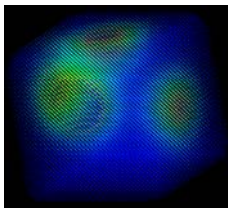
Directly Visualizing Volume Data

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

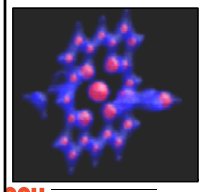
Volume Data: A Definition

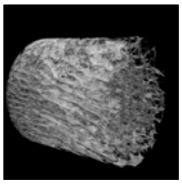
A *volume* is a 3D discretely sampled data set where the size of the voxels have been expanded to occupy the space to the neighboring voxels.



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.

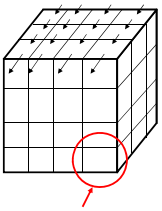
Understanding Volume Data Usually Involves a Compromise

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

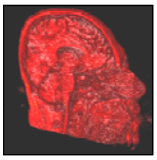
Because of these compromises, these are all considered to be ***indirect*** ways to visualize volume data

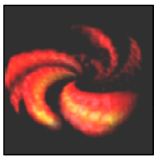
Direct Volume Rendering

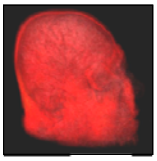
Composite the colors and alphas of the voxels



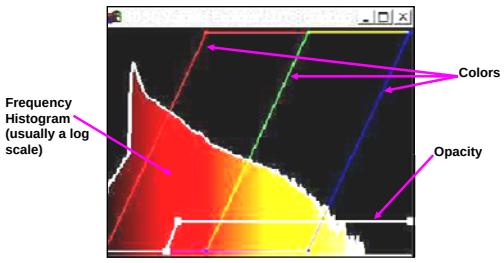
A *Volume Element*, or *voxel*







Transfer Function



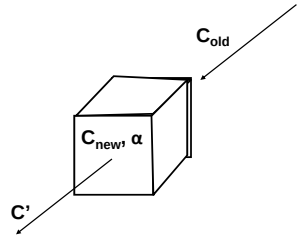
OSU *vx* Transfer Function Sculpting Window

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:

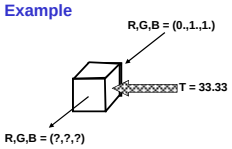


Voxel Compositing Example

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**

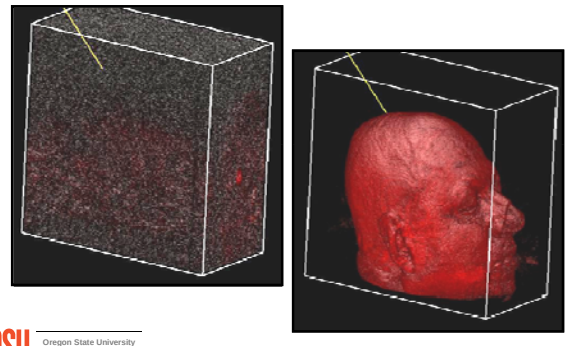
1. **What is the color of *just this voxel*?**
2. **What is the opacity of *just this voxel*?**
3. **What will the new running RGB values be when you are done compositing this voxel with the old running RGB values?**

What is the color of *just this voxel*?

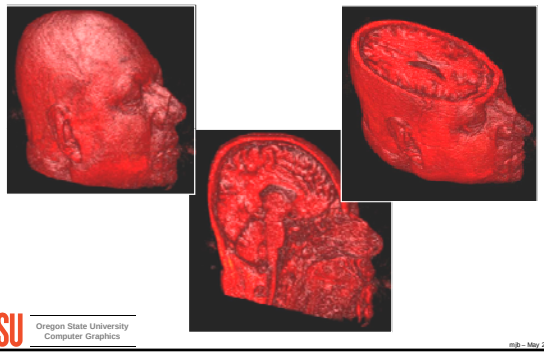
What is the opacity of *just this voxel*?

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

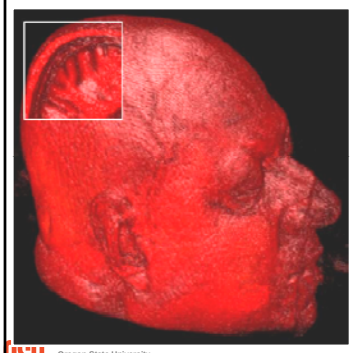
Cropping the Volume based on Data Value

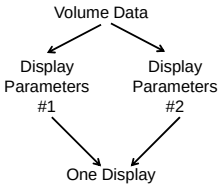


Cropping the Volume based on Spatial Location

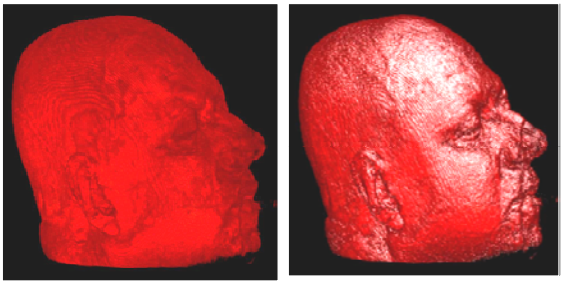


"Magic Lens" to Selectively Look Inside



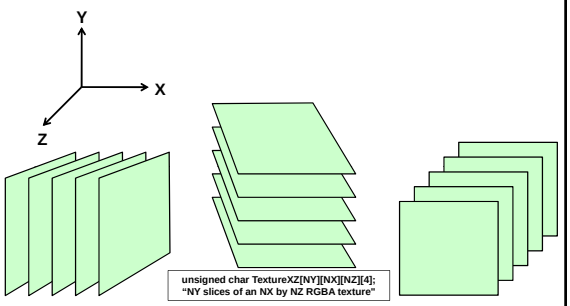


Lighting



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

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 = NodesRgb[0][z];
                    g = NodesRgb[1][z];
                    b = NodesRgb[2][z];
                    alpha = MaxAlpha;
                }

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

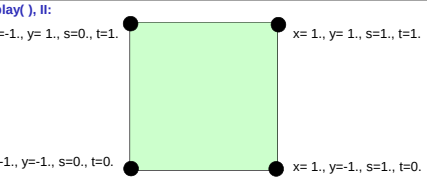
Zside is set from somewhere else

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 );
glPixelStore( 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 );
    }
```

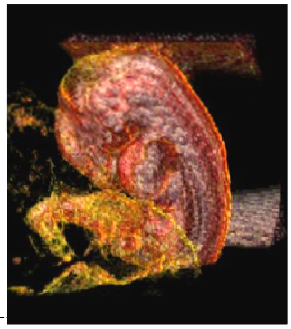
Sets the global variables Major, Xside, Yside, and Zside

In Display( ), II:

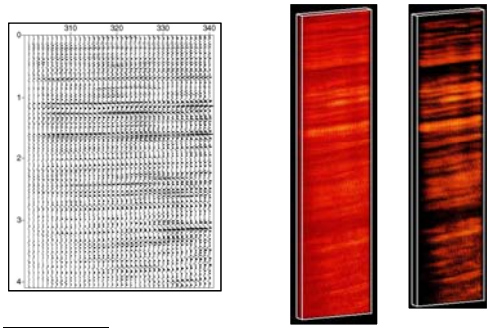



```
glBegin( GL_QUADS );
for( z = 0; z < NZ; z++, zcoord += dz )
{
    glTexImage2D( GL_TEXTURE_2D, 0, 4, NX, NY, 0, GL_RGBA, GL_UNSIGNED_BYTE, &TextureXY[z][0][0][0] );

    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 )
```

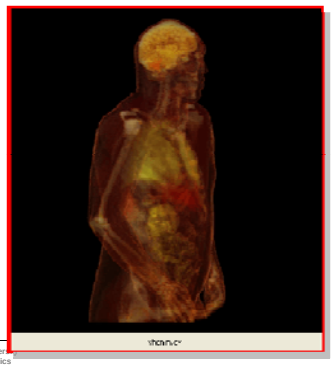
Human Embryo



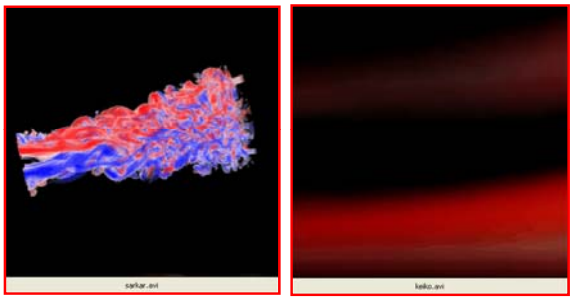
Geophysics



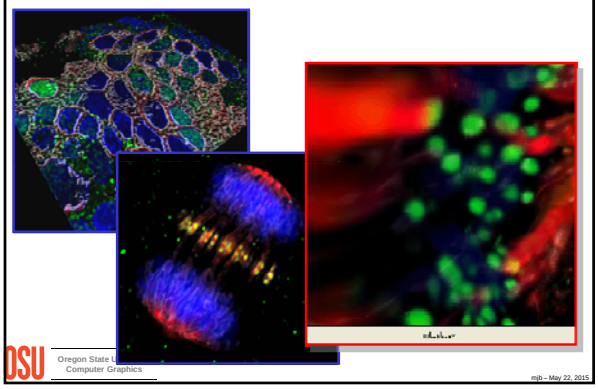
Volume Interaction: The Visible Human



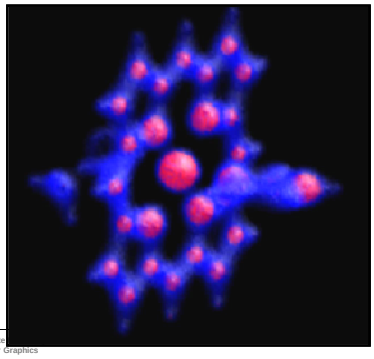
Interactive Volume Visualization for Computational Fluid Dynamics



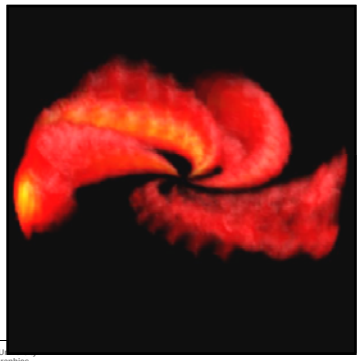
Volume Interaction in Cancer research



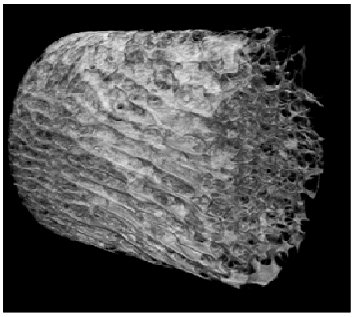
Molecular Science



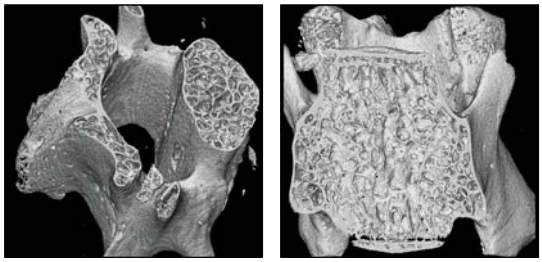
Solar Wind



OSU Sheepbone

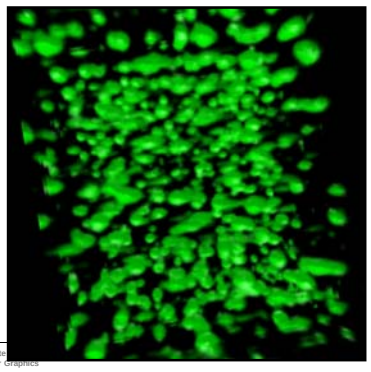


OSU Mouse Vertrebra



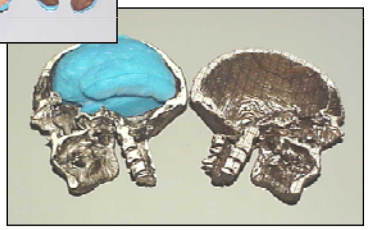
Professor Metoyer's Knee

Foliage Density



Isovolumes

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

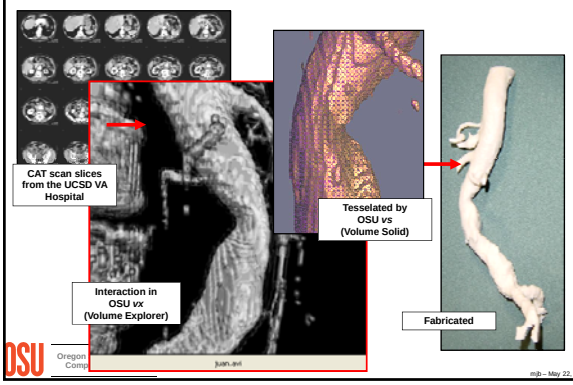


Isovolumes

Oregon State University
Computer Graphics

mjb – May 22, 2015

Putting the Tools Together:
Modeling and Making Anabolic Aortic Aneurysms



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