Session: Health, Medical and Science Visualization

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Web3D Showcase March 25, 2014

National Capitol Region

Presentation Outline

- Web3D Visualization:
  - **ISO/IEC Extensible 3D (X3D)**
- Advanced Imaging Visualization
  - Metadata and scene structure
  - X3DOM and HTML5 (X3D 4.0) Volume Rendering
- Surgical Training and Haptics
  - MMVR 2014 Review
  - X3D Haptics and Soft Body Physics components

X3D Scene Graph

Forward-compatible from VRML

Format and API above rendering library:

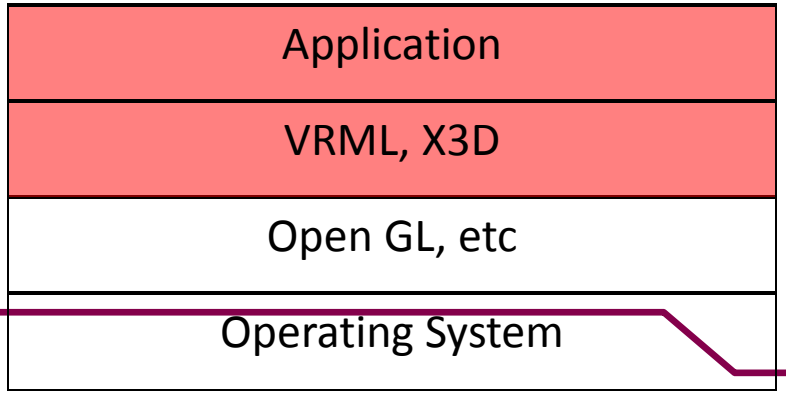
- Scene access to nodes, parameters and events for application-level control of 3D objects, viewpoints, lights and animations
- Can be implemented on top of any rendering library (e.g. OpenGL, DirectX, WebGL, POV-Ray)

Medical Interchange Profile node set is:

- Flexible & Expressive for the composition of data from web sources (URL/URIs)
- X3D Interchange + Volume Component + 3D Texturing Component + …

Foundations

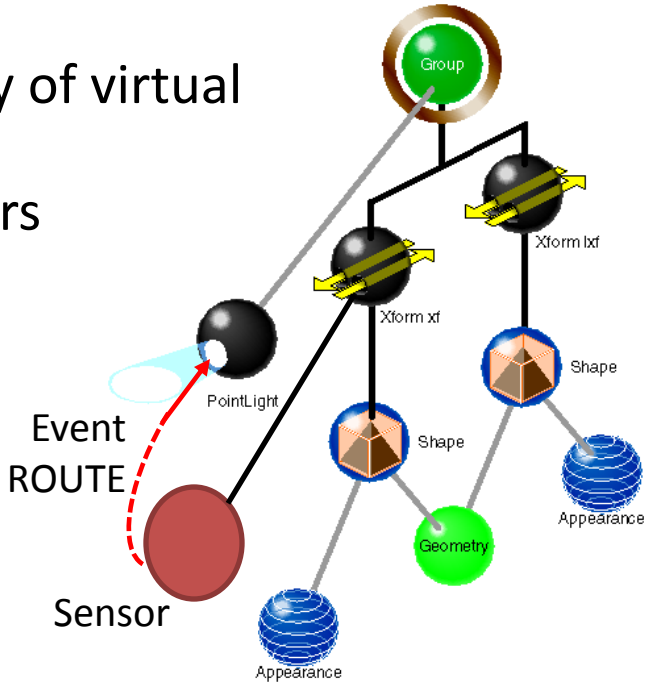
- ISO standard, openly published and royalty-free
- A layer above media and rendering libraries
- Multiple implementations including open source codebases
- X3D Scene graph includes the *Transformation graph* and the *Behavior graph*



Standard Scope

Scene graph for real-time interactive delivery of virtual environments over the web:

- Meshes, lights, materials, textures, shaders
- Integrated video, audio
- Animation
- Interaction
- Behaviors
- Scripts
- Application Programming Interfaces



- 3.3 examples for Medical Imaging, CAD and Geospatial support!

X3D Book & Online Resources

- http://www.x3dgraphics.com/

Extensible
3D Graphics
For Web Authors

From NPS grad class – slides, videos, examples all online!!!

Publishing X3D Worlds

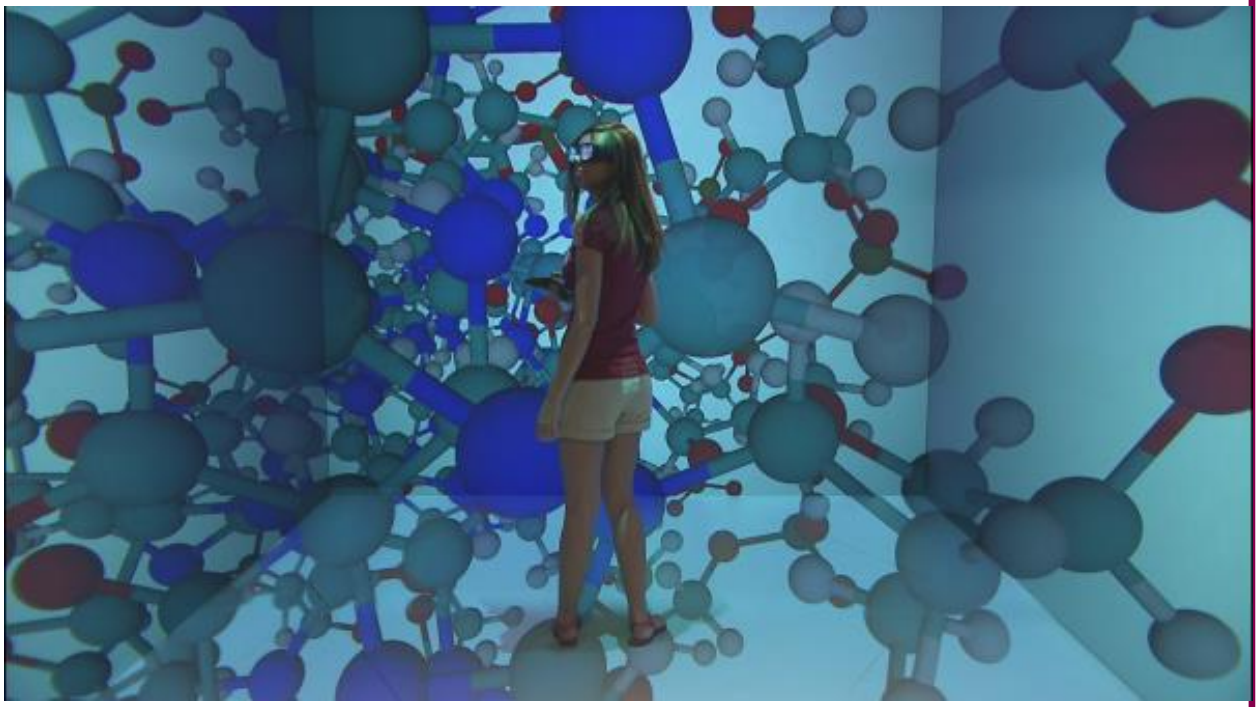
URLs- a file or CGI web request delivers to clients:

- Stand-alone applications
  - InstantReality.org, COVISE
- Plug-ins for an internet browser
  - Bitmangement.de, OctagaVS, Cortona3D
- New subset on top of HTML5 – native 3D with no plug-ins and works with WWW event system (X3DOM) !

Chemistry

VRML and X3D are supported in many tools related to materials and biology, most notably:

- Chimera
- VMD
- JMOL
- …



3D Printing for Health

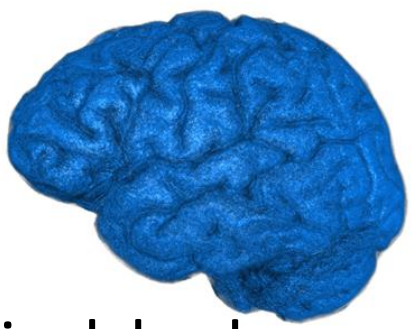
… and biosciences and education ….

- NIH 3D Print Exchange
  - Scriptable ***Meshlab.org*** for server-side validation and conversion
  - X3DOM native Web3D preview
  - Community upload and validation

Web3D.org Medical Working Group

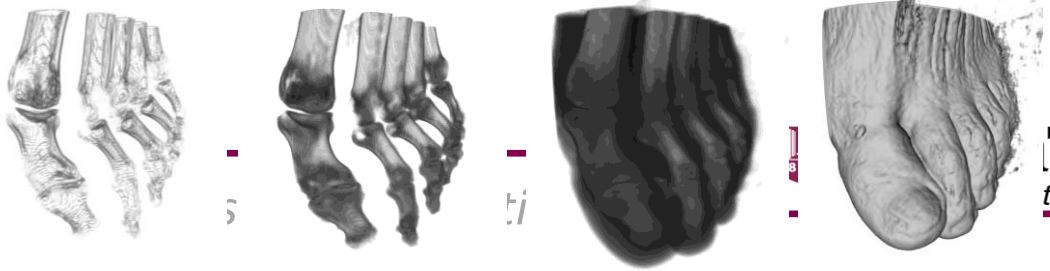
- ***Reproducible*** rendering and presentations for stakeholders throughout the healthcare enterprise
- An n-D Presentation state must be:
  - Structured and interactive virtual environment display of 2D & 3D medical imaging objects and time series
  - Platform-independent, royalty-free technology to enable vendor innovation
    - Handeld and immersive displays
    - Input devices
  - Lossless with provenance metadata and ontology references
  - Web-aware

Volume Presentation



Many techniques:

- Volume rendering
  - 3DSplatting, ray tracing, pixelshaders
  - Established CPU and GPU algorithms
- Surfaces – actual meshes
- Segments – identifying voxels as groups
- ISOSurfaces – rendered at a threshold



ISO/IEC X3D 3.3 Volume Rendering

- Composable Render Styles covering the state of the art
  - Formalizes parameters and transfer functions for the ***Greatest Common Denominator***

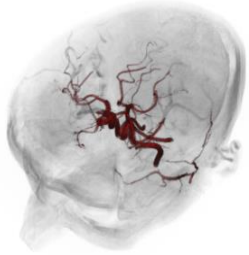
  Of 3D rendering & blending:
    - BoundaryEnhancementVolumeStyle
    - CartoonVolumeStyle
    - ComposedVolumeStyle
    - EdgeEnhancementVolumeStyle
    - OpacityMapVolumeStyle
    - ProjectionVolumeStyle
    - ShadedVolumeStyle
    - SilhouetteEnhancementVolumeStyle
    - ToneMappedVolumeStyle

Opacity Map

Silhouette

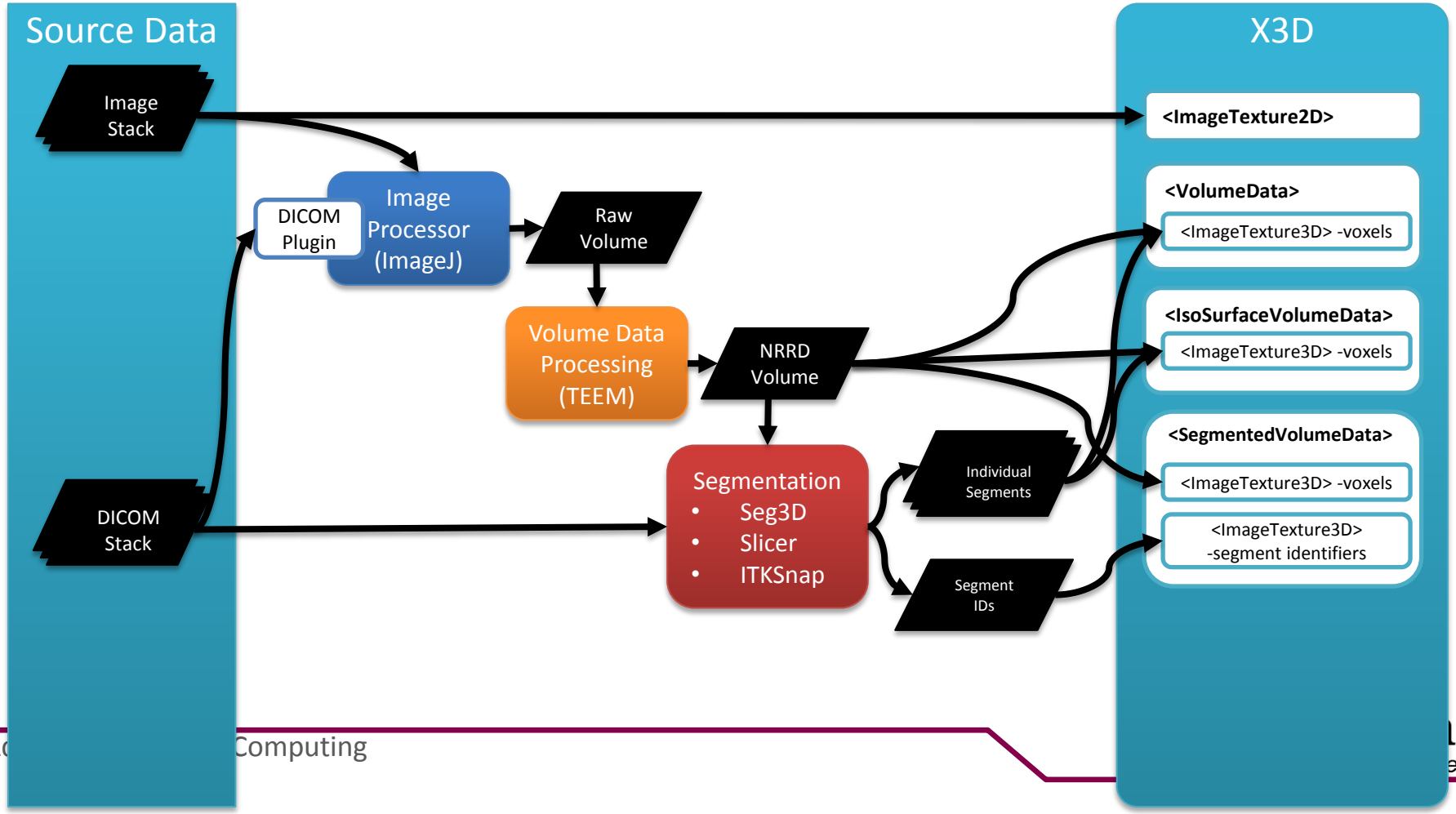
Cartoon

- Assign different RenderStyles to different segments, blend two volumes:
  - BlendedVolumeStyle
  - SegmentedVolumeData
  - IsoSurfaceVolumeData

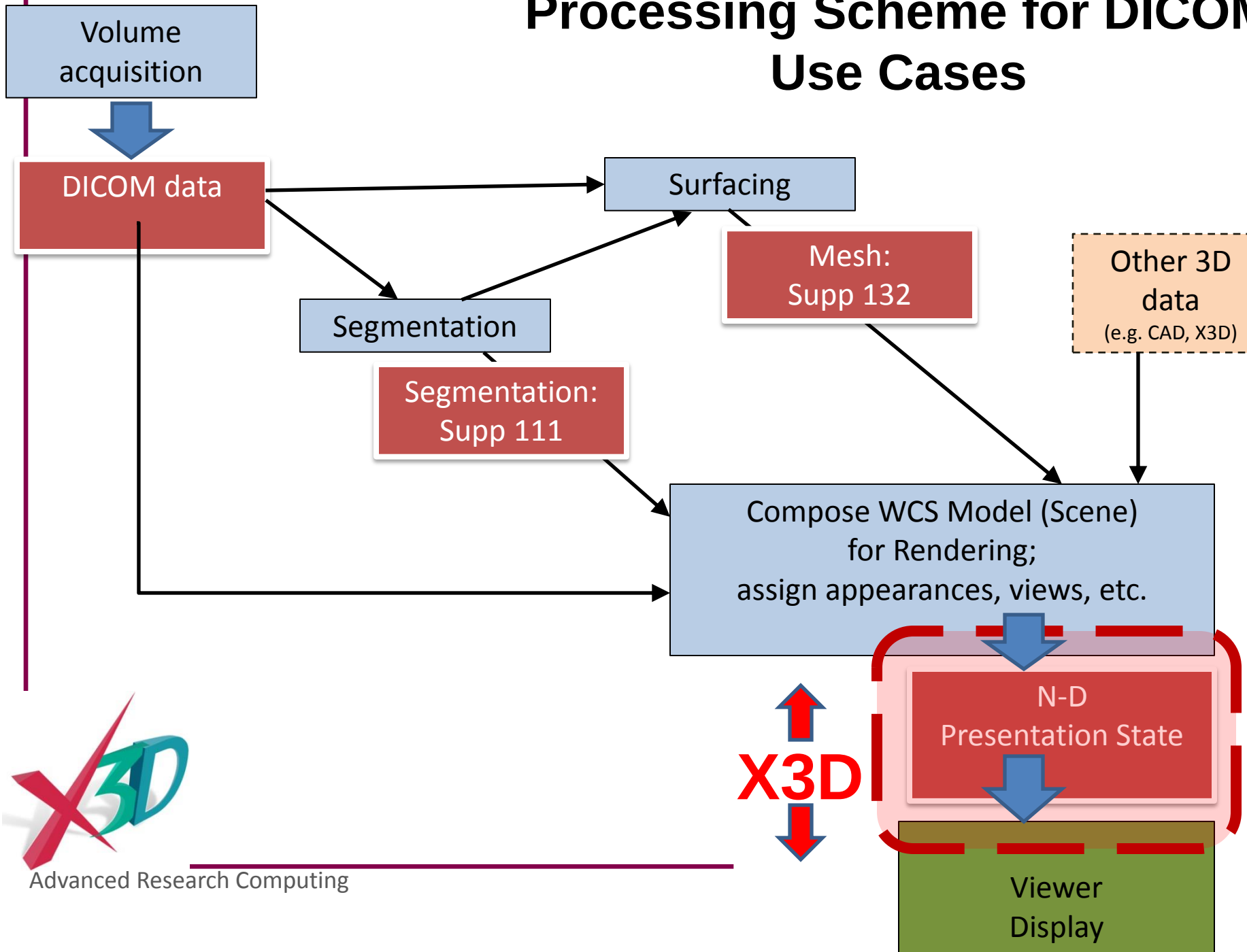


- Clipping Planes are already specified in X3D 3.2 Rendering Component

Volume Processing Pipelines



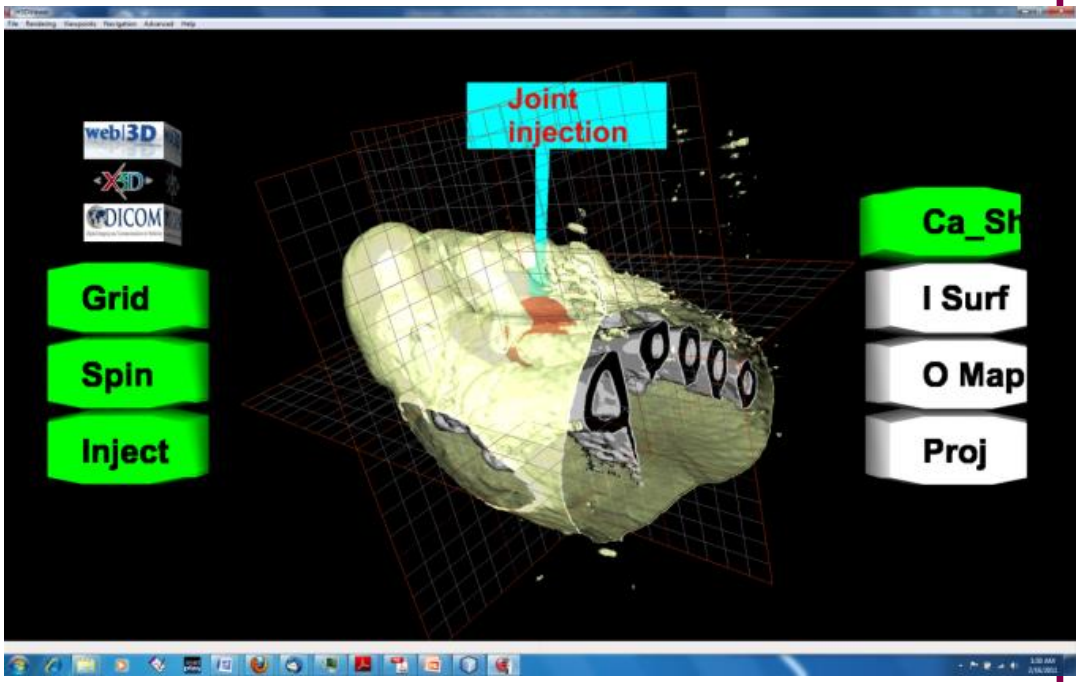
Processing Scheme for DICOM Use Cases



X3D Medical Interchange Profile

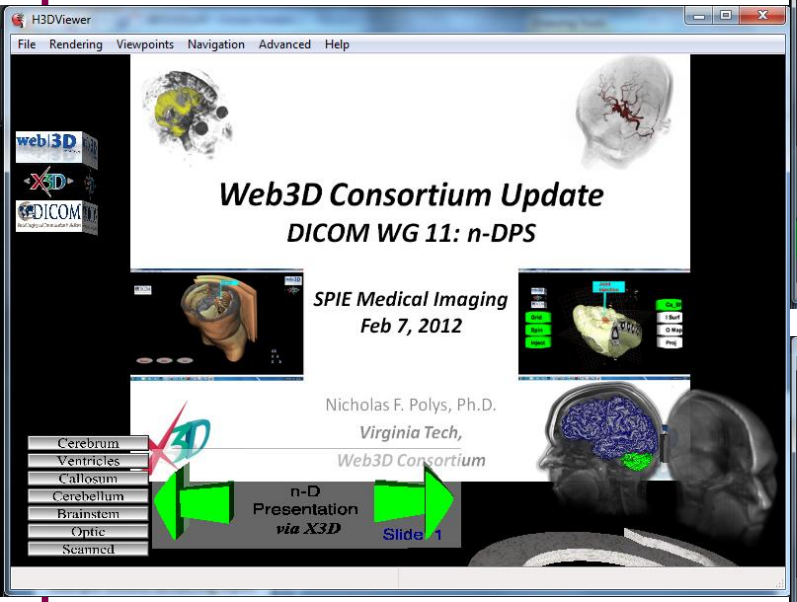
Minimal X3D node set (footprint) to meet DICOM requirements:

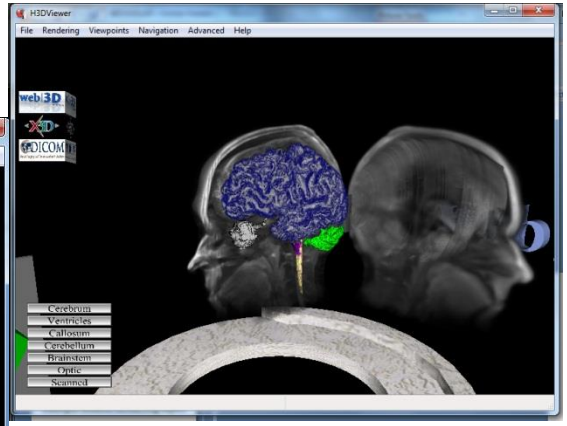
- Core
- Time
- Networking
- Grouping
- Rendering
- Shape
- Geometry3D
- Geometry2D
- Text
- Lighting
- Texturing
- Interpolation
- Navigation
- Environmental effects
- Event utilities
- Texturing3D
- Volume rendering

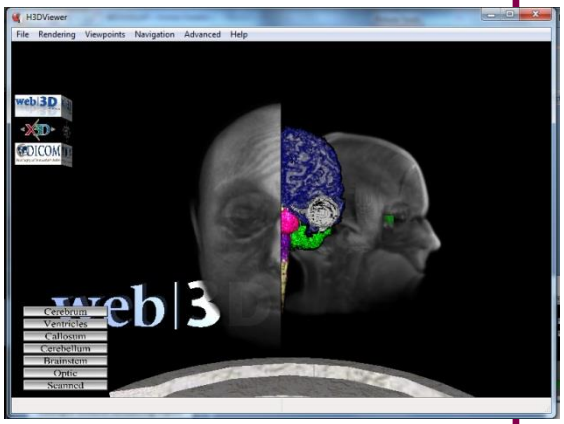


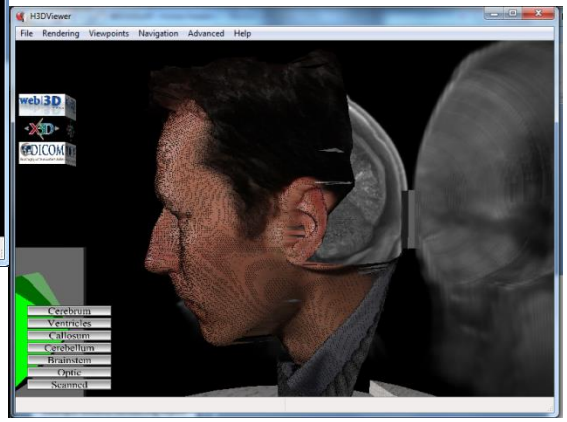
Includes polygon, line and point rendering; metadata on any node

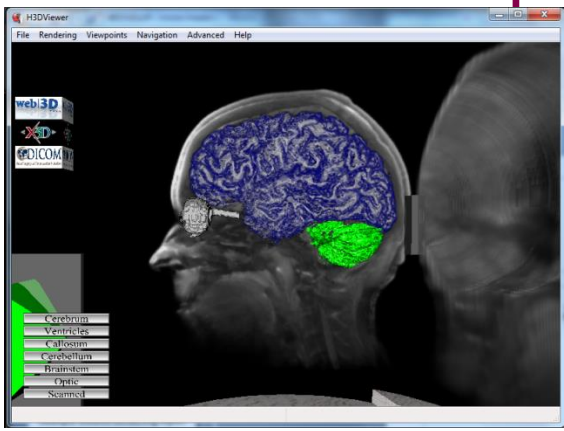
X3D Presentation Demo











Screenshots

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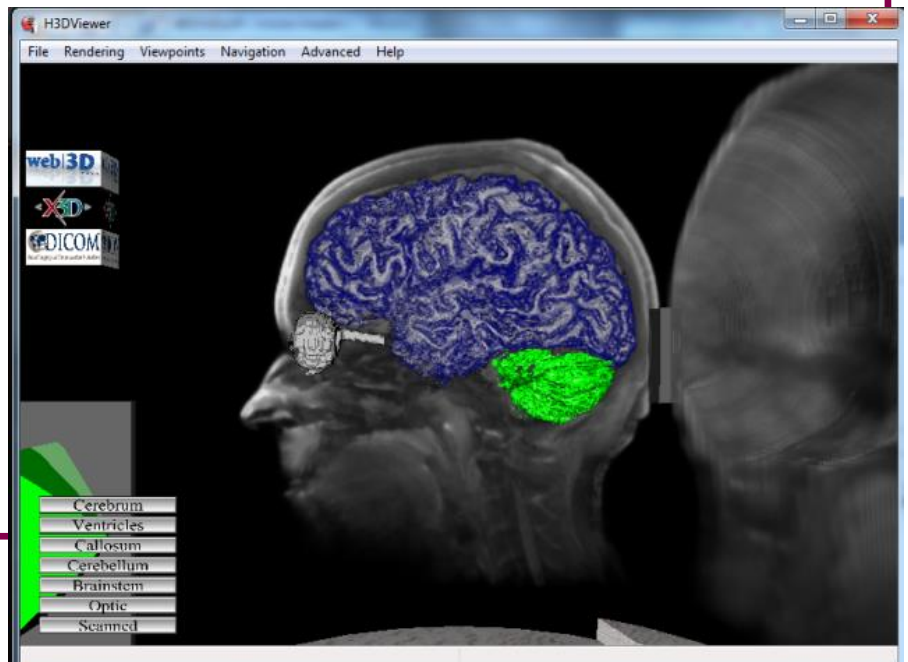
Advanced Research Computing
Virginia Tech

Example Volume Rendering Styles

(Head MRI, XML encoding)

```
<Transform DEF='backdrop' >
    <VolumeData dimensions='.75 1 1' >
        <ImageTexture3D containerField="voxels" url='"./Segments/masked-vispart.nrrd"'/>
        <OpacityMapVolumeStyle />
    </VolumeData>
</Transform>
```



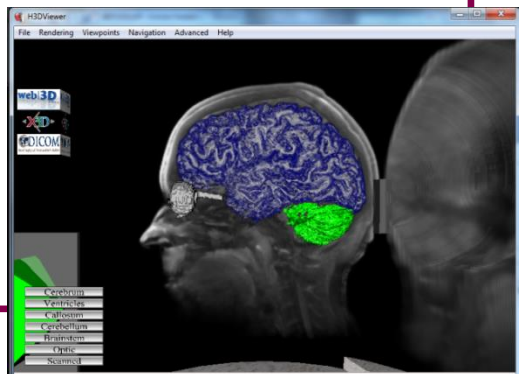
Example Volume Rendering Styles

(Head MRI, optic segment)

```
<ISOSurfaceVolumeData surfaceValues='.15' dimensions='.75 1 1' >
    <ImageTexture3D containerField="voxels" url='"./Segments/masked-optic.nrrd"'/>
    <CartoonVolumeStyle />
</ISOSurfaceVolumeData>
```

(Head MRI, cerebrum segment)

```
<VolumeData dimensions='.75 1 1' >
    <ImageTexture3D containerField="voxels" url='"./Segments/masked-
    cerebrum.nrrd"'/>
    <ComposedVolumeStyle>
        <CartoonVolumeStyle />
        <EdgeEnhancementVolumeStyle gradientThreshold='.8' edgeColor='0 0 .5' />
    </ComposedVolumeStyle>
</VolumeData>
```



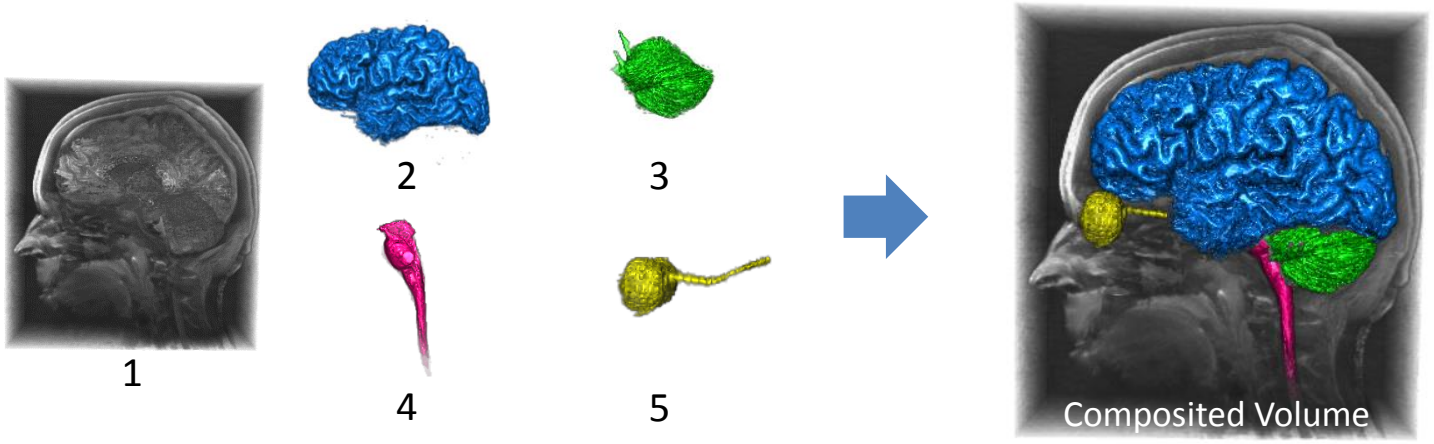
Multi-part Volumes: Multiple Volumes

- Use different VolumeData nodes to represent each segment
- More computationally expensive than SegmentedVolumeData, but more flexible
  - Can manipulate individual segments
  - More fine-grained rendering control
- Requires masked volumes (more pre-processing)

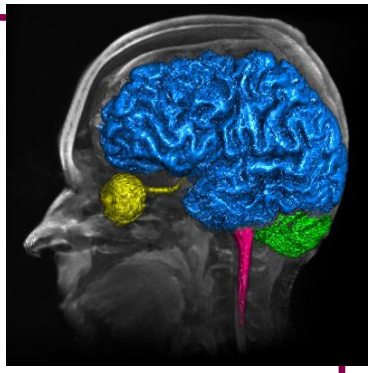
Multi-part Volumes: Multiple Volumes

```
<VolumeData dimensions='.75 1 1' >
Segment1    <ImageTexture3D containerField="voxels" url='"./Segments/masked-halfhead.nrrd"'/>
Style 1     <OpacityMapVolumeStyle />
</VolumeData>

<VolumeData dimensions='.75 1 1' >
Segment2    <ImageTexture3D containerField="voxels" url='"./Segments/masked-cerebrum.nrrd"'/>
            <ShadedVolumeStyle lighting="TRUE" shadows="TRUE" >
Style 2                 <Material diffuseColor='0 .5 1' specularColor='1 1 1' ambientIntensity='0.8' shininess='0.08' />
            </ShadedVolumeStyle>
</VolumeData>
```



Multi-part Volumes: SegmentedVolumeData



- Requires two 3Dtextures: voxels (as normal volume) and segment identifiers for each voxel
- Specify multiple render styles in identifier/segment order (default is opacity map)
  - If more segments than styles, last style applies to remaining segments
- Individual segments may be turned on or off using “segmentEnabled” field
  - Styles still required to maintain indexing

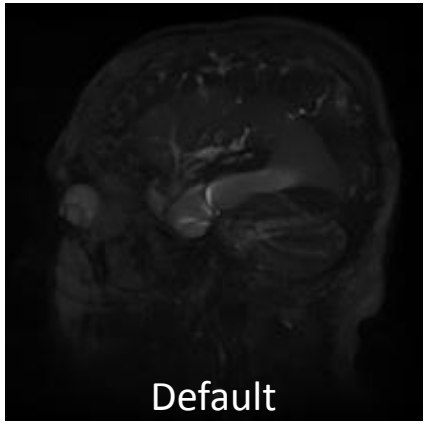
Multi-part Volumes: SegmentedVolumeData

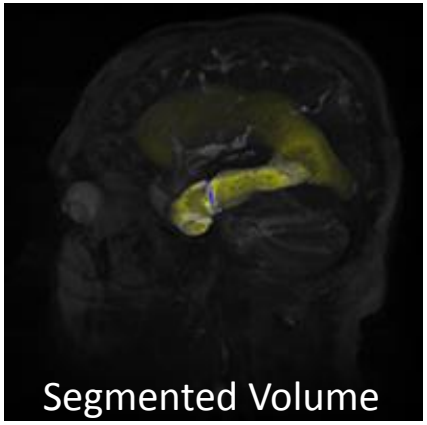
```
<SegmentedVolumeData dimensions='2.304 2.304 1.116' containerField='children'>
  <ImageTexture3D containerField='voxels' repeatS='false' repeatT='false' repeatR='false'
    url=' "mri_ventricles.nrrd" '/>
  <ImageTexture3D containerField='segmentIdentifiers' repeatS='false' repeatT='false' repeatR='false'
    url=' "mri_ventricles_segment.nrrd" '/>
  <OpacityMapVolumeStyle enabled='true' containerField='renderStyle'/>
  <ToneMappedVolumeStyle enabled='true' coolColor='0 0 1 0' warmColor='1 1 0 0'
    containerField='renderStyle'/>
</SegmentedVolumeData>
```

Voxels

Segments

Styles



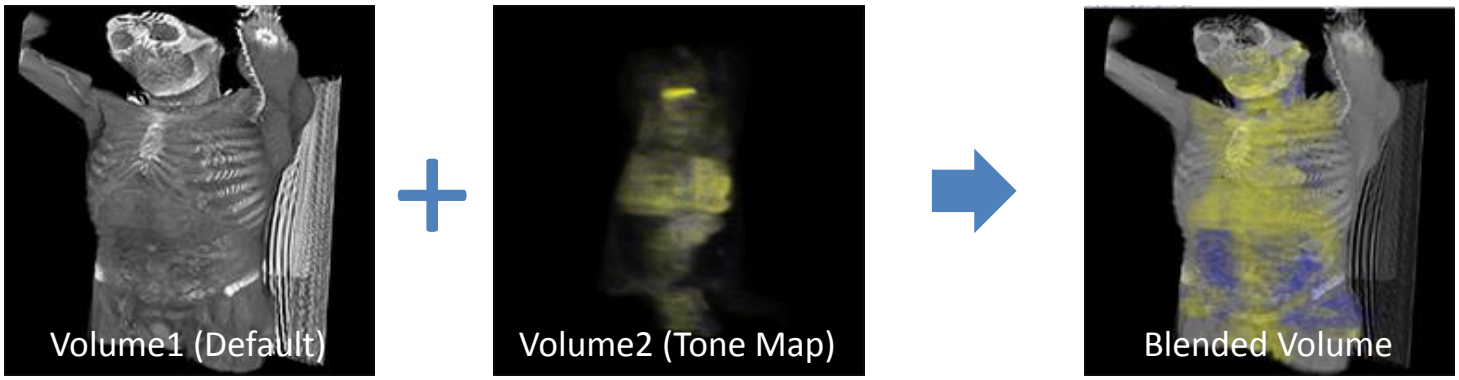


Multi-part Volumes: Blended Render Style

- Blends multiple volumes/segments in one VolumeData node
- BlendedVolumeStyle node contains its own voxels and render style nodes
  - Contained voxels rendered according to styles, then blended with parent
  - Weight of blending is configurable
- BlendedVolumeStyle is composable and nestable!

Multi-part Volumes: BlendedVolumeStyle

```
<VolumeData dimensions='512 512 452' containerField='children'>                    Default Style1
        <BlendedVolumeStyle weightConstant1='0.51' enabled='true' weightConstant2='0.5'
         weightFunction1='CONSTANT' weightFunction2='CONSTANT' containerField='renderStyle'>
Style2      <ToneMappedVolumeStyle enabled='true' coolColor='0 0 1 0' warmColor='1 1 0 0'
             containerField='renderStyle'/>
Volume2     <ImageTexture3D containerField='voxels' repeatS='false' repeatT='false'
             repeatR='false' url=' "internals.nrrd" '/>
        </BlendedVolumeStyle>
Volume1 <ImageTexture3D containerField='voxels' repeatS='false' repeatT='false' repeatR='false'
         url=' "body.nrrd" '/>
</VolumeData>
```

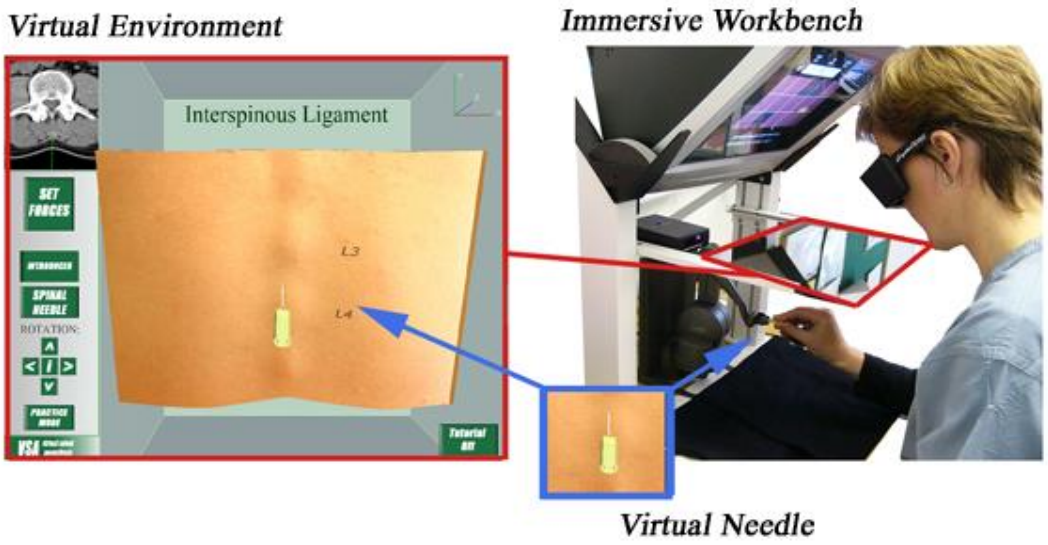


X3D Metadata Scheme

- Metadata and Metadata Sets can be children of any node in the scene graph
- DEF, reference, name and value attributes can be used to integrate ***ontology terms and provenance***
- Follows the pattern:
  - *VolumeData
    - Segmentations
      - ImageTexture3D

Surgical Training and Haptics

- MMVR 2014 Review
- X3D Haptics and Soft Body Physics components
- H3D.org



Breaking News

- **X3D for HTML-5** **www.X3DOM.org**
  - ***Native 3D rendering in Browser with WebGL***
  - Control of scene graph through DOM & Javascript
  - Firefox, Chrome, Safarai, Opera (including Mobile!)
  - Even IE Explorer
  - MedX3DOM - volume rendering!

X3DOM – Declarative (X)3D in HTML5

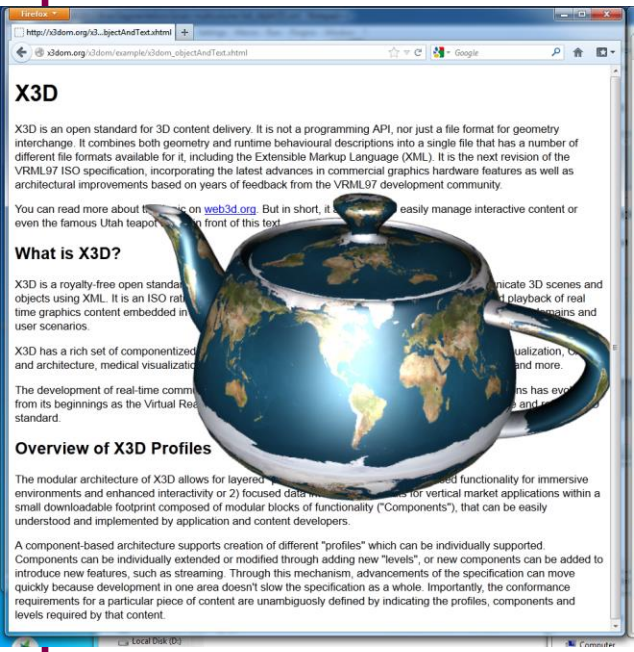
Completes todays graphics technologies

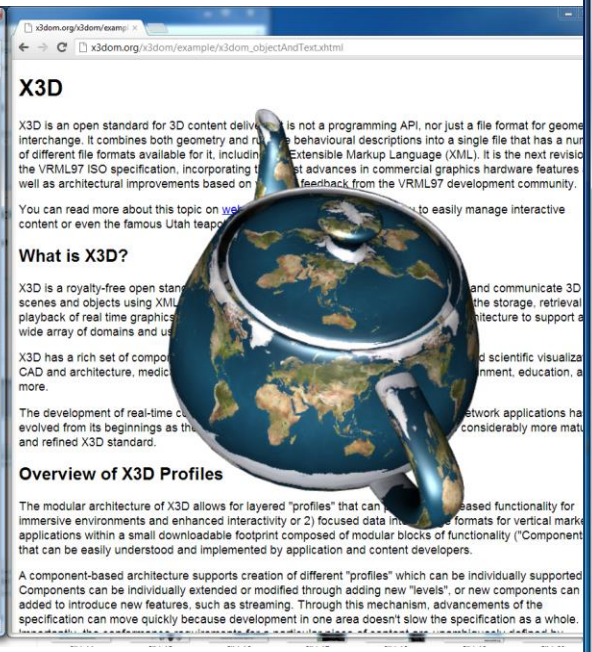
	2D (Final HTML5 spec)	3D (No W3C spec yet)
Declarative Scene-graph Part of HTML document DOM Integration CSS / Events		
Imperative Procedural API Drawing context Flexible		

X3DOM.org

Firefox

Chrome





Also: Safari, Opera, Internet Explorer

Volume Rendering (MedX3DOM)

HTML 5 with Web3GL and X3D!

Web3D and X3D Next Steps

- X3DOM.org – full Volume Rendering support in WebGL 1.0 and 2.0
- X3D Annotation Component
- MPR /CPR support, Wado
- X3D Haptics Component
- X3D Soft-body Physics Component

! Web3D 2014 !

w/ SIGGRAPH in Vancouver, CA

www.web3d2014.web3d.org

Acknowledgements

- Daniel Evestedt and Sebastian Ullrich (Sensegraphics)
- Don Brutzman (NPS)
- Nigel John U Wales Bangor, Richard Puk
- Yvonne Jung, Johannes Behr (Fraunhofer IGD)
- Luis Kabongo, John Congote (Vicomtech)

Join Us!

www.Web3D.org

X3D Medical Working Group

- ***Web3D Consortium*** ***President*** *(elected)*
  - ***Nicholas F. Polys, Ph.D.,*** ***Virginia Tech*** ***npolys@vt.edu***

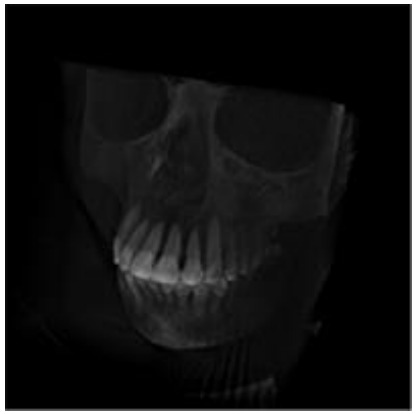
Supplemental Material

- Web3D 2013 Tutorial is online (excerpts below)
- See web3d.org Medical WG Public Wiki

Rendering a Volume: VolumeData Node

- Most basic volume rendering node in X3D
- Contains the voxels to be rendered and render styles to do so

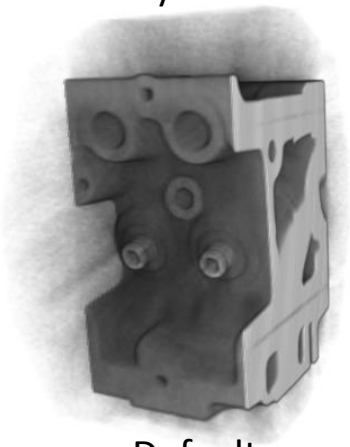
```
<VolumeData dimensions='1.28 1.28 1.0' >
        <!-- VolumeRenderStyle node here (optional) -->
        <ImageTexture3D containerField='voxels' url='  "path_to_dataset" '/>
</VolumeData>
```



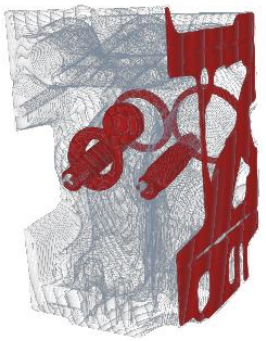
Opacity Map VolumeStyle

- The default style, the basis for all enhancement styles
- Has only one field, “transferFunction”
  - Two or three dimensional texture
  - One to four components

```
<OpacityMapVolumeStyle>
        <ImageTexture3D containerField='transferFunction' url='"engineTransferSchnitt.png"' />
</OpacityMapVolumeStyle>
```



Default



With Transfer Function

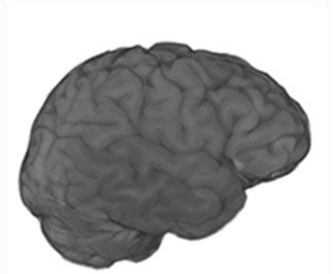
Projection VolumeStyle

- A raycasting technique
- Depending on the value of the “type” field, returns either the MAX, MIN, or AVERAGE of the voxel values along the ray
- If “intensityThreshold” is specified, returns the first local min/max above/below the threshol

```
<ProjectionVolumeStyle type='MAX' enabled='true' intensityThreshold='0'
  containerField='renderStyle'/>
```

Per-Voxel VolumeStyles

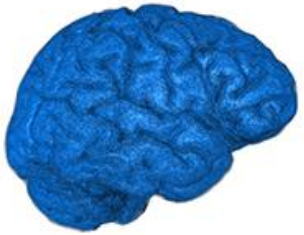
- View-Dependent
  - Opacity Map (default)
  - Enhancement Styles
    - Boundary, Edge, Silhouette
  - Cartoon
- Lighting-Dependent
  - Tone Map
  - Shaded



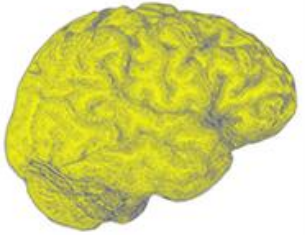
Opacity Map

Edge Enhanced

Cartoon



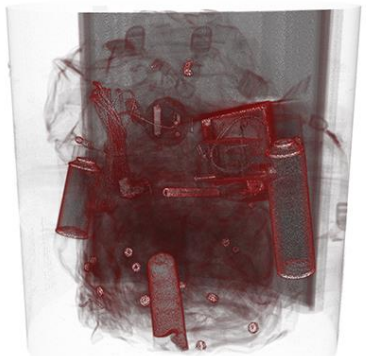
Shaded



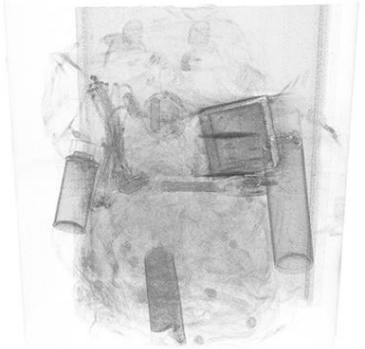
Tone Map

Combining Styles: ComposedVolumeStyle

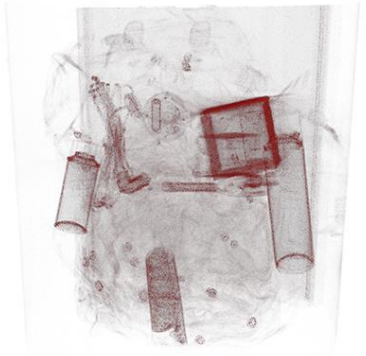
```
<ComposedVolumeStyle enabled='true' ordered='false' containerField='renderStyle'>
        <SilhouetteEnhancementVolumeStyle silhouetteBoundaryOpacity='1'
          silhouetteRetainedOpacity='.1' silhouetteSharpness='10' enabled='true'
          containerField='renderStyle'/>
        <EdgeEnhancementVolumeStyle edgeColor='.5 0 0' gradientThreshold='.8'
          enabled='true' containerField='renderStyle'/>
</ComposedVolumeStyle>
```



Style1 (Edge Enhance)



Style2 (Silhouette)



Composed Styles

Rendering a Volume: IsoSurfaceVolumeData

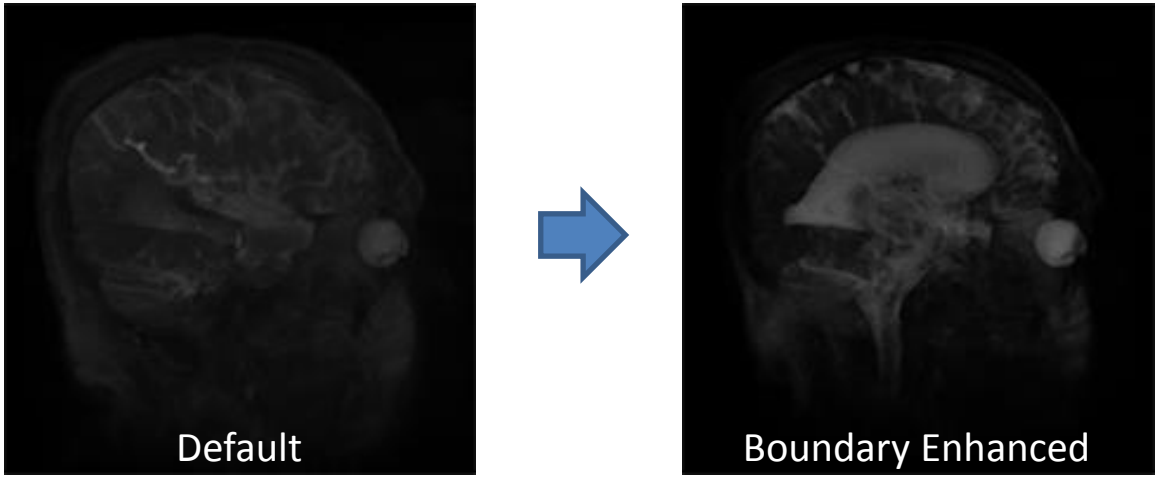
- Similar to the basic VolumeData node, but renders a surface across voxel gradients

```
<IsoSurfaceVolumeData dimensions='1.28 1.28 1.28‘ surfaceValues='.15'
 contourStepSize='0' surfaceTolerance='0' containerField='children'>
            <CartoonVolumeStyle colorSteps='32' />
            <ImageTexture3D containerField='voxels' url=' "skull.nrrd" '/>
</IsoSurfaceVolumeData>
```

Boundary Enhancement Style

- Modifies voxels based on how quickly their surface normals are changing:

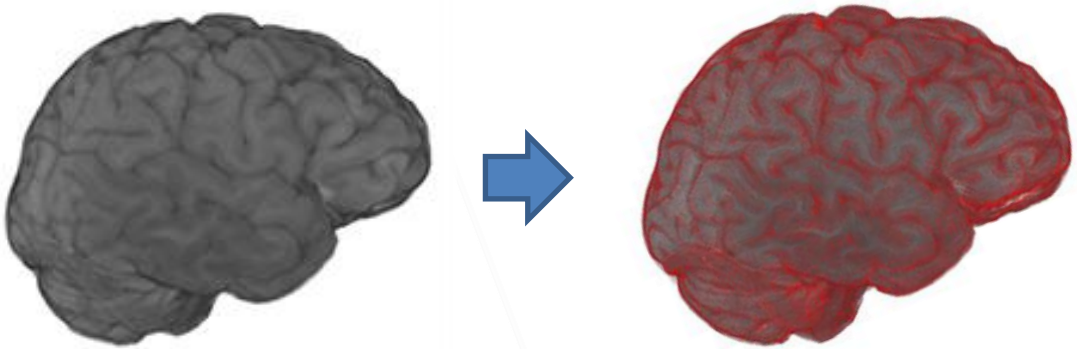
```
<BoundaryEnhancementVolumeStyle boundaryOpacity='0.9' opacityFactor='0.9'
  retainedOpacity='0.2'>
```



Edge Enhancement

- Voxels are colored based on how close to perpendicular their normal are to the view, outside of a threshold.
- Useful for surface features, not internal features.

```
<EdgeEnhancementVolumeStyle enabled='true' edgeColor='1 0 0 1'
  gradientThreshold='0.4' containerField='renderStyle'/>
```



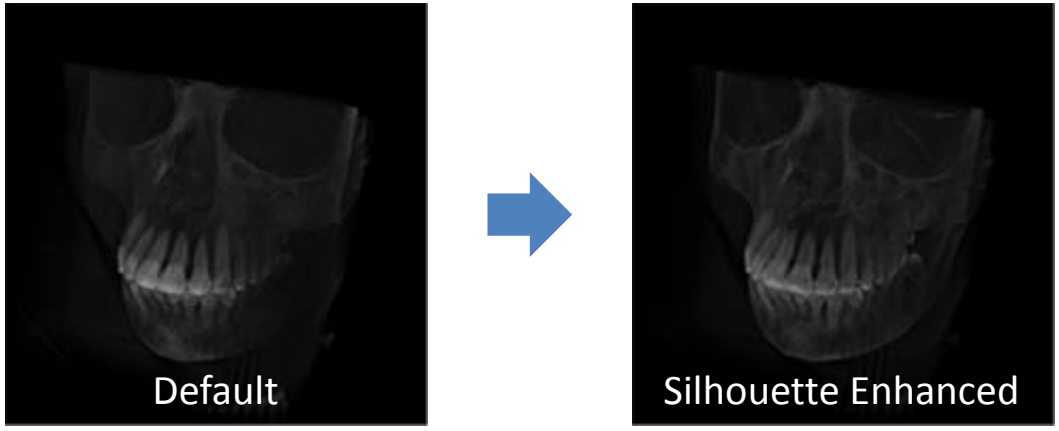
Default

Edge Enhanced

Silhouette Enhancement

- Modifies the color and opacity of voxels based on their normal values
- Unlike edge enhancement, it can be used to reveal internal features

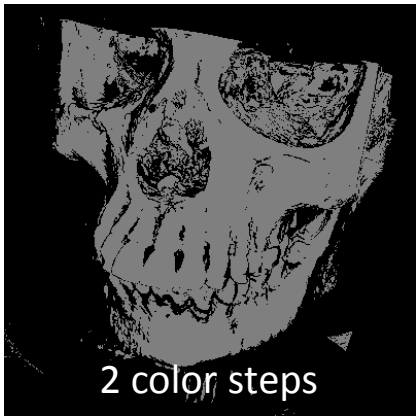
```
<SilhouetteEnhancementVolumeStyle silhouetteBoundaryOpacity='1'
  silhouetteRetainedOpacity='.5' silhouetteSharpness='10' enabled='true'
  containerField='renderStyle'/>
```

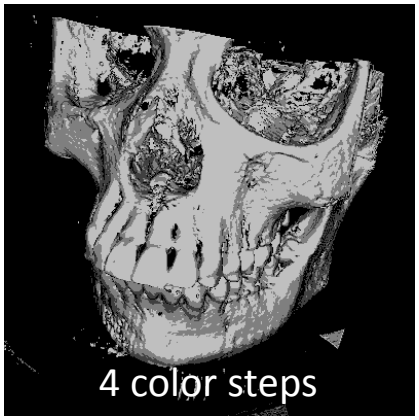


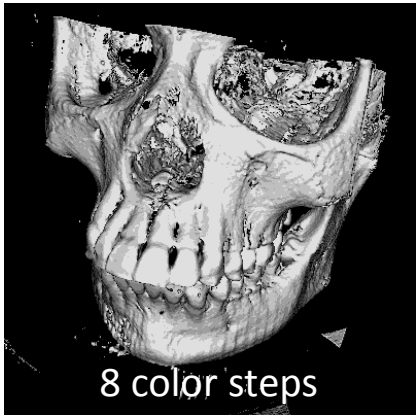
Cartoon VolumeStyle

- Renders voxels based on the normal value as one of a specified number of color steps between an orthogonal (plane surface) color and parallel color:

```
<CartoonVolumeStyle enabled='true' colorSteps='4' orthogonalColor='1 1 1 1'
  parallelColor='0 0 0 1' containerField='renderStyle'/>
```



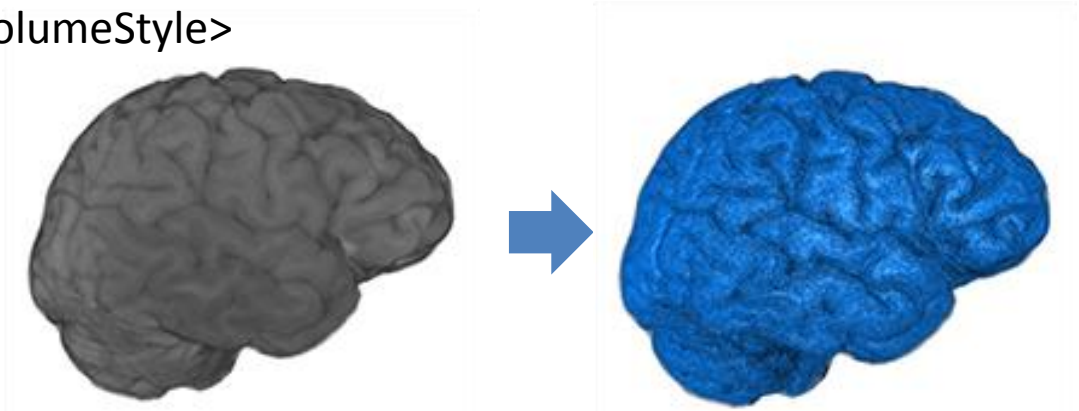




Shaded VolumeStyle

- Voxel appearance is controlled by a material node, similar to normal geometry (relative to light source)
- Can be computationally expensive

```
<ShadedVolumeStyle lighting='true' shadows='true' enabled='true'
  phaseFunction='Henyey-Greenstein' containerField='renderStyle'>
            <Material ambientIntensity='0.8' diffuseColor='0 .5 1‘ shininess='0.08'
             specularColor='1 1 1'/>
</ShadedVolumeStyle>
```



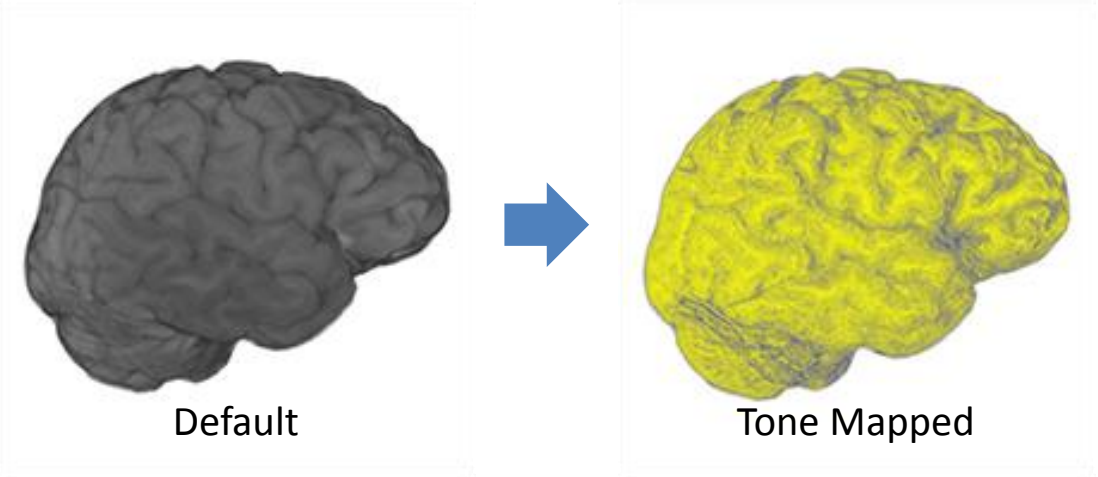
Default

Shaded

Tone Mapped VolumeStyle

- Uses the Gooch shading model to color voxels based on their orientations relative to a light source, between a warm (facing light) and cool (facing away) color

```
<ToneMappedVolumeStyle warmColor='0 0 1 0' coolColor='1 1 0 0' />
```



Online Videos & Examples

- Web Video summary:
  - *Extensible 3D (X3D) Volume Rendering*
    - https://snoid.sv.vt.edu/medical/X3DVolumes/videos/VolumeVis-X3D-collected.mp4 (65 mb)
- X3D Examples
  - http://www.web3d.org/x3d/content/examples/Basic/VolumeRendering/index.html
- For other other Videos, Images and Scenes using the VolumeData and VolumeRenderStyles of X3D 3.3 Clause 41, please visit:
  - https://snoid.sv.vt.edu/medical/X3DVolumes/

Volume Processing and Presentation Tools

- **Data**
  - Sample xxxxx.dcm
  - X3D Content Examples http://www.web3d.org/x3d/content/examples/Basic/VolumeRendering/index.html
  - Volvis.org
  - http://www.osirix-viewer.com/datasets/
    - Warning: some are compressed w/ jpg2000 !
- **Tools**
  - ImageJ : http://rsbweb.nih.gov/ij/
    - Plugins: DICOM reader, DICOM header inspector
  - Seg3D.org
  - Slicer.org; ITK-Snap
  - X3D-Edit 3.3
- **Viewers**
  - H3D.org
  - InstantReality.org
  - MedX3DOM