Once Used the Stencil Buffer to Create a *Magic Lens* for Volume Data[12]
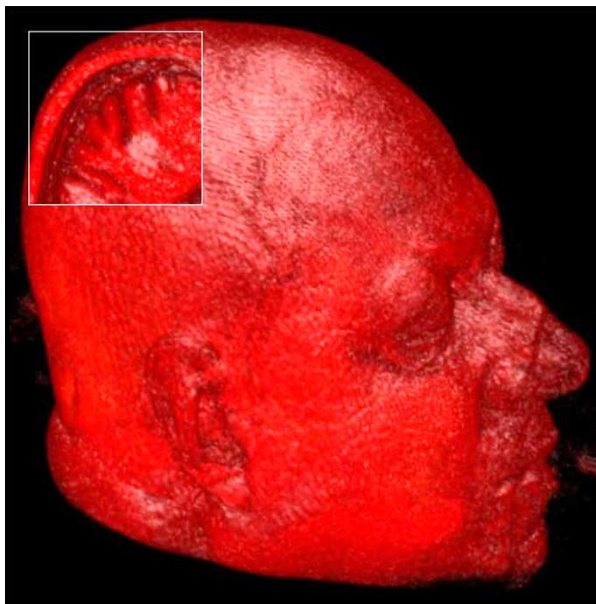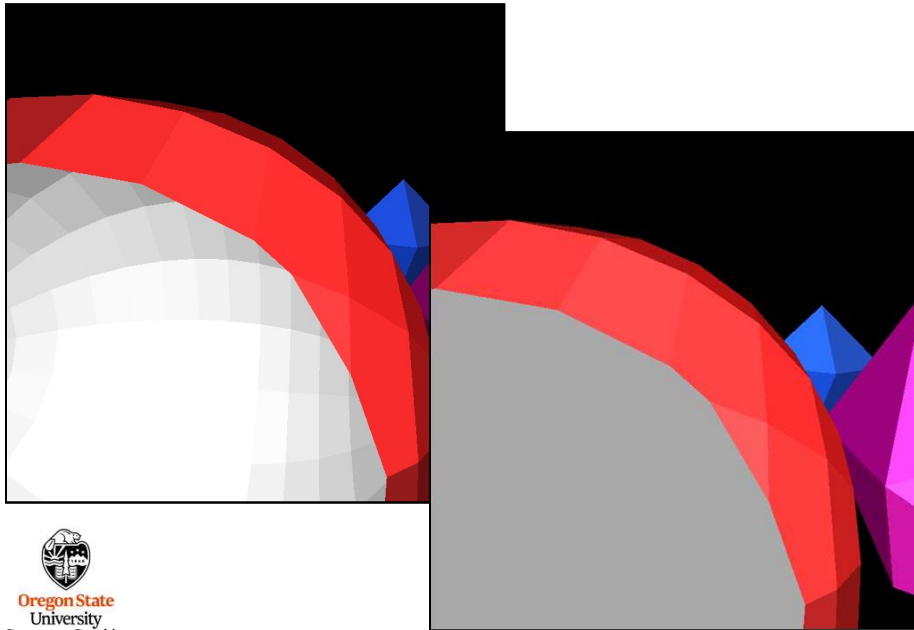

In this case, the scene inside the lens was created by drawing the same object, but drawing it with its near clipping plane being farther away from the eye position

University
Computer Graphics

mjb – August 30, 2022

1. Clear the SB = 0
2. Enable the SB
3. Draw the polygons, setting SB = ~ SB: 0's → 1's, 1's → 0's
4. Draw a large gray polygon in front of the entire scene wherever SB != 0
5. Disable the SB
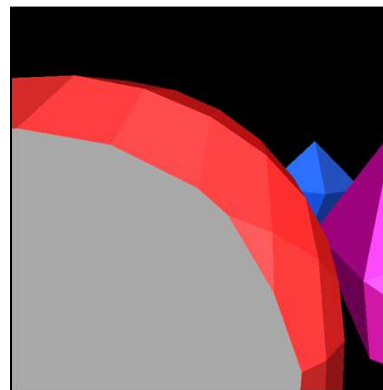
Using the Stencil Buffer to Perform *Polygon Capping*

```
glStencilFunc( GL_ALWAYS, 0, STENCILBIT );
glStencilOp( GL_INVERT, GL_INVERT, GL_INVERT );
<< draw all objects >>
```

As we draw the **solid** objects, always invert the stencil bits:
0's → 1's
1's→ 0's

Because these were all **solid** objects, they had a front face and a back face drawn. Thus, most of the time, the SB values got inverted back to 0. If they didn't, that means that the solid object penetrated the near clipping plane and now needs to be capped.

```
glMatrixMode( GL_PROJECTION );
glLoadIdentity( );

glMatrixMode( GL_MODELVIEW );
glLoadIdentity( );

glDisable( GL_LIGHTING );
glDisable( GL_LIGHT0 );
glStencilFunc( GL_NOTEQUAL, 0, STENCILBIT );
glStencilOp( GL_KEEP, GL_KEEP, GL_KEEP );
glShadeModel( GL_FLAT );
glColor3f( .5f, .5f, .5f );
glBegin( GL_QUADS );
    glVertex3f( -BIGX, -BIGY, CLOSEZ );
    glVertex3f(  BIGX, -BIGY, CLOSEZ );
    glVertex3f(  BIGX,  BIGY, CLOSEZ );
    glVertex3f( -BIGX,  BIGY, CLOSEZ );
glEnd( );
```
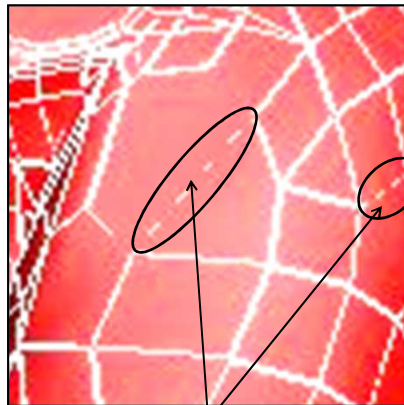
Only draw the large gray plane in front where the SB != 0

Oregon State University
Computer Graphics

mjb – August 30, 2022

Using the Stencil Buffer to Better Outline Polygons

Before

After

Z-fighting

Oregon State University
Computer Graphics

mjb – August 30, 2022

Using the Stencil Buffer to Better Outline Polygons

```
Clear the SB = 0

Enable the SB

for( each polygon )
{
      Draw the edges, setting SB = 1
      Draw the filled polygon wherever SB  !=  1
      Draw the edges again, setting SB = 0
}

Disable the SB
```
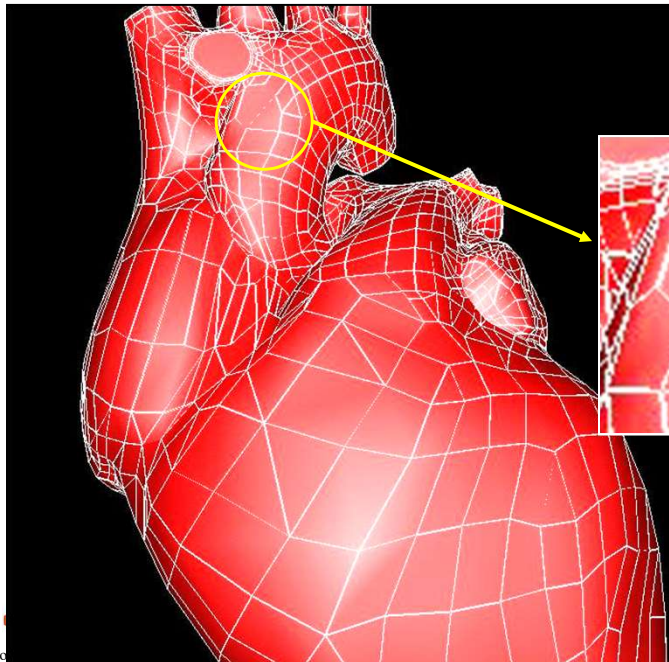
Before

After

Oregon State
University
Computer Graphics

mjb – August 30, 2022

Outlining Polygons the Naïve Way

1.   Draw all polygons
2.   Draw all edges

Z-fighting

Computer Graphics
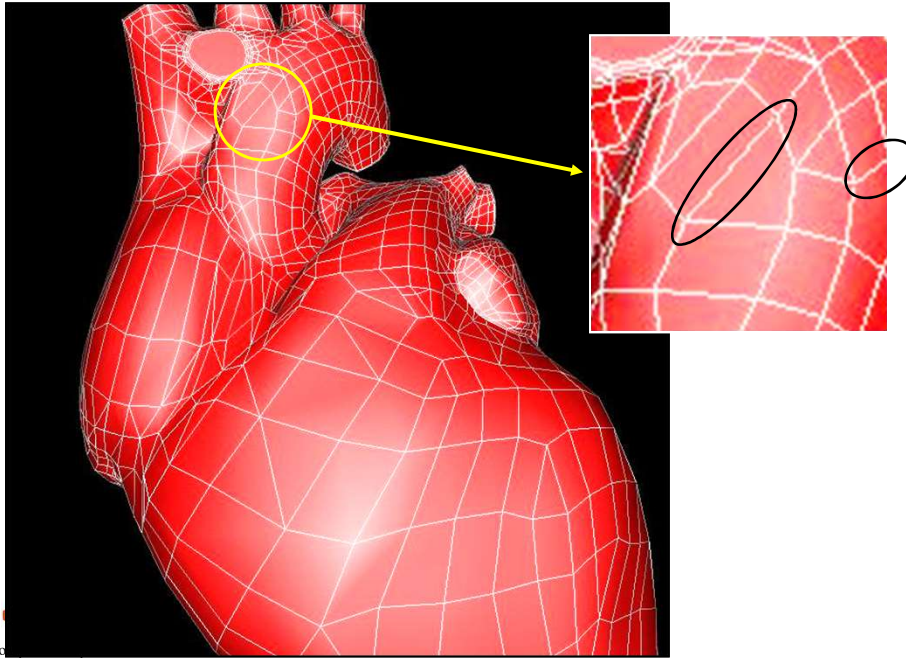
mjb – August 30, 2022

Using the Stencil Buffer to Better Outline Polygons

Using the Stencil Buffer to Better Outline Polygons

```
for( int f = 0; f < NumFaces; f++ )
{
                glStencilFunc( GL_ALWAYS, 1, STENCILBIT );
                glStencilOp( GL_REPLACE, GL_ REPLACE, GL_ REPLACE );
                glDisable( GL_LIGHTING );
                glShadeModel( GL_FLAT );
                glColor3f( 1., 1., 1. );
                glBegin( GL_LINE_LOOP );
                for( int v = FirstVertex[f];  v < FirstVertex[f+1];  v++ )
                {
                                glVertex3f( Vertices[v].x, Vertices[v].y, Vertices[v].z );
                }
                glEnd( );


                glStencilFunc( GL_EQUAL, 0, STENCILBIT );
                glStencilOp( GL_KEEP, GL_KEEP, GL_KEEP );
                glEnable( GL_LIGHTING );
                glShadeModel( GL_SMOOTH );
                glMaterialfv( … );
                glBegin( GL_POLYGON );
                for( int v = FirstVertex[f];  v < FirstVertex[f+1];  v++ )
                {
                                glNormal3f( Normals[v].x, Normals[v].y, Normals[v].z );
                                glVertex3f( Vertices[v].x,  Vertices[v].y, Vertices[v].z );
                }
                glEnd( );

                glStencilFunc( GL_ALWAYS, 0, STENCILBIT );
                glStencilOp( GL_ REPLACE, GL_ REPLACE, GL_ REPLACE );
                glDisable( GL_LIGHTING );
                glShadeModel( GL_FLAT );
                glColor3f( 1., 1., 1. );
                glBegin( GL_LINE_LOOP );
                for( int v = FirstVertex[f];  v < FirstVertex[f+1];  v++ )
                {
                                glVertex3f( Vertices[v].x, Vertices[v].y, Vertices[v].z );
                }
                glEnd( );
}
```
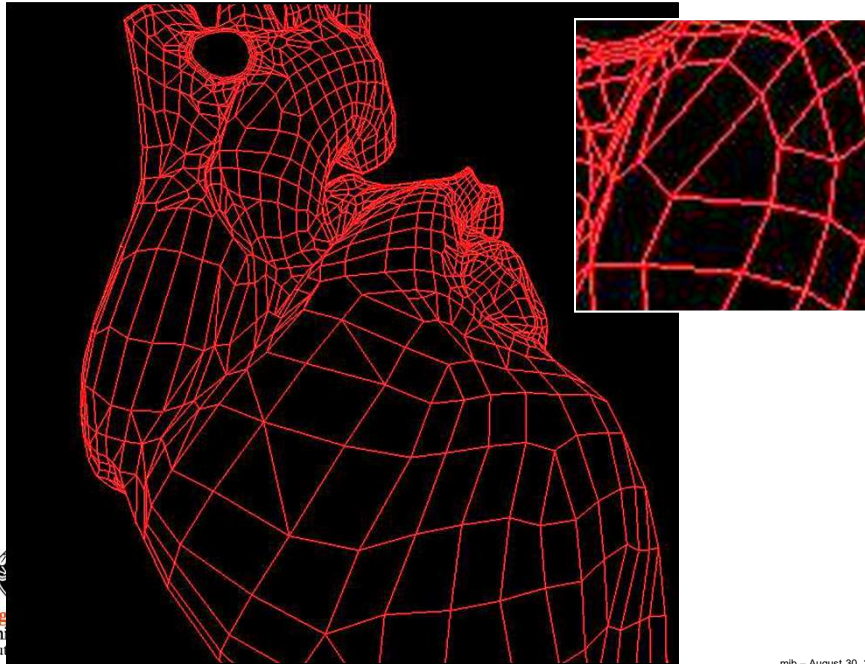
Put "masking tape" down on the polygon edges

Paint the polygon, which also paints the edges

Pull the "masking tape" up and paint just the polygon edges

Oregon State
University
Computer Graphics

Using the Stencil Buffer to Perform *Hidden Line Removal*

mjb – August 30, 2022

Using the Stencil Buffer to Perform *Hidden Line Removal*

```
Clear the SB = 0
Enable the SB

for( each polygon )
{
      Draw the edges, setting SB = 1
      Draw the polygon, unlit and flat shaded, in the background color wherever SB  !=  1
      Draw the edges again, setting SB = 0
}

Disable the SB
```

Oregon State
University
Computer Graphics

mjb – August 30, 2022

11

Before

After

After

Oregon State
University
Computer Graphics

mjb – August 30, 2022

Hidden Line Removal in Pre-Vis for the 2019 Movie *Dumbo*

Oregon State
University
Computer Graphics

mjb – August 30, 2022