Directly Visualizing Volume Data

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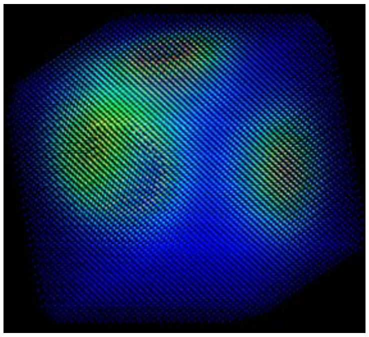
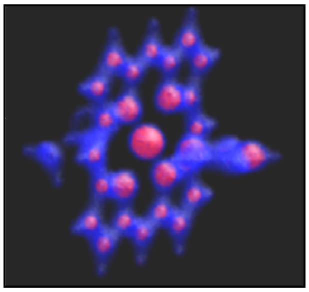
Volume Data: A Definition

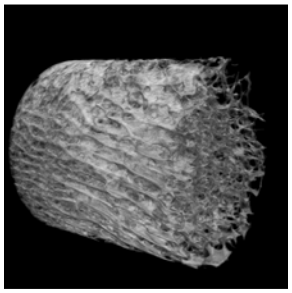
A *volume* is a 3D discretely sampled data set where the size of the voxels have been expanded to occupy the space to the neighboring voxels.



Why Do We Care About Volume Visualization?

- Medical: CAT, MRI, 3D ultrasound
- Science and engineering: CFD, stress, thermal, molecular
- Volumes are normally very difficult to comprehend





How can you get a volume dataset? (Ewww…)

Montreal Neurological Institute at McGill University

Researchers used a tool called a microtome to cut a brain into slices 20 micrometers thick.

Understanding Volume Data Usually Involves a Compromise

Point Clouds ➡ All values everywhere, hard to see very much, distracting artifacts

Interpolated-colors cutting planes ➡ All values in a single plane

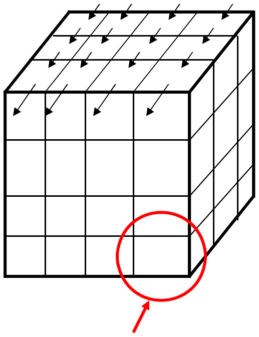
Contours cutting plane ➡ Discrete values in a single plane

Isosurfaces ➡ A single value everywhere

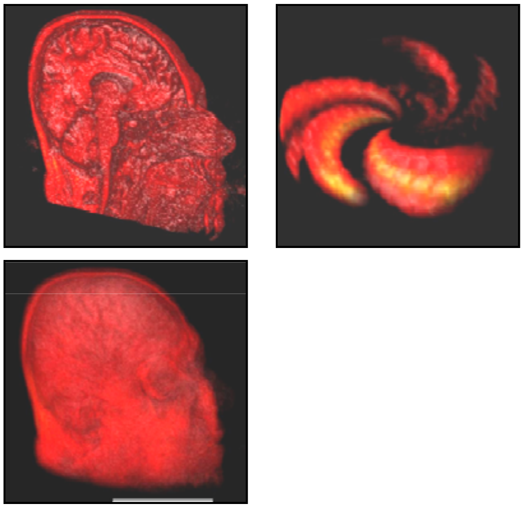
Because of these compromises, these are all considered to be ***indirect*** ways to visualize volume data

Direct Volume Rendering

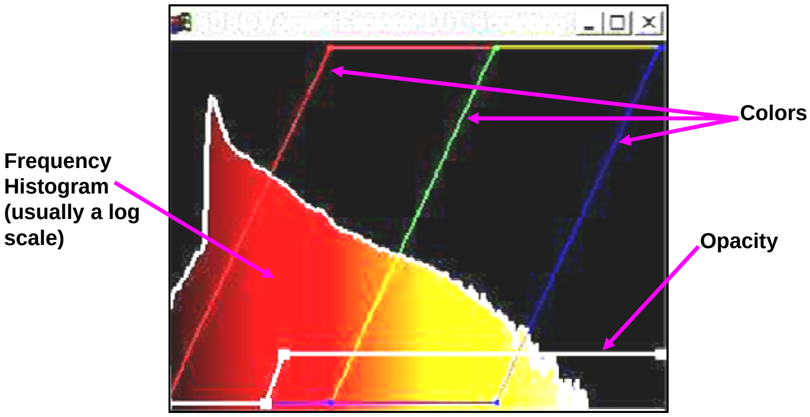
Composite the colors and alphas of the voxels



A *Volume Element*, or *voxel*



Transfer Function



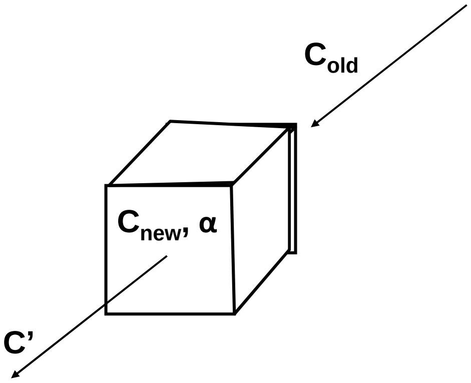
OSU vx Transfer Function Sculpting Window

Voxel Compositing

Recall this color blending equation from the OpenGL Transparency notes:

$$C' = \alpha C_{new} + (1. - \alpha) C_{old}$$

In “Voxel World”, things work the same way:

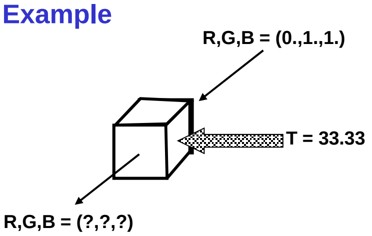


Voxel Compositing Example

TMIN = 0.
TMAX = 100.

The color transfer function is a **Black-Red-Yellow-White heated object scale**, mapping a scalar value of 0. to Black, and 100. to White.

The opacity transfer function is a linear ramp so that the opacity is 1. (opaque) when T = 100. and 0. (transparent) when T = 0.



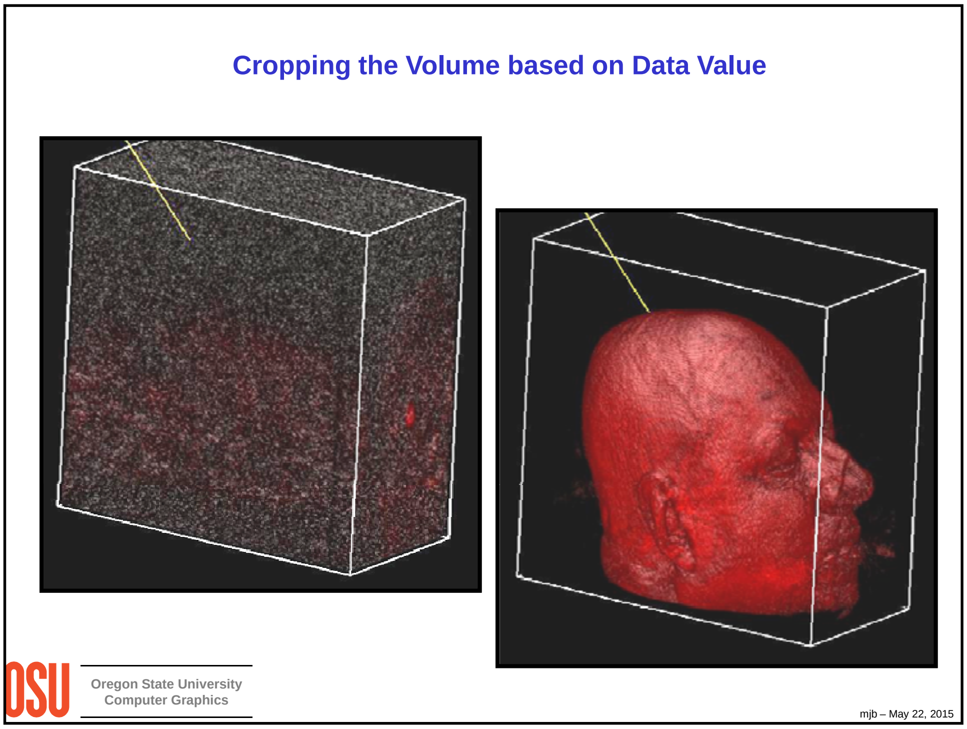
You are compositing back-to-front through the volume. At this moment, the running values of RGB are **(0., 1., 1.) .** The next voxel you encounter has a **T value of 33.33**

1. **What is the color of *just this voxel*?**
2. **What is the opacity of *just this voxel*?**
3. **What will the new running RGB values be when you are done compositing this voxel with the old running RGB values?**

What is the color of *just this voxel*?

What is the opacity of *just this voxel*?

What will the new running RGB values be when you are done compositing this voxel with the old running RGB values?



Cropping the Volume based on Data Value

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Computer Graphics

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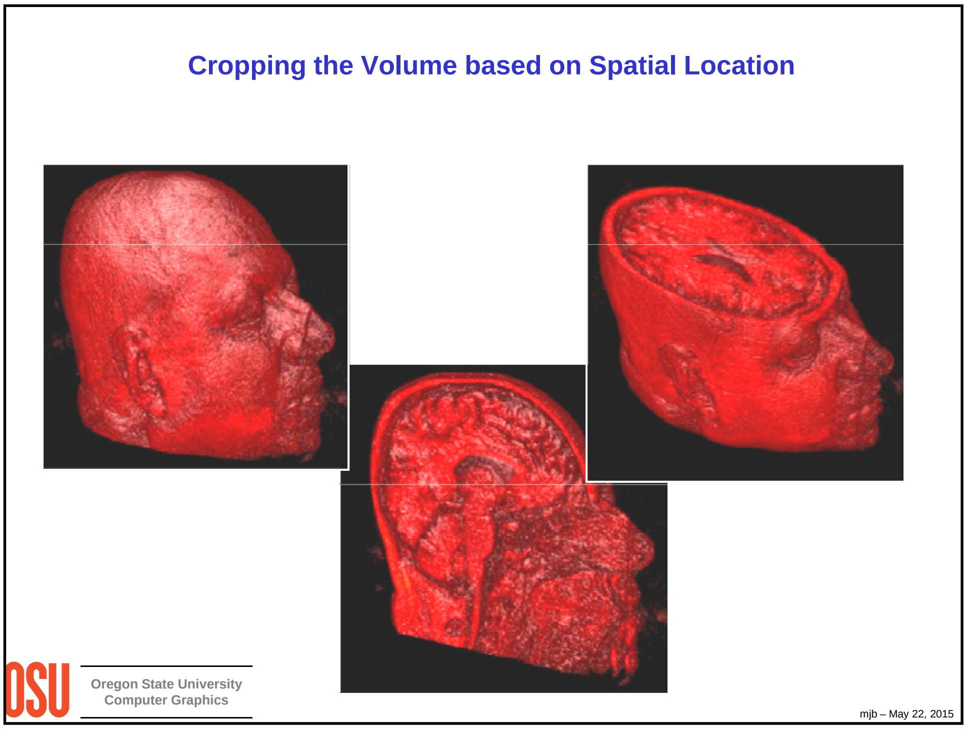

Cropping the Volume based on Spatial Location

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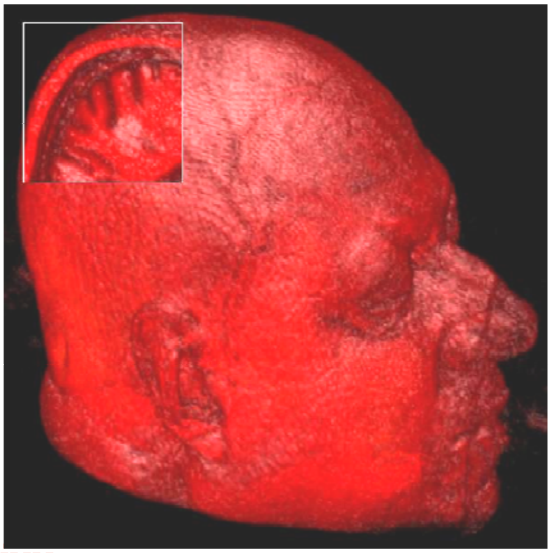
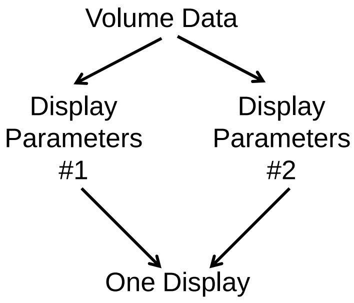
“Magic Lens” to Selectively Look Inside





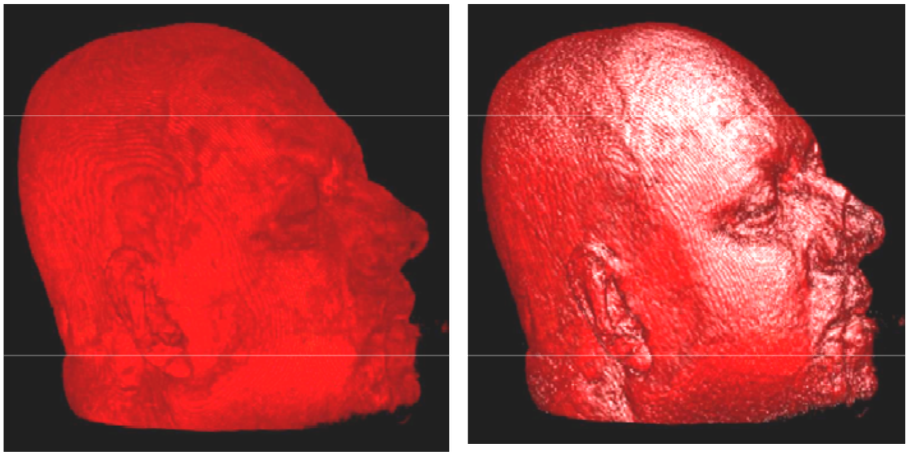
Volume Data

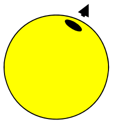
Display Parameters #1

Display Parameters #2

One Display

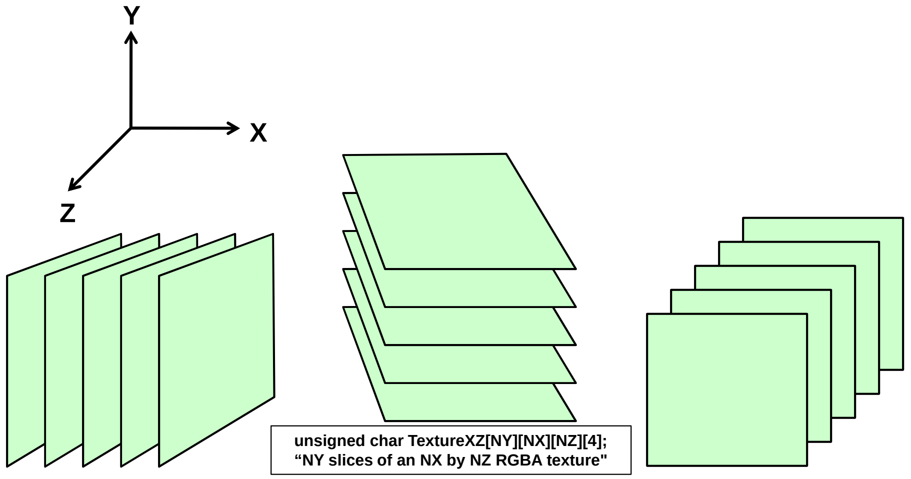
Lighting





$$\vec{n} = (\frac{dS}{dx}, \frac{dS}{dy}, \frac{dS}{dz}) = \nabla S$$

Volume Rendering with Parallel Texture Planes



unsigned char TextureXZ[NY][NX][NZ][4];
“NY slices of an NX by NZ RGBA texture"

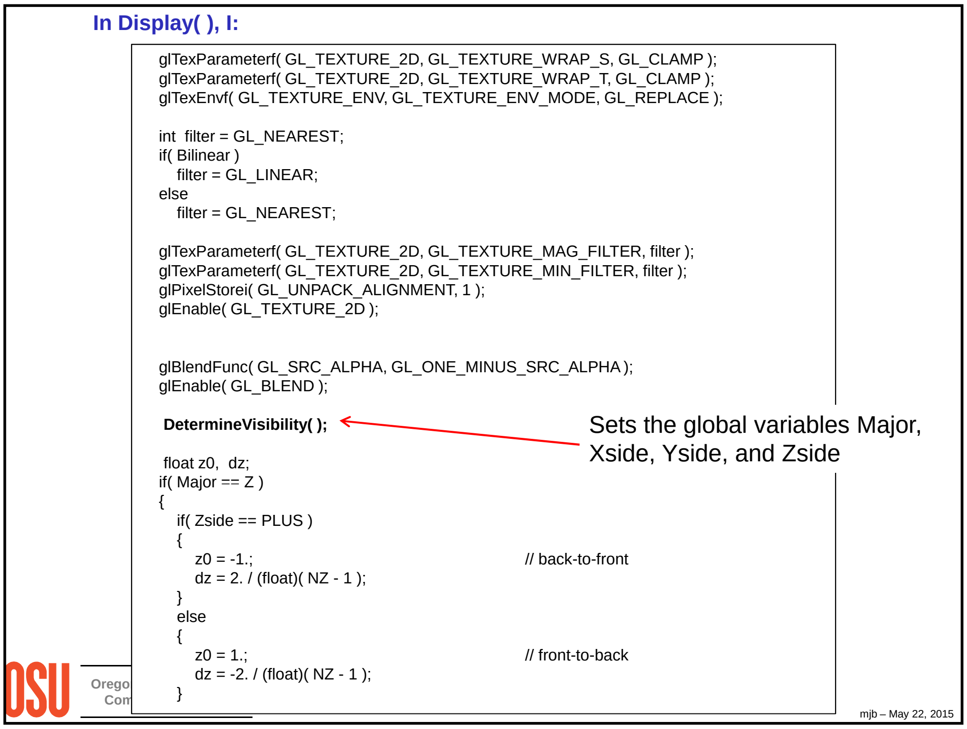
unsigned char TextureYZ[NX][NY][NZ][4];
“NX slices of an NY by NZ RGBA texture"

unsigned char TextureXY[NZ][NX][NY][4];
“NZ slices of an NX by NY RGBA exture"

In a callback that is called whenever the opacity transfer function changes:

```
void
FillXY( void )
{
    float alpha;        // opacity at this voxel
    float r, g, b;      // running color composite

    for( int x = 0; x < NX; x++ )
    {
        for( int y = 0; y < NY; y++ )
        {
            r = g = b = 0.;
            for( int zz = 0; zz < NZ; zz++ )
            {
                // which direction to fill:

                int z;
                if( Zside == PLUS )
                    z = zz;
                else
                    z = ( NZ-1 ) - zz;

                if(  … this scalar value is not in the range you want to view …  )
                {
                    r = g = b = 0.;
                    alpha = 0.;
                }
                else
                {
                    r = Nodes[x][y][z].r;
                    g = Nodes[x][y][z].g;
                    b = Nodes[x][y][z].b;
                    alpha = MaxAlpha;
                }

                TextureXY[zz][y][x][0] = (unsigned char) ( 255.*r + .5 );
                TextureXY[zz][y][x][1] = (unsigned char) ( 255.*g + .5 );
                TextureXY[zz][y][x][2] = (unsigned char) ( 255.*b + .5 );
                TextureXY[zz][y][x][3] = (unsigned char) ( 255.*alpha + .5 );
            }
        }
    }
}
```

Zside is set from somewhere else



In Display( ), I:

```
glTexParameterf( GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_CLAMP );
glTexParameterf( GL_TEXTURE_2D, GL_TEXTURE_WRAP_T, GL_CLAMP );
glTexEnvf( GL_TEXTURE_ENV, GL_TEXTURE_ENV_MODE, GL_REPLACE );

int  filter = GL_NEAREST;
if( Bilinear )
    filter = GL_LINEAR;
else
    filter = GL_NEAREST;

glTexParameterf( GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, filter );
glTexParameterf( GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, filter );
glPixelStorei( GL_UNPACK_ALIGNMENT, 1 );
glEnable( GL_TEXTURE_2D );


glBlendFunc( GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA );
glEnable( GL_BLEND );

 DetermineVisibility( );

 float z0,  dz;
if( Major == Z )
{
    if( Zside == PLUS )
    {
        z0 = -1.;                                   // back-to-front
        dz = 2. / (float)( NZ - 1 );
    }
    else
    {
        z0 = 1.;                                    // front-to-back
        dz = -2. / (float)( NZ - 1 );
    }
```

Sets the global variables Major, Xside, Yside, and Zside

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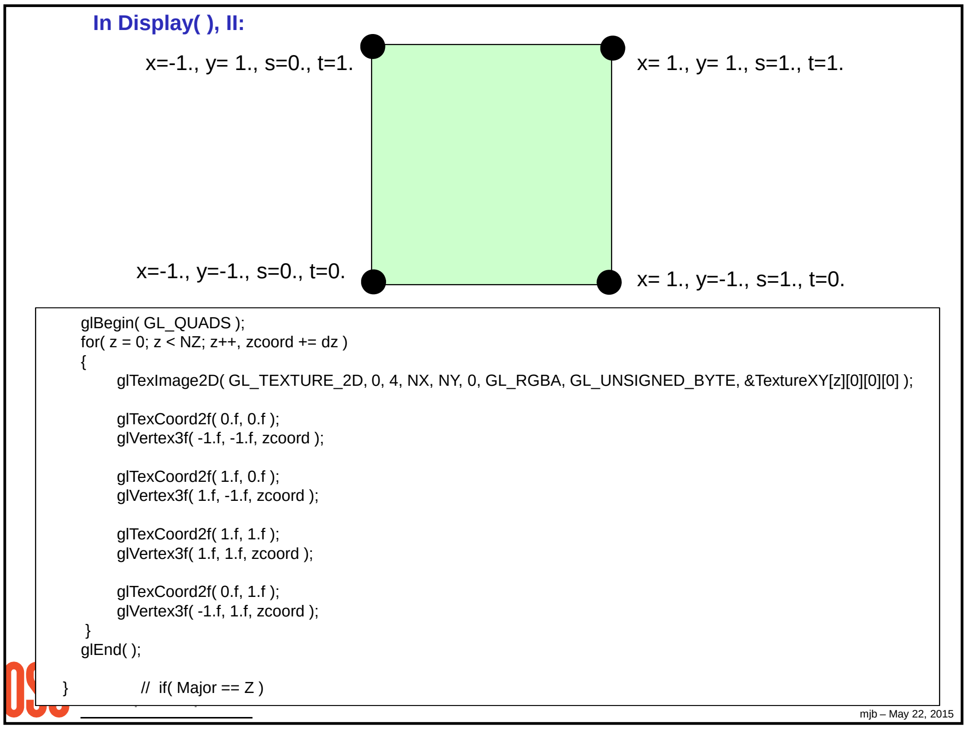

In Display( ), II:

x=-1., y= 1., s=0., t=1.
x= 1., y= 1., s=1., t=1.
x=-1., y=-1., s=0., t=0.
x= 1., y=-1., s=1., t=0.

```
     glBegin( GL_QUADS );
     for( z = 0; z < NZ; z++, zcoord += dz )
     {
          glTexImage2D( GL_TEXTURE_2D, 0, 4, NX, NY, 0, GL_RGBA, GL_UNSIGNED_BYTE, &TextureXY[z][0][0][0] );

          glTexCoord2f( 0.f, 0.f );
          glVertex3f( -1.f, -1.f, zcoord );

          glTexCoord2f( 1.f, 0.f );
          glVertex3f( 1.f, -1.f, zcoord );

          glTexCoord2f( 1.f, 1.f );
          glVertex3f( 1.f, 1.f, zcoord );

          glTexCoord2f( 0.f, 1.f );
          glVertex3f( -1.f, 1.f, zcoord );
      }
     glEnd( );

  }            //  if( Major == Z )
```

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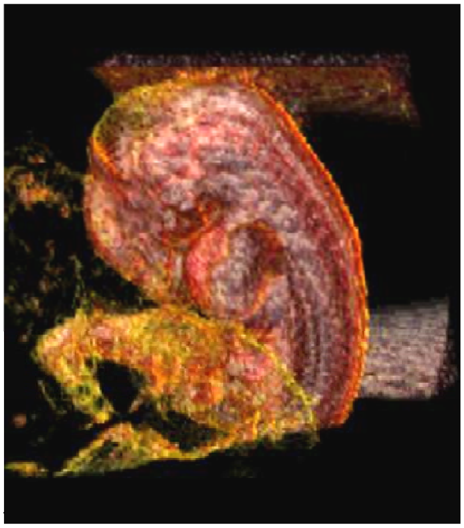
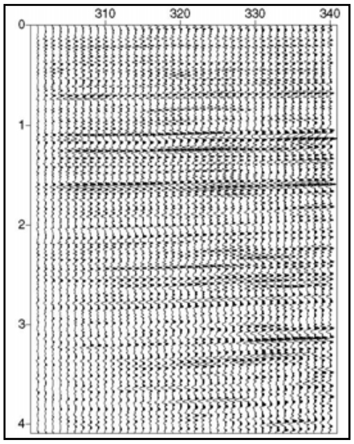
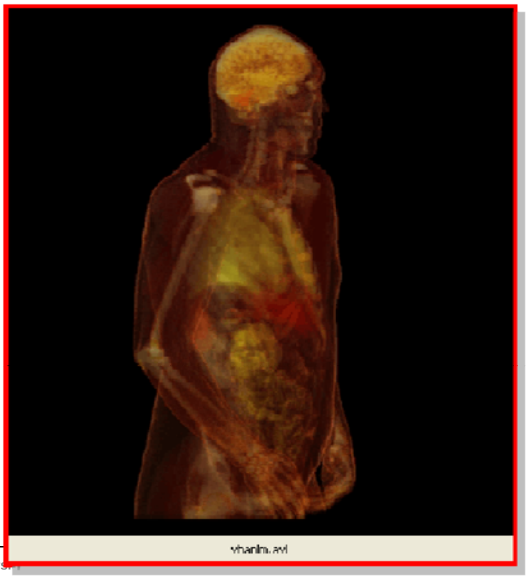
Human Embryo



Geophysics

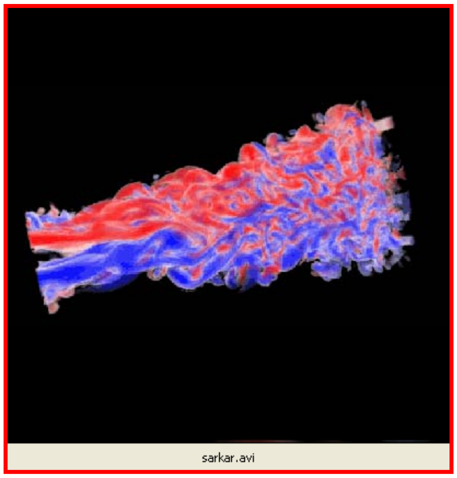


Volume Interaction: The Visible Human

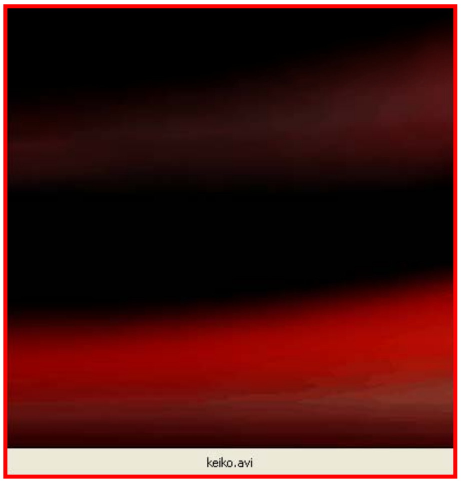


vhanim.avi

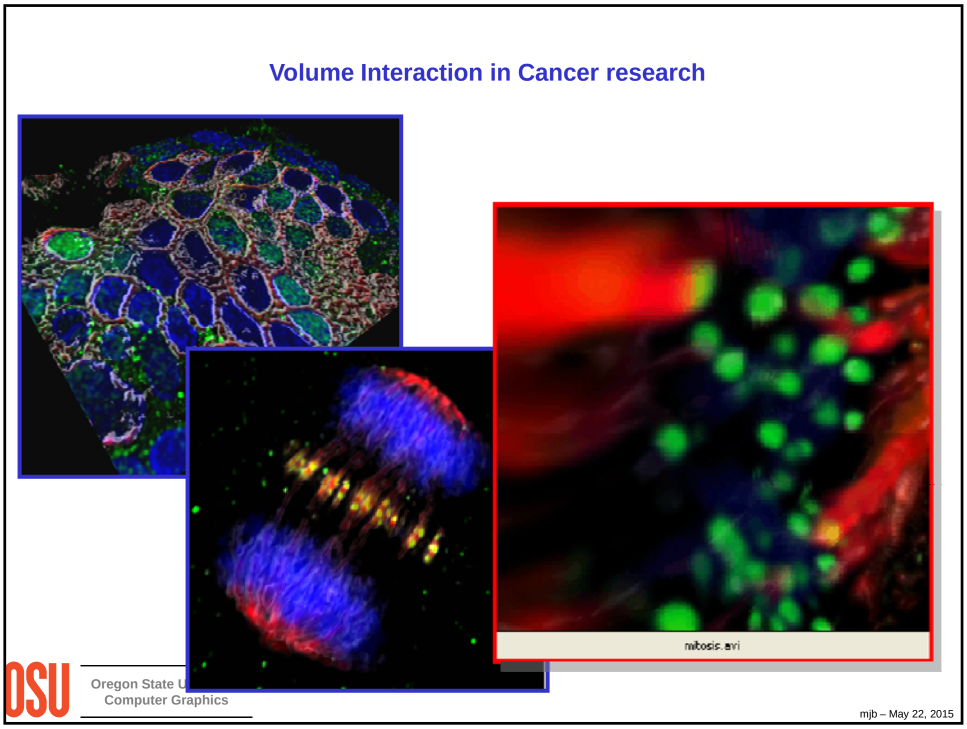
Interactive Volume Visualization for Computational Fluid Dynamics



sarkar.avi



keiko.avi



Volume Interaction in Cancer research

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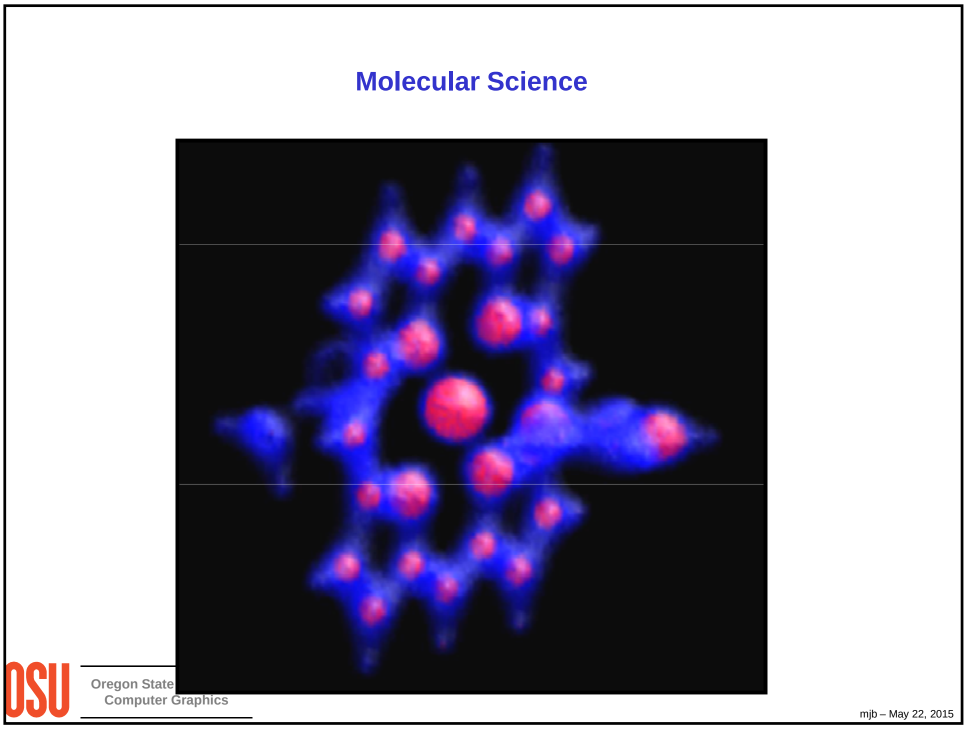

Molecular Science

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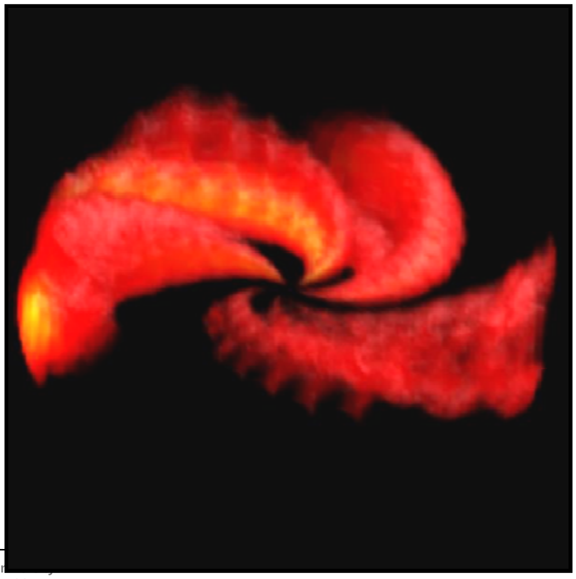
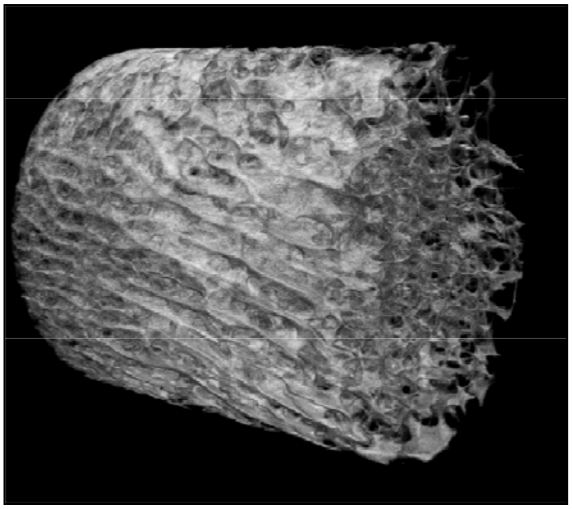
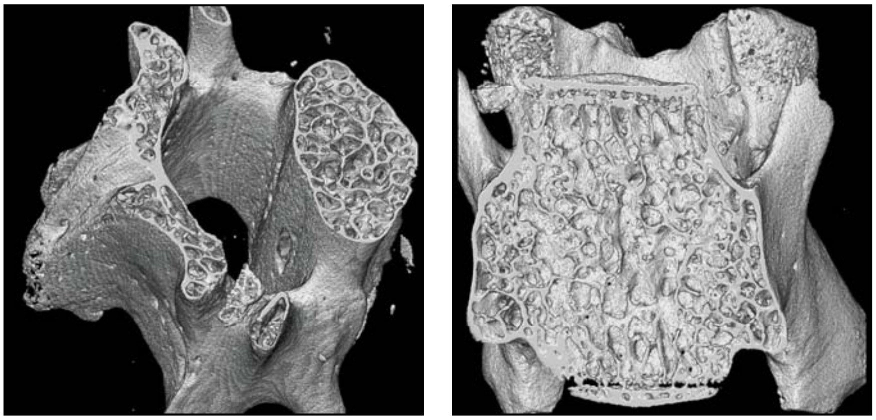
Solar Wind



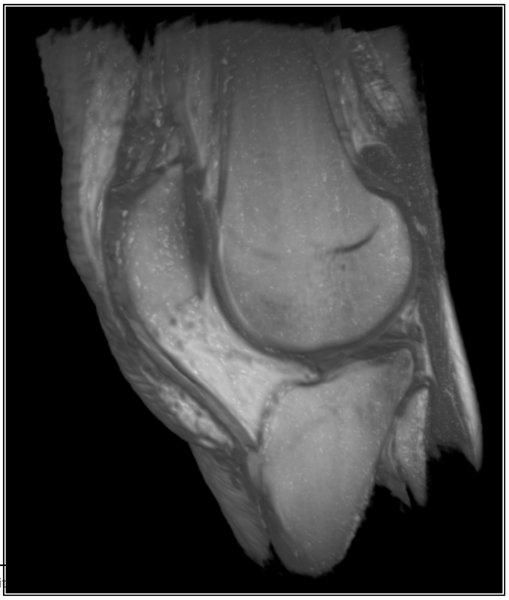
OSU Sheepbone



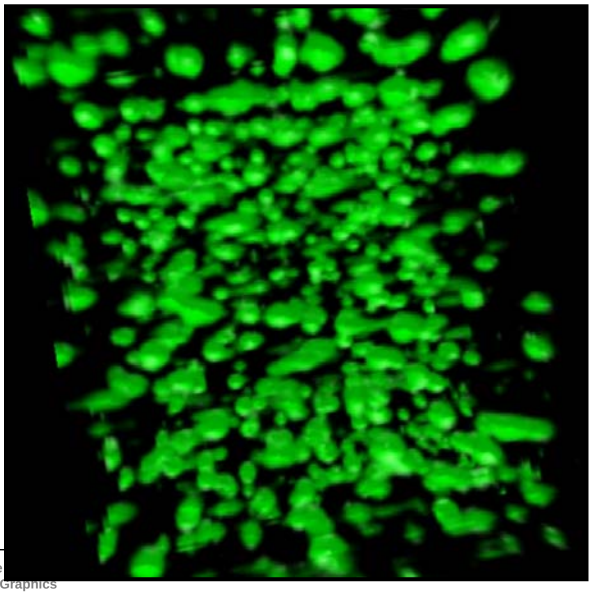
OSU Mouse Vertrebra



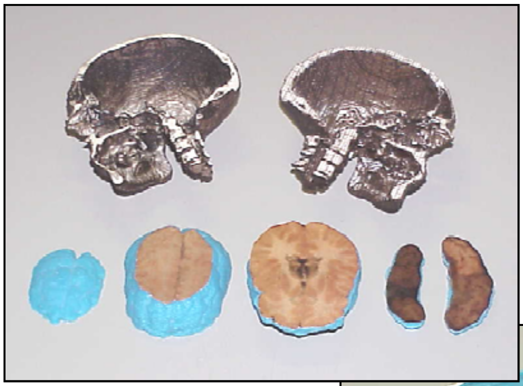
Professor Metoyer’s Knee



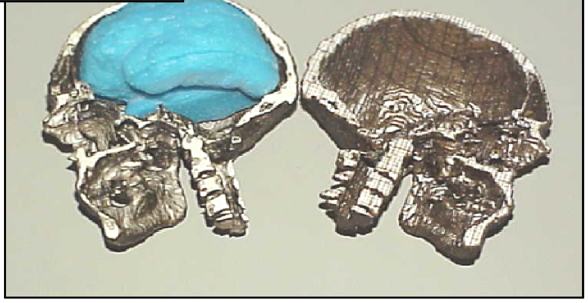
Foliage Density



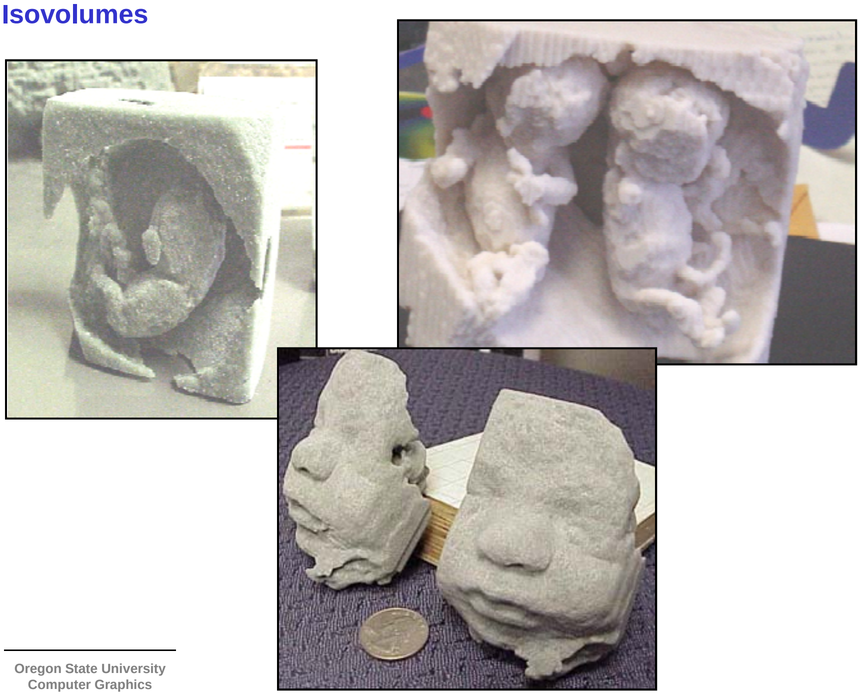
Isovolumes



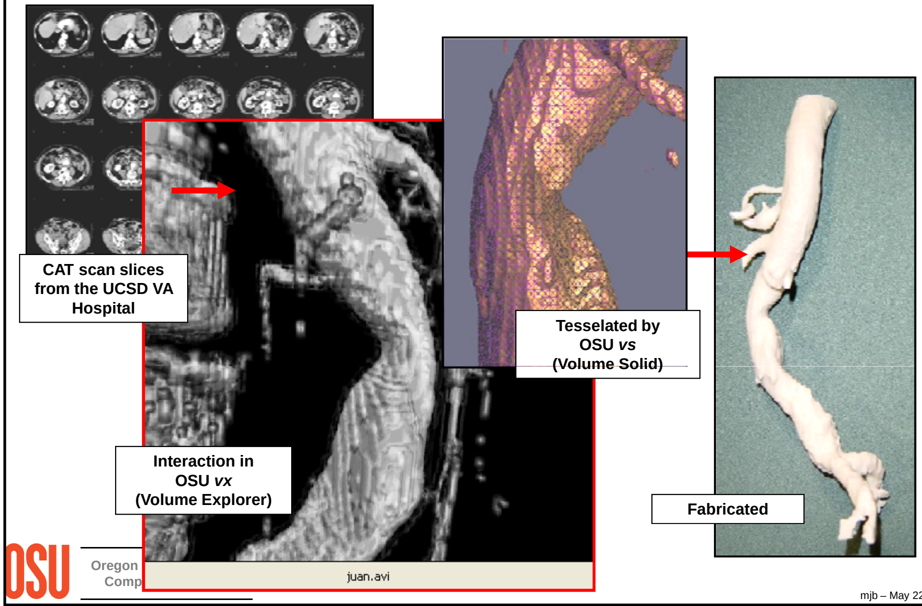
To be manufactureable, there must be finite material between two isosurfaces



Isovolumes



Putting the Tools Together:
Modeling and Making Anabolic Aortic Aneurysms



CAT scan slices from the UCSD VA Hospital

Interaction in OSU *vx* (Volume Explorer)

Tesselated by OSU *vs* (Volume Solid)

Fabricated