Using the Stencil Buffer

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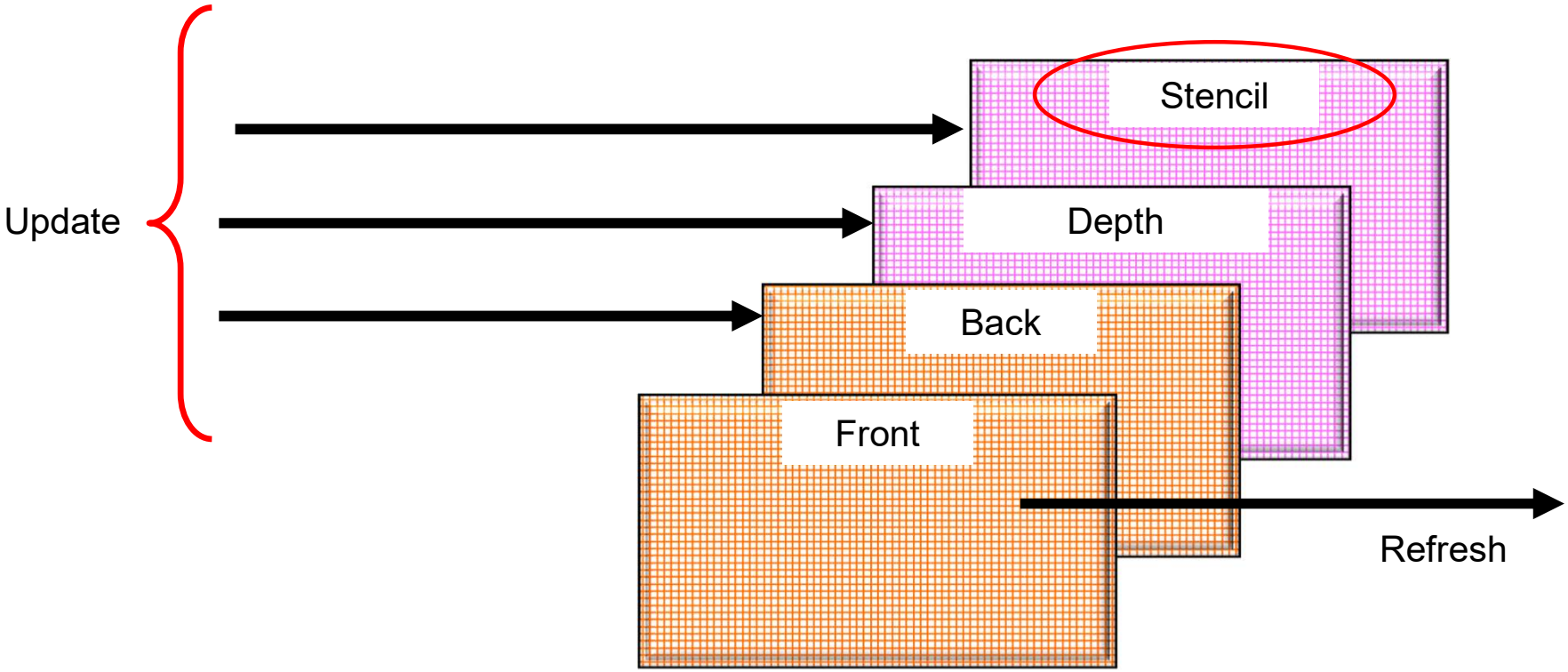
The Framebuffers



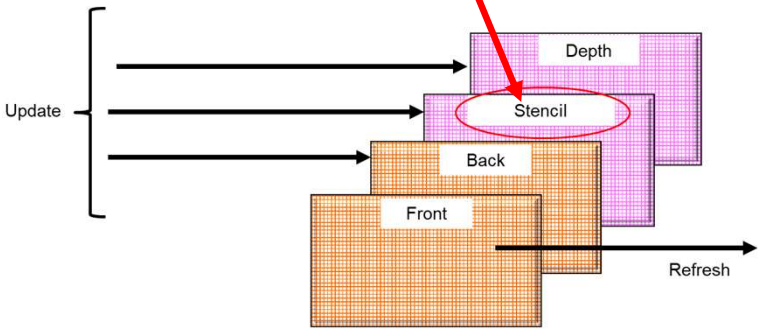
Here's what the Stencil Buffer can do for you:

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. While drawing into the Back Buffer, the Stencil Buffer can be used to write-protect certain parts of the Back Buffer.

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.

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;
}
```

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:

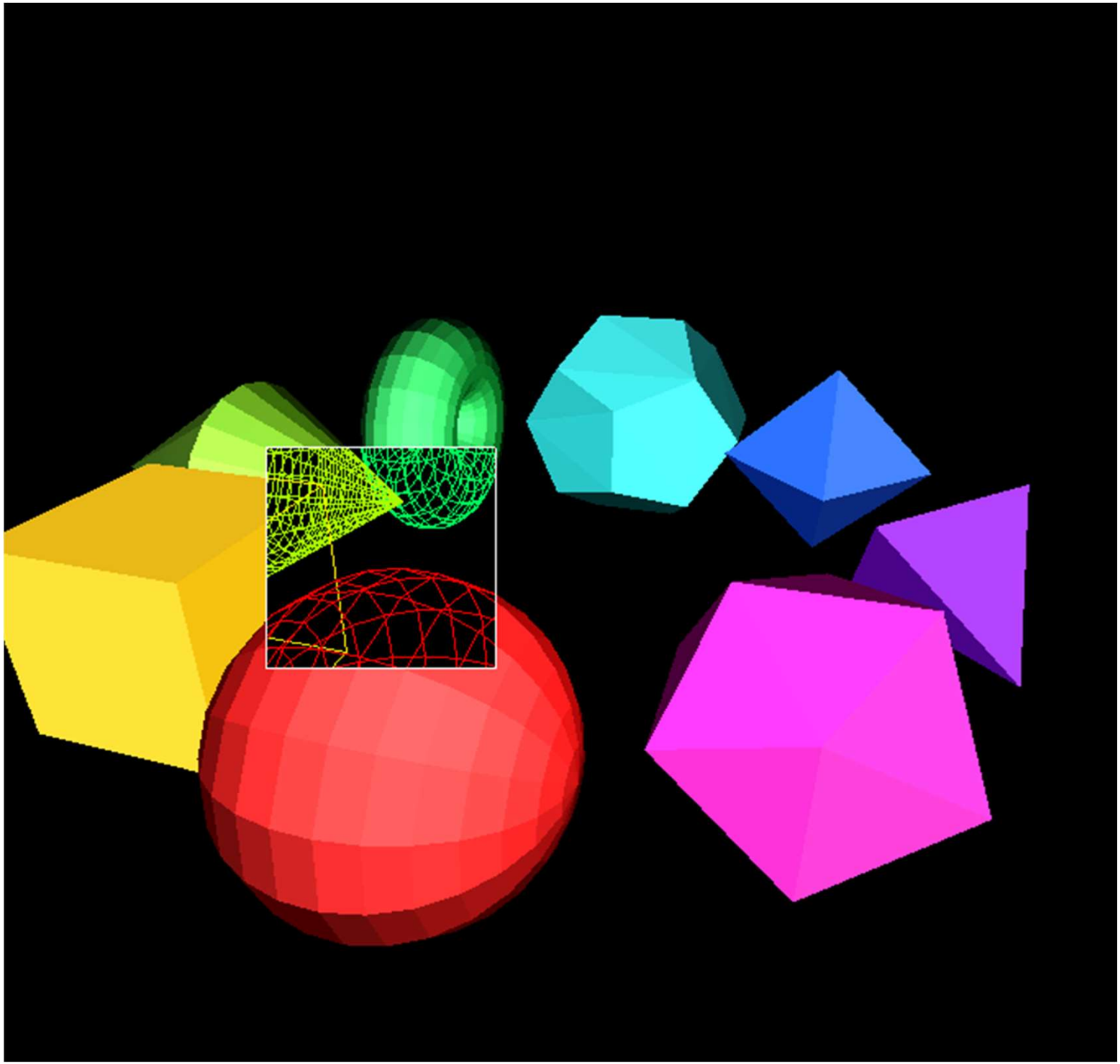
GL_KEEP	Retain the existing stencil value
GL_ZERO	Set the stencil value to zero
GL_REPLACE	Replace the stencil value with **ref** from the Stencil Func
GL_INCR	Increment the stencil value, with clamping
GL_INCR_WRAP	Increment the stencil value, without clamping
GL_DECR	Decrement the stencil value, with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

Setting Up the Stencil Buffer

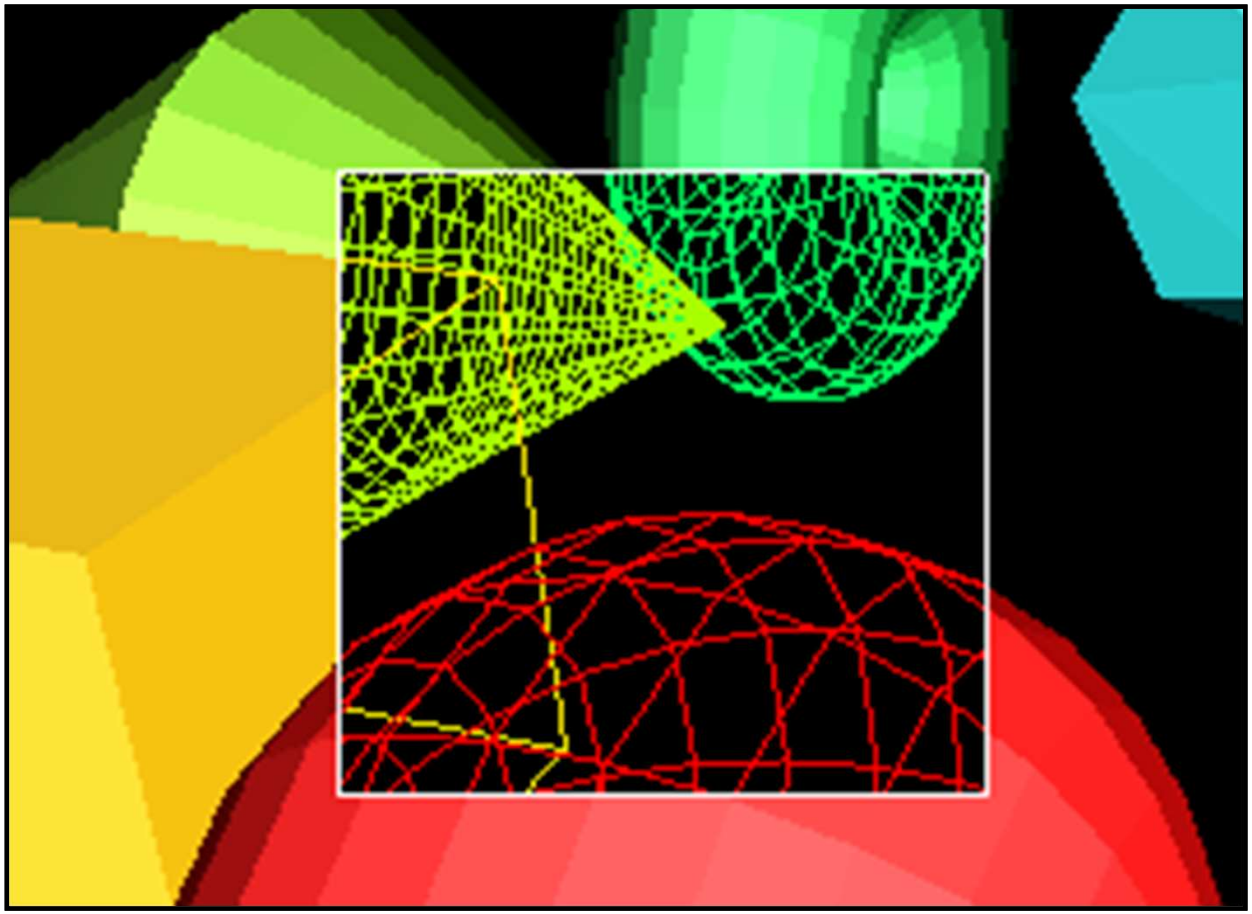
```
// at the top of the program:

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 );
. . .
```

Using the Stencil Buffer to Create a *Magic Lens*



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



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)

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Using the Stencil Buffer to Create a *Magic Lens*


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

glMatrixMode( GL_MODELVIEW );
glLoadIdentity( );

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

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

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( );

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

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

Write protect the depth and color buffers

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

Draw a filled-in box

Write-enable the depth and color buffers

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 ] );
}

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 ] );
}

<< 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 solids everywhere *except* inside the lens

Draw the wireframes *only* inside the lens

Draw the boundary of the lens

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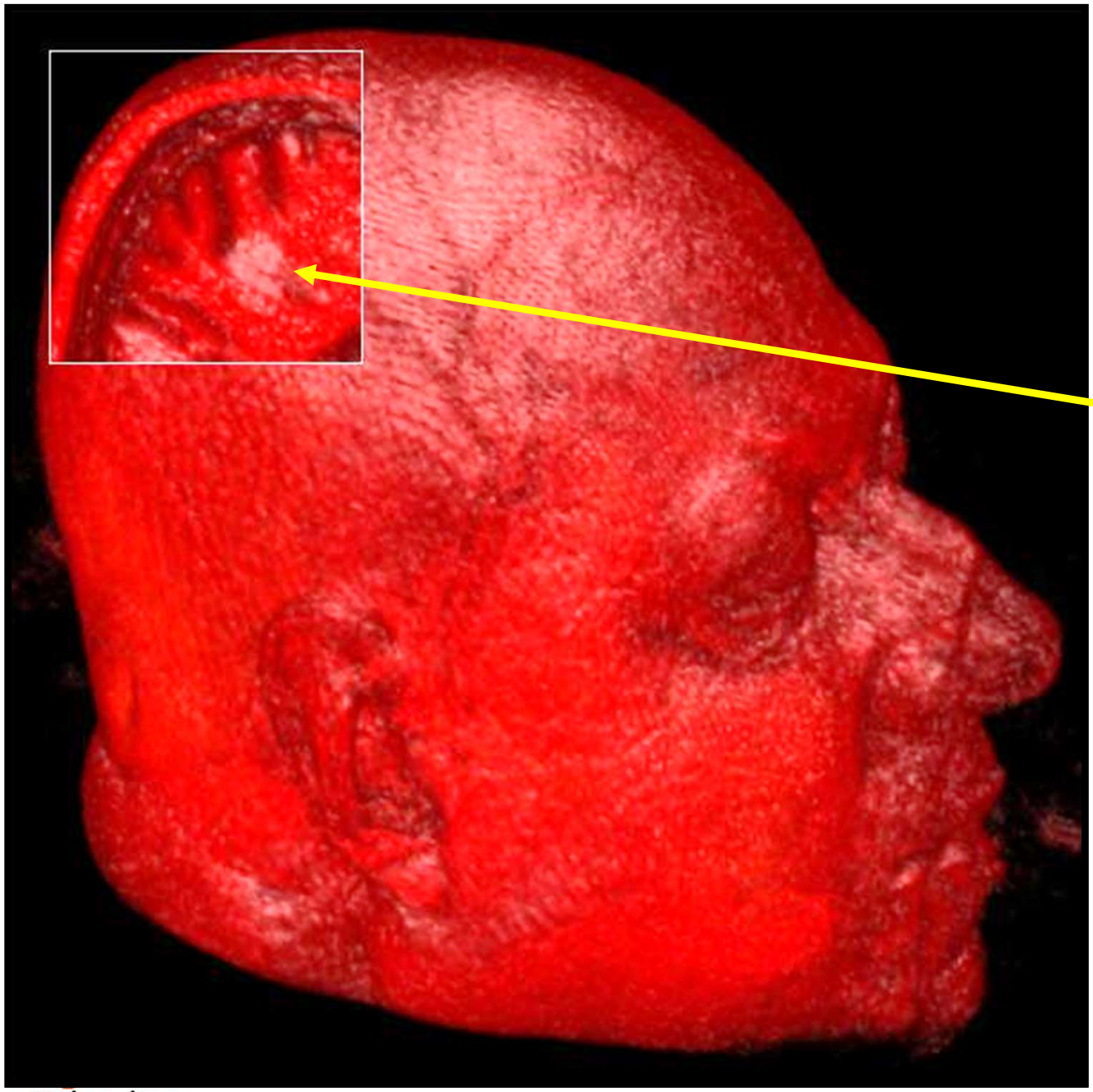
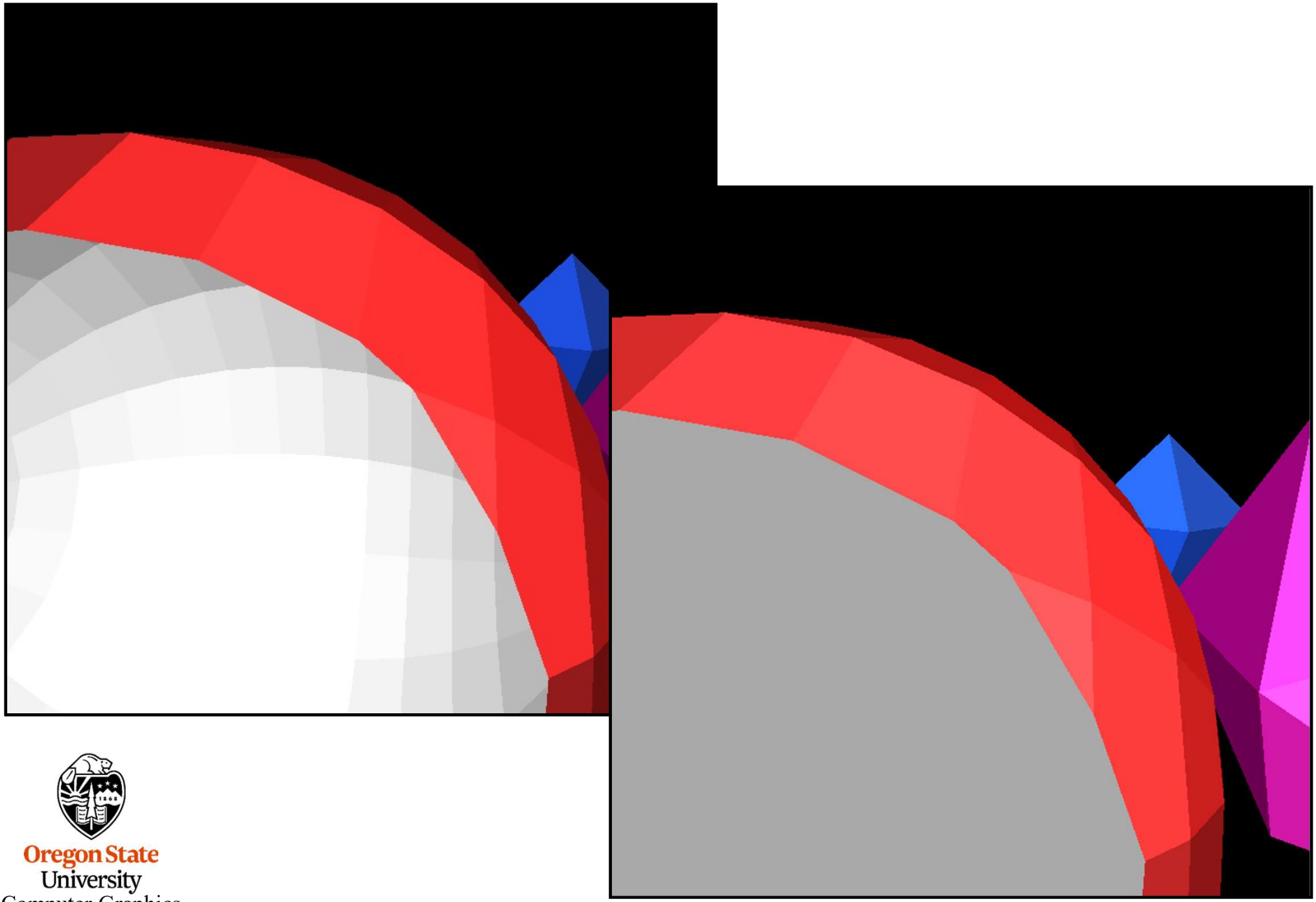
I Once Used the Stencil Buffer to Create a *Magic Lens* for Volume Data



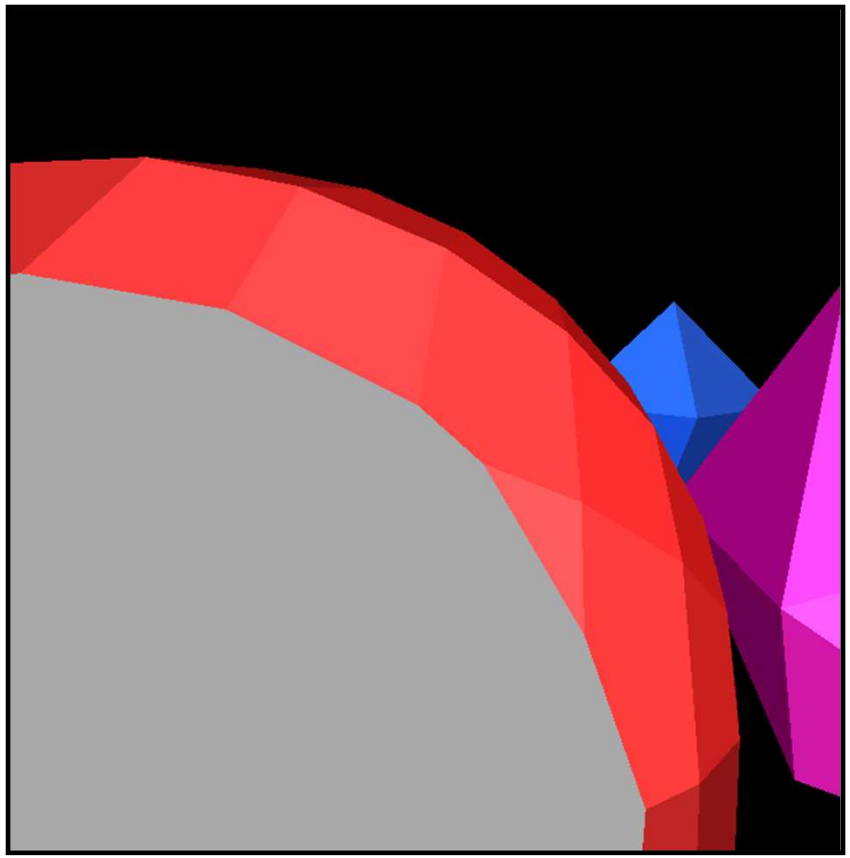
In this case, the scene inside the lens was created by drawing the same object, but drawing it with its near clipping plane positioned partways into the data

Using the Stencil Buffer to Perform *Polygon Capping*



Using the Stencil Buffer to Perform *Polygon Capping*

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

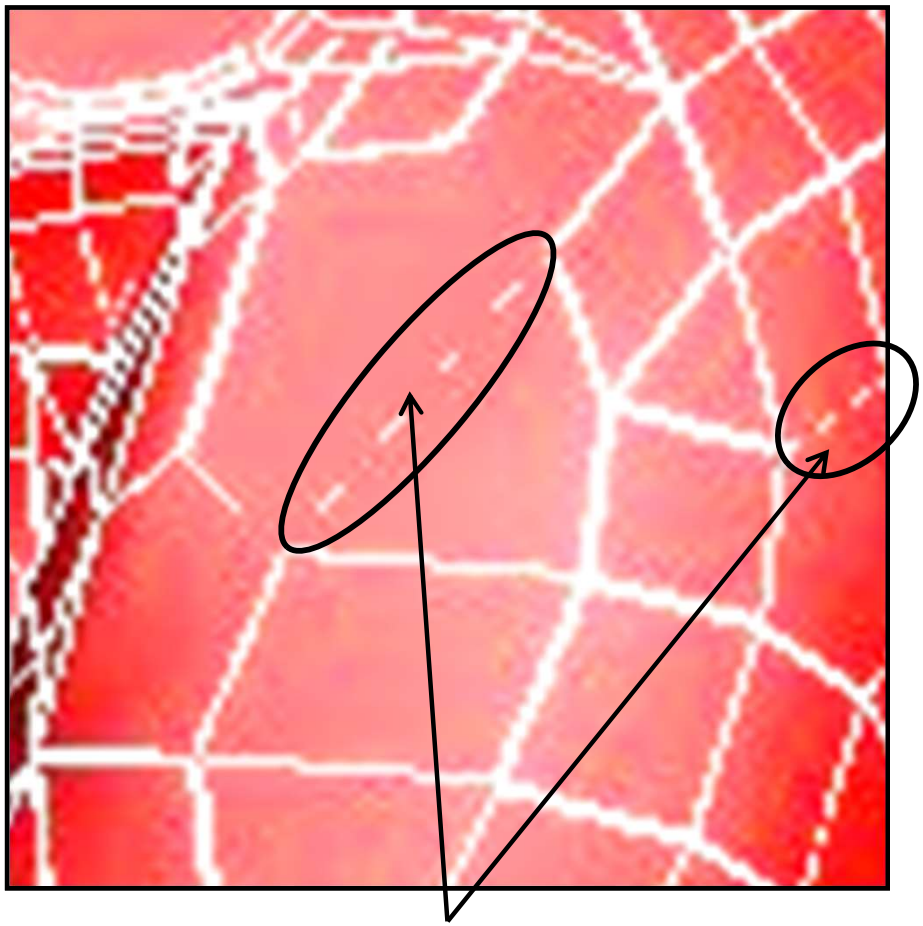
Because these were all ***solid*** objects, they had a front face and a back face drawn. Thus, most of the time, the SB values got inverted back to 0. If they didn't, that means that the solid object penetrated the near clipping plane and now needs to be capped.

```
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

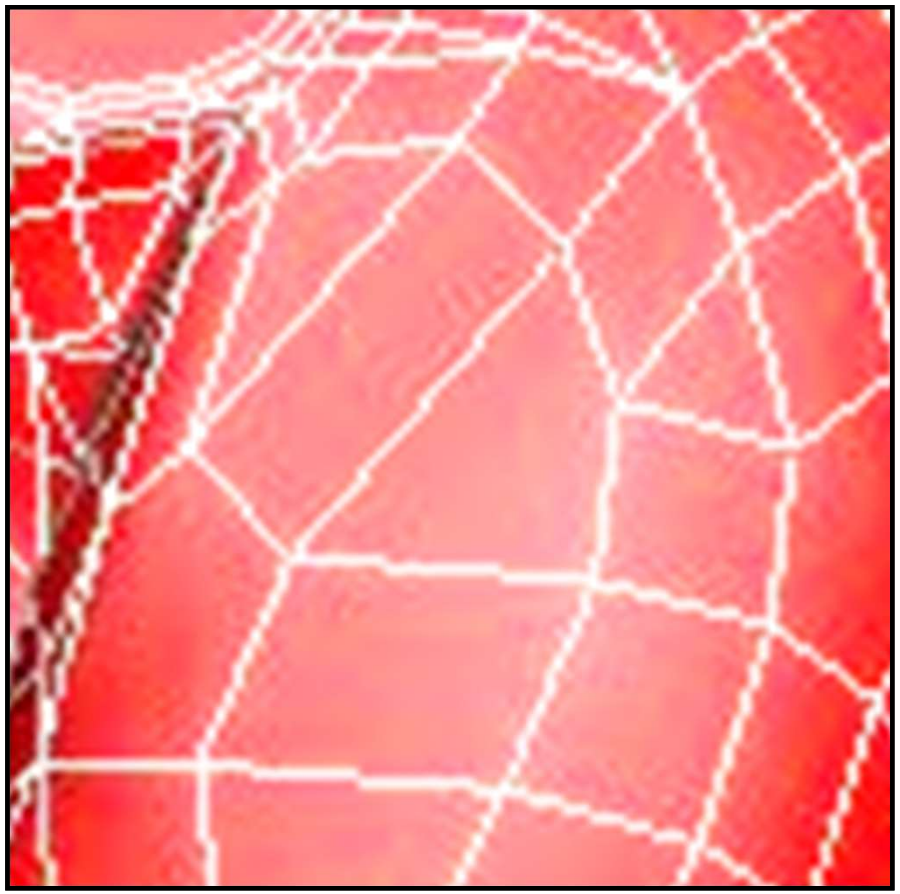
Using the Stencil Buffer to Draw Better Polygon Outlines

Before



Z-fighting

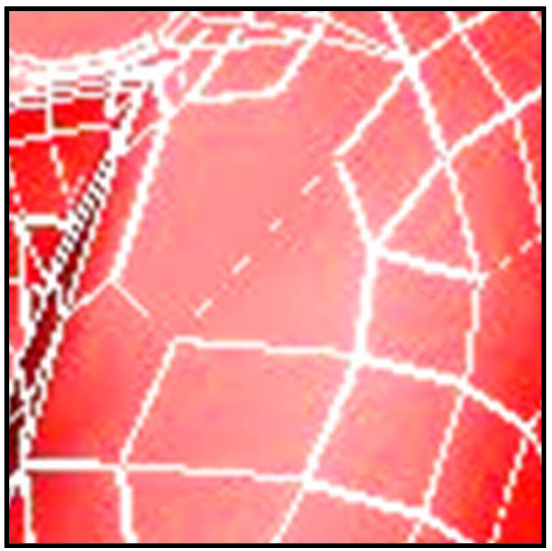
After

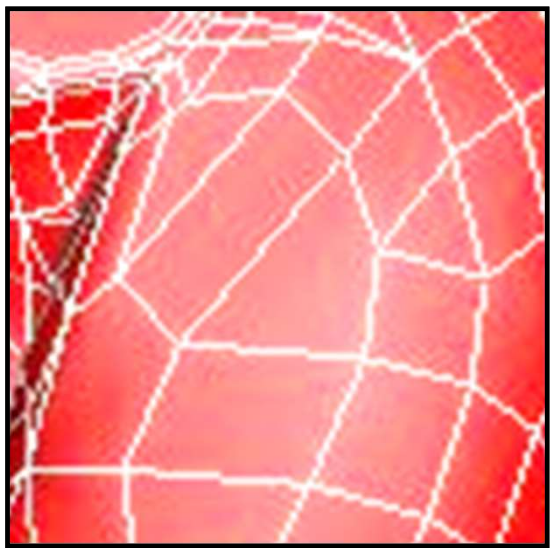


Using the Stencil Buffer to Draw Better Polygon Outlines

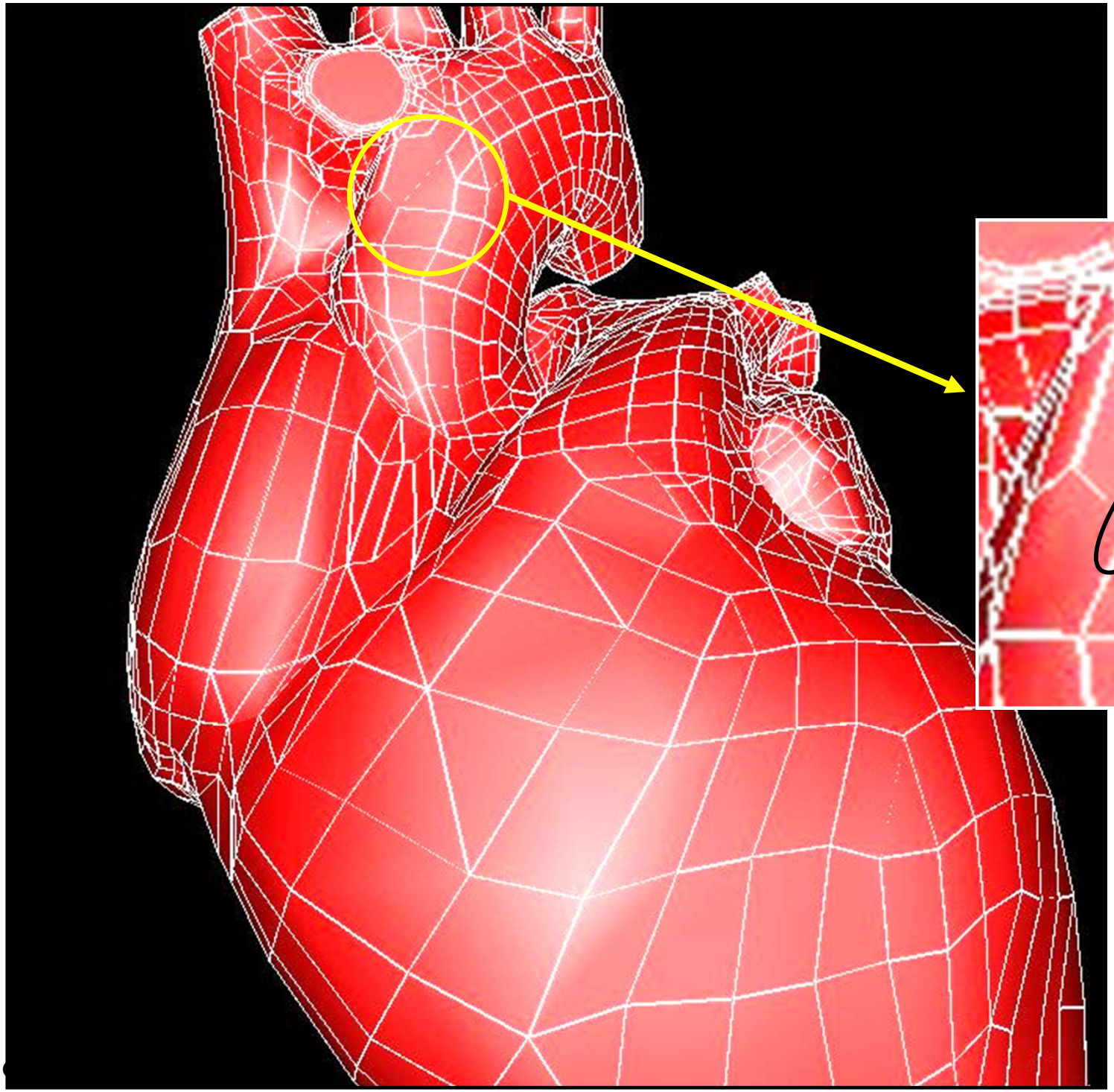

```
Clear the SB = 0

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**





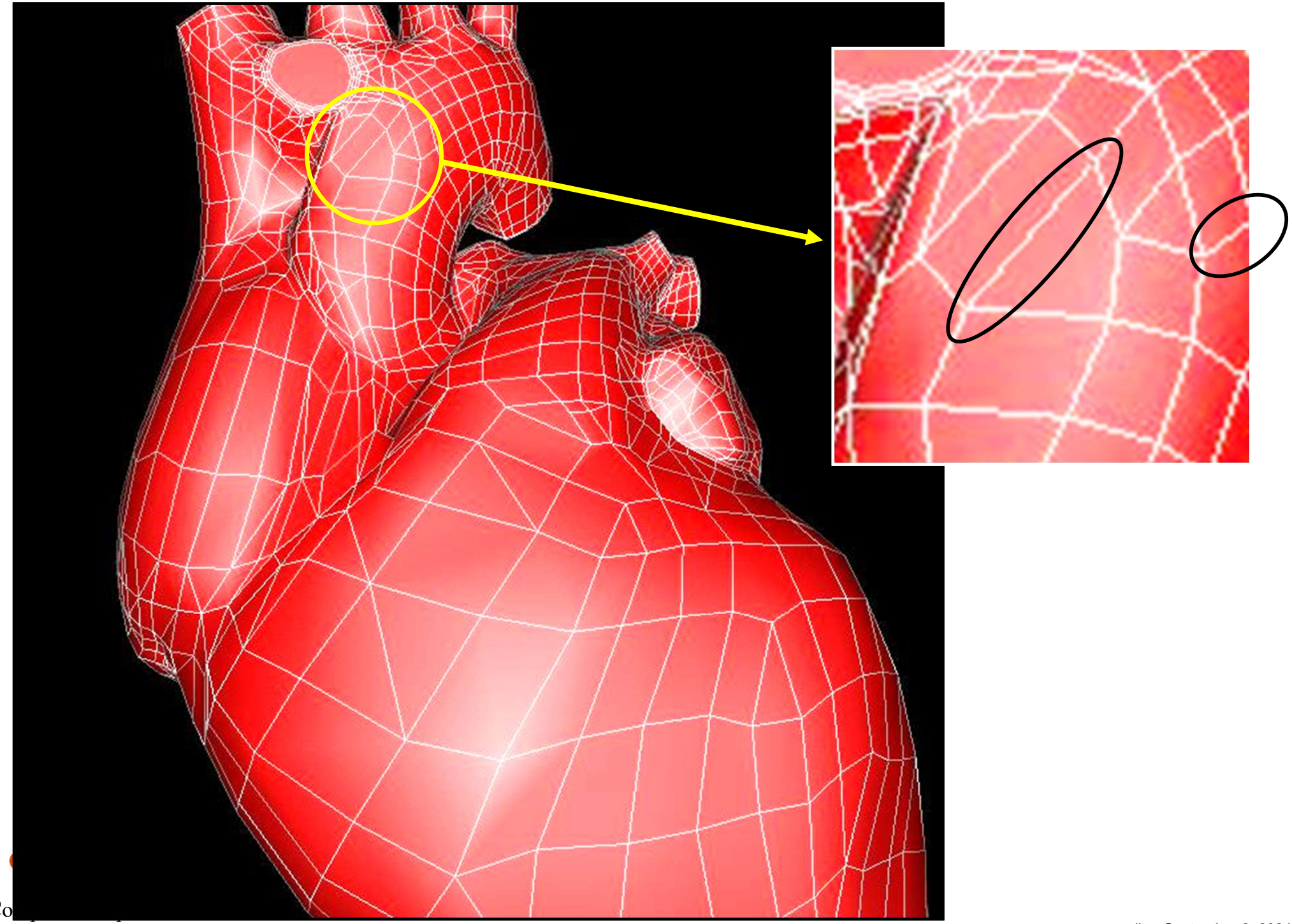
Outlining Polygons the Naïve Way Results in Z-Fighting



1. Draw all polygons
2. Draw all edges

Z-fighting

Using the Stencil Buffer to Draw Better Polygon Outlines



Using the Stencil Buffer to Draw Better Polygon Outlines

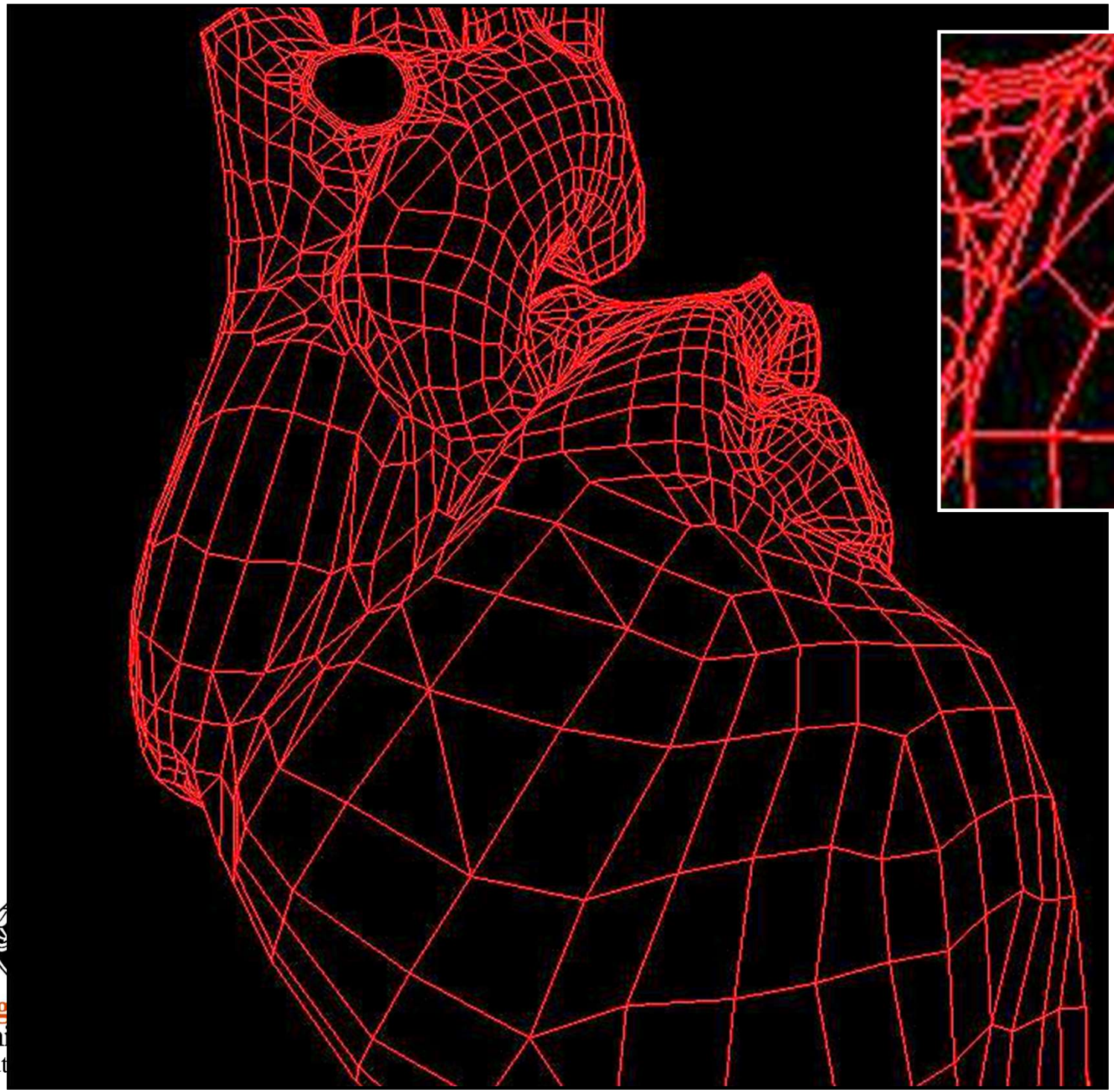

```
for( int f = 0; f < NumFaces; f++ )
{
        glStencilFunc( GL_ALWAYS, 1, STENCILBIT );
        glStencilOp( GL_REPLACE, GL_ REPLACE, GL_ REPLACE );
        glDisable( GL_LIGHTING );
        glShadeModel( GL_FLAT );
        glColor3f( 1., 1., 1. );
        glBegin( GL_LINE_LOOP );
        for( int 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( );
}
```

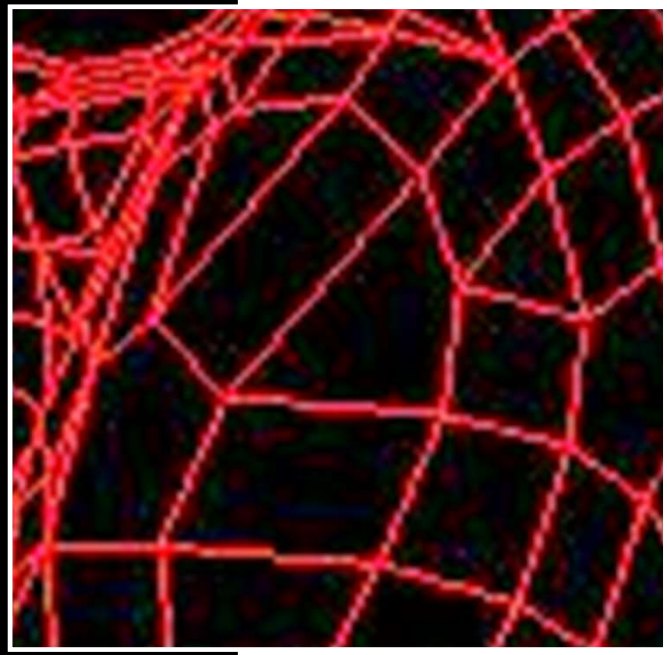
Put "masking tape" down on the polygon edges

Paint the polygon, which also paints the edges

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

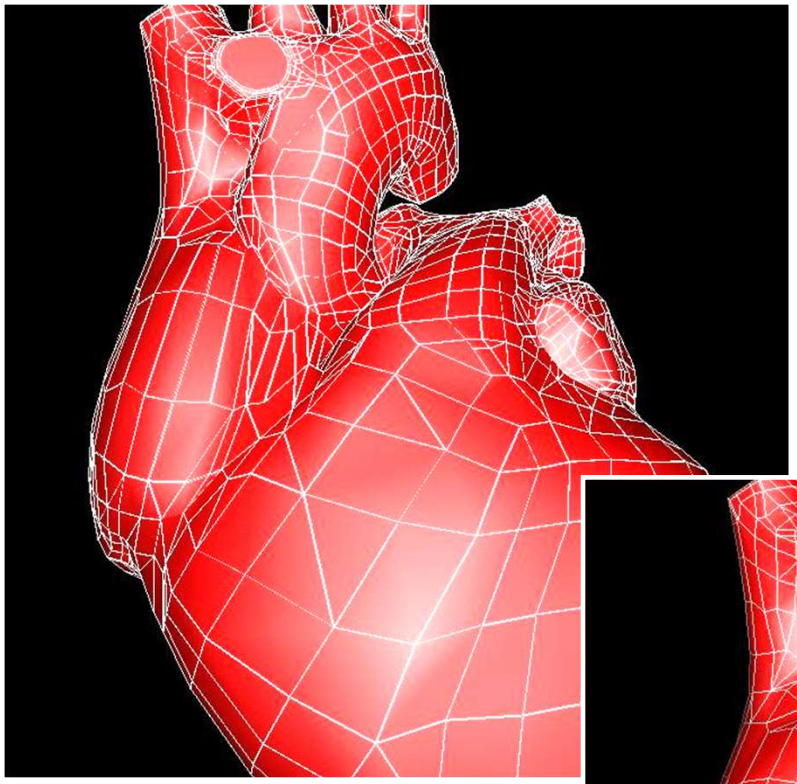
Using the Stencil Buffer to Perform *Hidden Line Removal*





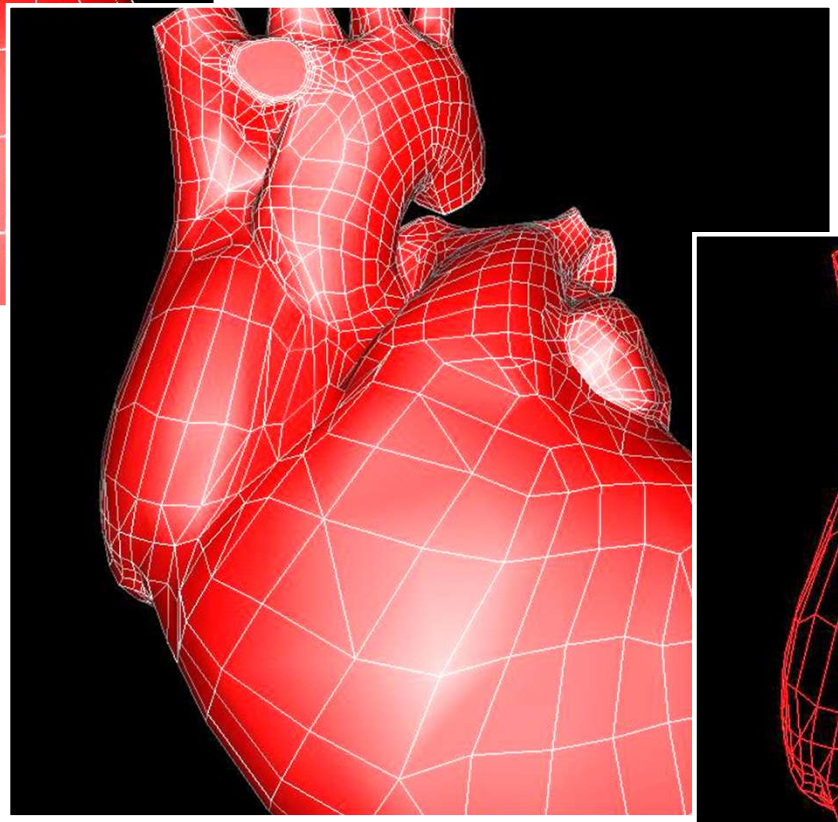
Using the Stencil Buffer to Perform *Hidden Line Removal*


```
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
```



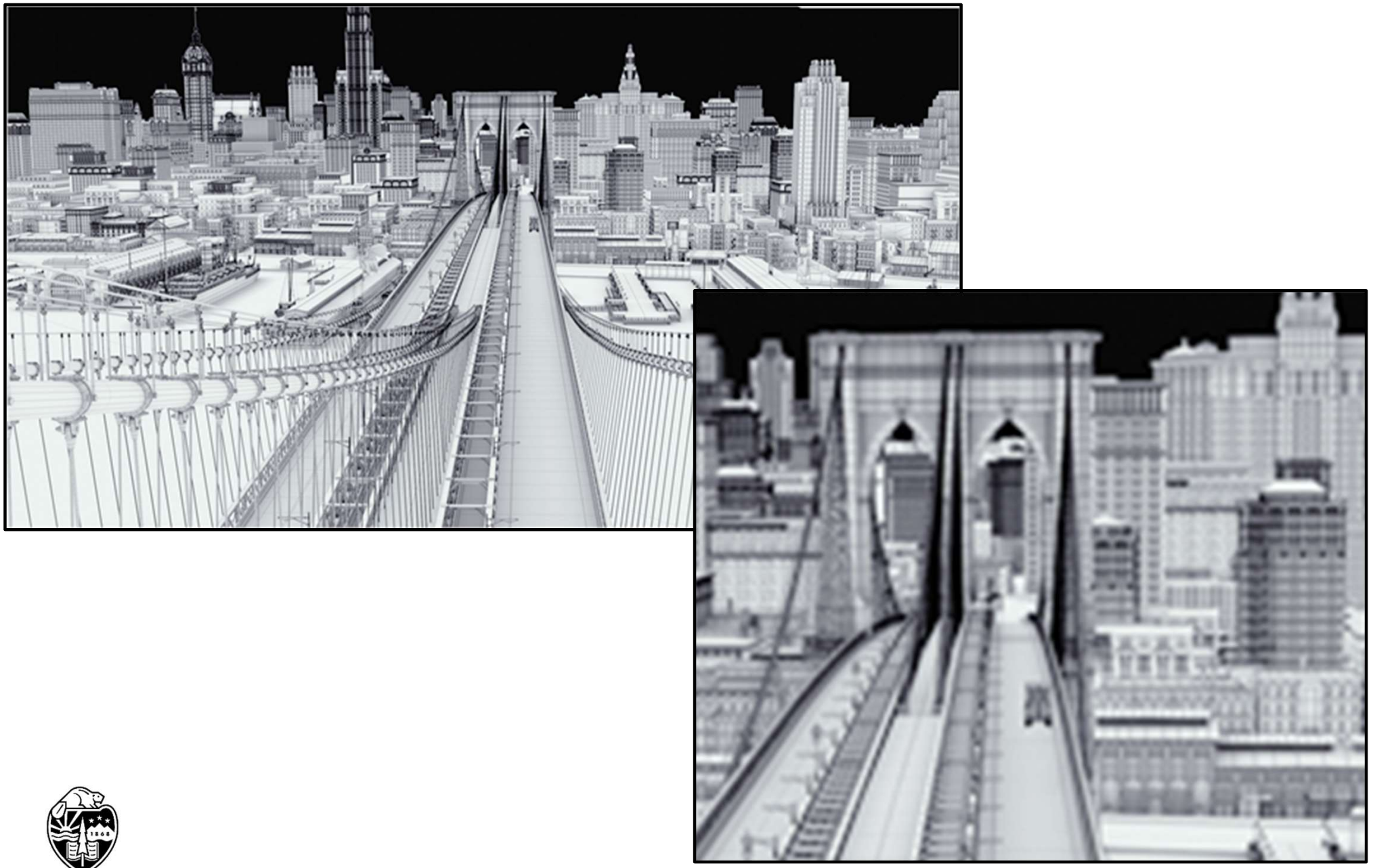
Before

After



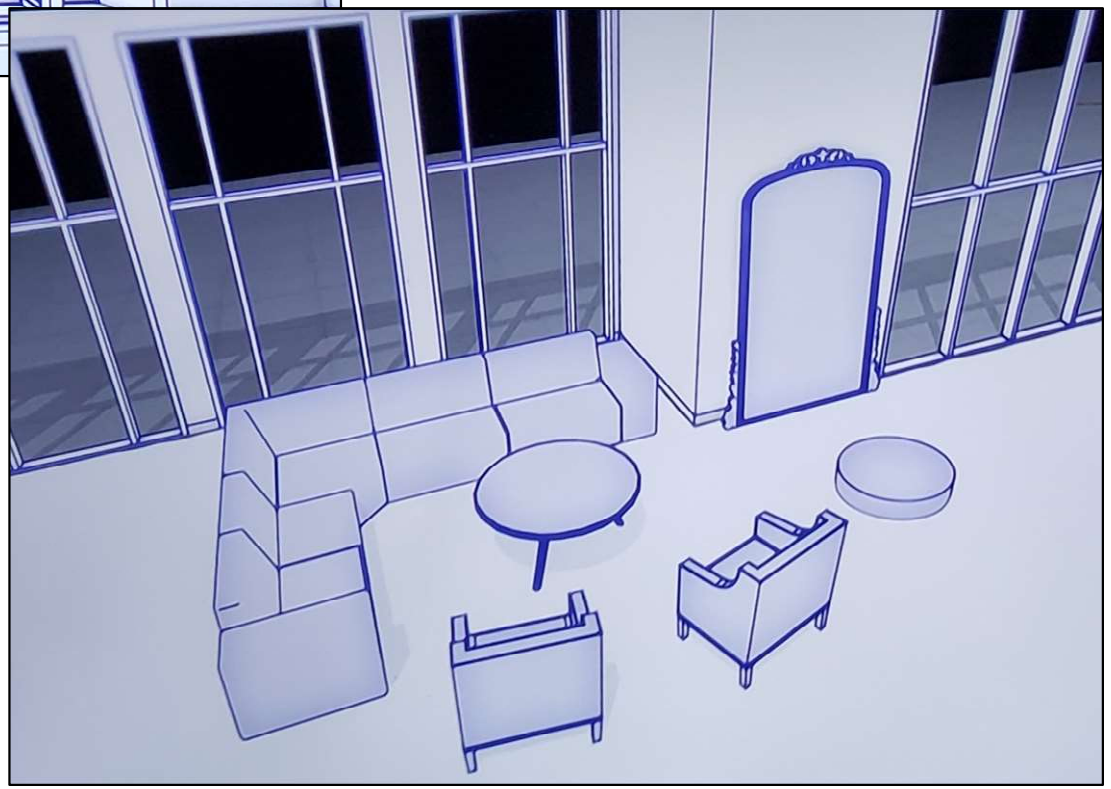
After-After

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



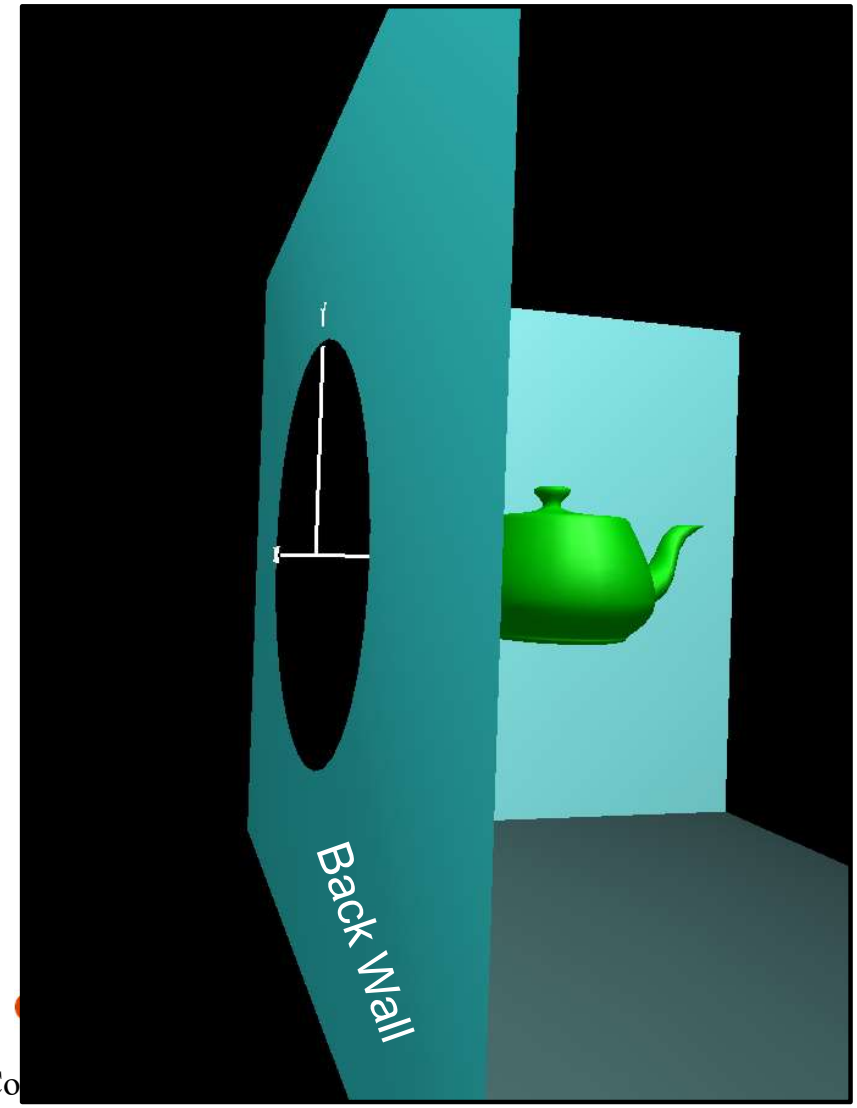
Hidden Line Removal in Construction Shows

I've noticed that some of the construction reality TV shows use hidden line removal like this, presumably to create a blueprint-ish effect. This came from the show *Good Bones*.

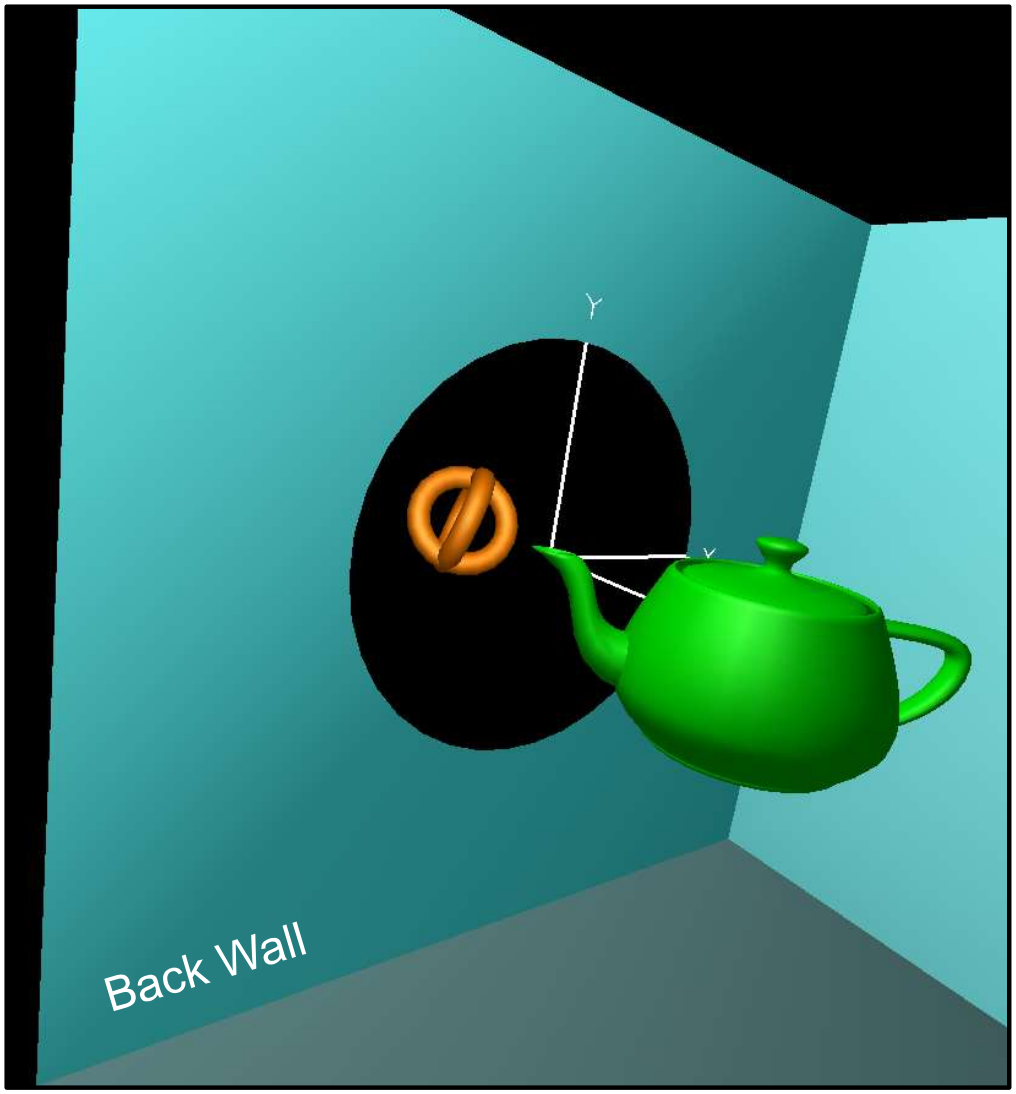


Stencil Buffers can be used to Create Portals

Here we have a room with a teapot in it and a hole in the Back Wall. You can tell that it is a hole because the axes obviously go through it. Clearly there is nothing behind the Back Wall.



But if we look at the scene from within the room, there is indeed a 3D object (the orange torii) seen through the hole. The hole is acting like a "portal" to another 3D space.



Stencil Buffers can be used to Create Portals

Here's the process:

1. Draw the teapot and the axes like normal
2. Turn off writing into the depth and color framebuffers
3. Draw an invisible large square behind the Back Wall setting SB=1
4. Draw an invisible circle on that wall setting SB=0
5. Draw an invisible large square behind the back Wall between there and the viewer setting SB=1
6. Draw the cyan room walls and the orange torii only where SB=0 – this makes the portal

The first large square (SB=1) plus circle (SB=0) ends up making the Stencil Buffer look like this:

1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	0	1	1	1	1	1	1
1	1	1	1	1	0	0	0	0	0	1	1	1	1
1	1	1	1	1	0	0	0	0	0	1	1	1	1
1	1	1	1	0	0	0	0	0	0	0	1	1	1
1	1	1	1	1	0	0	0	0	0	1	1	1	1
1	1	1	1	1	0	0	0	0	0	1	1	1	1
1	1	1	1	1	1	1	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1