

Web3D Quickstart

AMIA Summit 2019
San Francisco

Nicholas Polys, Anita Havele, Mike Aratow
Web3D Consortium
web3d.org

web|3D
CONSORTIUM



Goals of this Workshop

A broad introduction to the technologies and capabilities of the ISO-IEC Web3D standard Extensible 3D (X3D) and Humanoid Animation (H-ANIM). Attendees will gain a comprehensive understanding of the standard specifications, tool chains, and publishing platforms for 3D health informatics information.

<http://www.web3d.org/web3d-quickstart>

Structure of this Workshop

Introduction & Motivation

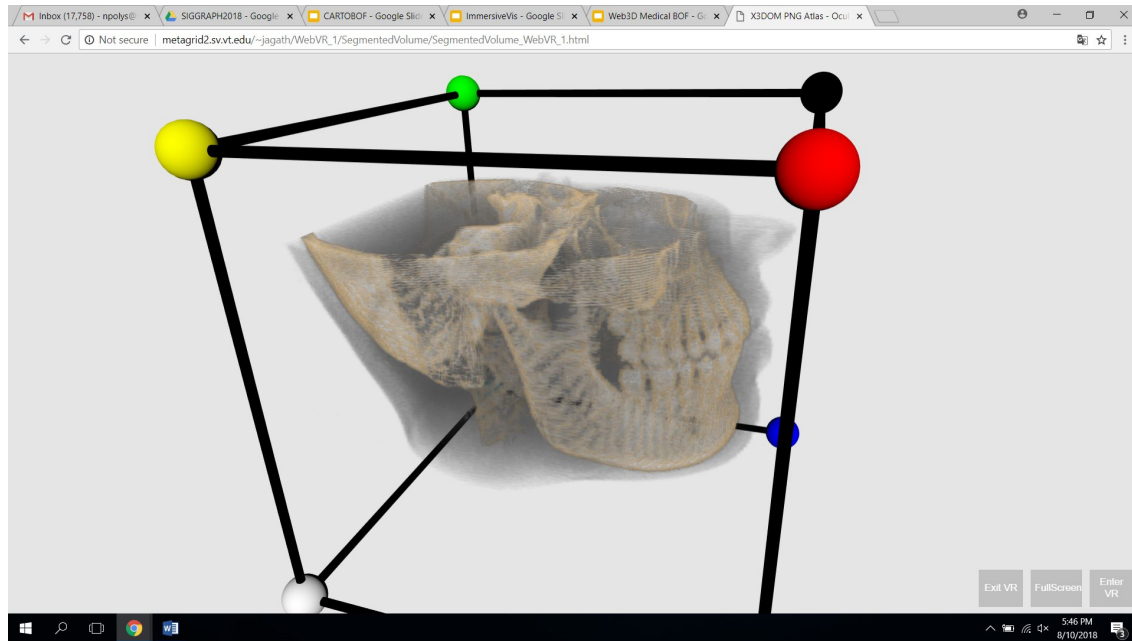
History: Web3D Medical WG

X3D Applications & Demos

10 am Break

X3D Technologies

Exploration & Activities



Speakers

Nicholas Polys

Virginia Tech

Anita Havele

Web3D Consortium

Michael Aratow

San Mateo Medical Center



Web3D Quickstart

Part 2

AMIA Summit 2019
San Francisco



Nicholas Polys, Anita Havele, Mike Aratow
Web3D Consortium
web3d.org

Goals of this Workshop

A broad introduction to the technologies and capabilities of the ISO-IEC Web3D standard Extensible 3D (X3D) and Humanoid Animation (H-ANIM). Attendees will gain a comprehensive understanding of the standard specifications, tool chains, and publishing platforms for 3D health informatics information.

More X3D!

- [Zebrafish Brain Browser](#)
- [NIH 3D Print Exchange](#)
- [CAD model: Stent](#)
- [3D Ontology Vis](#)
- [NIST DLMF](#)
- [X3DOM + D3](#)
- [X3D Examples : Medical](#)
- <http://volumerc.org/>

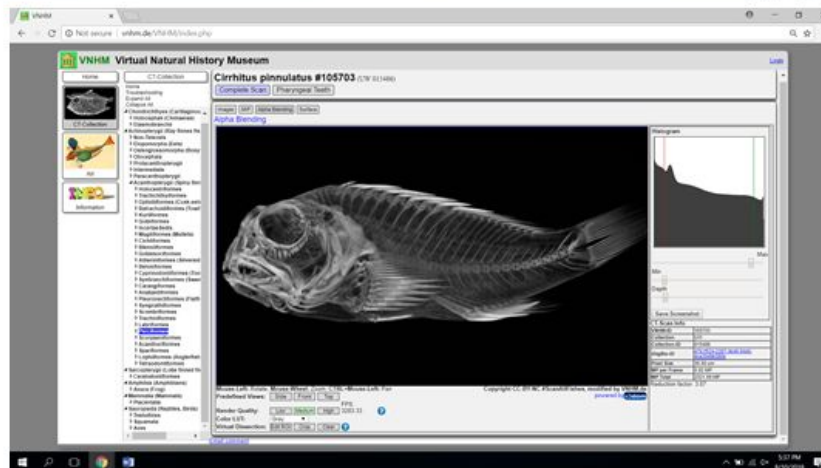
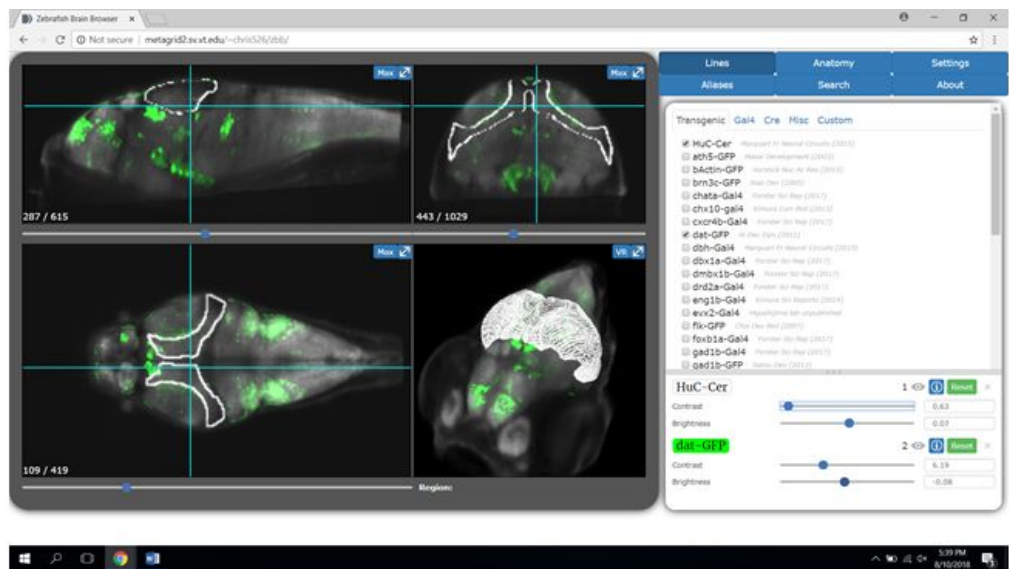
More links at:

<http://www.web3d.org/web3d-quickstart>

Access: WWW and VR

- HTML5 + X3D Portals

- *Zebrafish genetic and neuro atlas*: zbbrowser.com
- *Virtual Natural History Museum*: <http://vnhm.de>
- CNS-PF [neuron viewer](#)
- Cell image library
- NIH 3D Print Exchange



Modeling Organs for Presentation

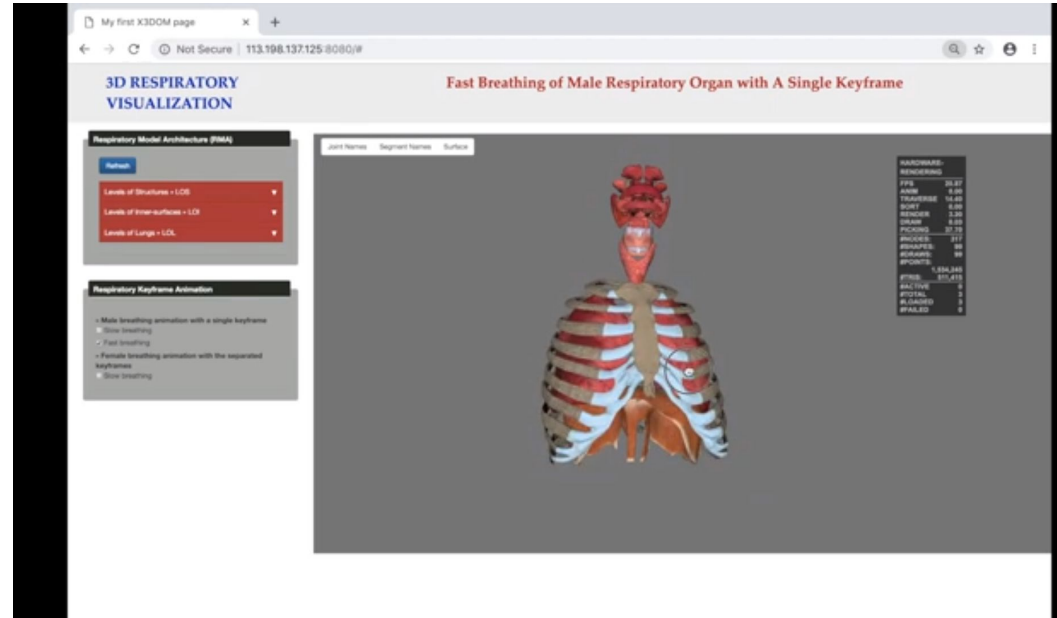
Modeling Respiratory System part 1

<https://www.youtube.com/watch?v=bmUdfD54fLc>

Animating Respiratory System part 2

<https://www.youtube.com/watch?v=9G6ituEL-Rs>

Based on HANIM concepts:
'Spines' and 'skins'



NIH 3D Print Exchange

3dprint.nih.gov

Access: NIH X3D Printing

3dprint.nih.gov



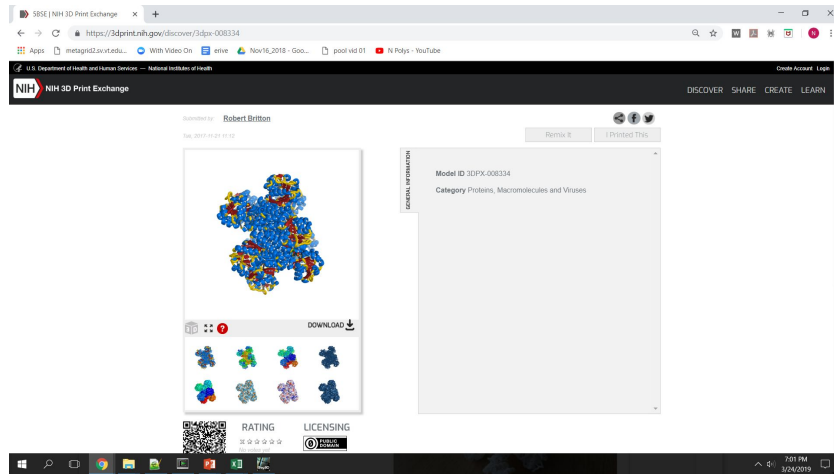
3D printed heart : Case Study

From the patient's MRI, a model was 3D printed and fitted with magnets



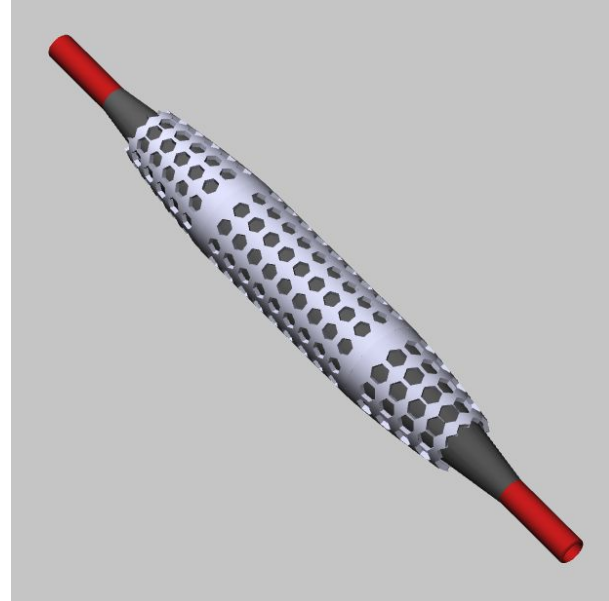
3D Print Exchange

- Drupal 8 backend
- Automated processing scripts: including MeshLab
- X3D , STL file outputs



Prosthetics and Implants

Detailed 3D visualizations of mechanical structures generated with Computer-Aided Design processes and interoperable ISO CAD standards.

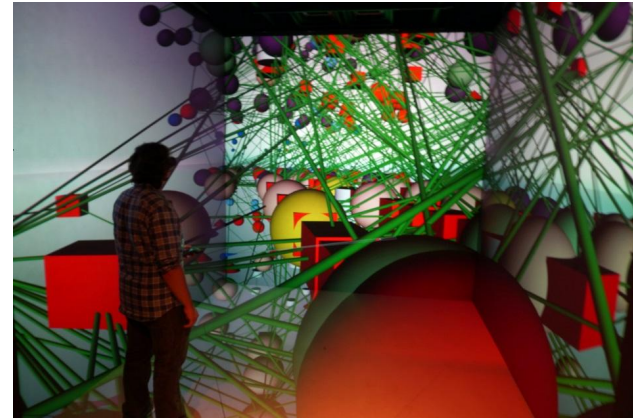
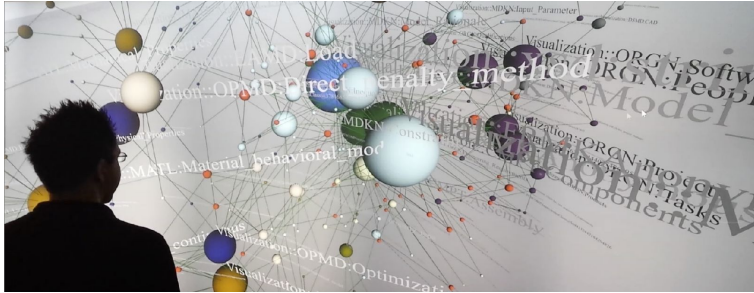


http://www.kshell.com/pages/stent_with_balloon/index.html

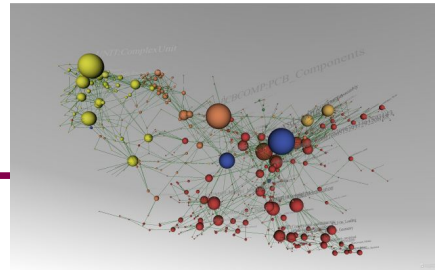
BioPax Ontology Vis



Peter J. Radics, **Nicholas F. Polys**, Shawn P. Neuman, and William H. Lund. "OSNAP! Introducing the open semantic network analysis platform". *Proceedings of Visualization and Data Analysis*, IS&T/SPIE Electronic Imaging; 2015.



<http://vis.arc.vt.edu/projects/osnap/Gallery.html>



3D Graphs and Plotting with X3D

- **MatLab:**

- <https://www.mathworks.com/help/sl3d/x3d-extensible-3d-graphics.html?requestedDomain=true>

- <https://www.mathworks.com/matlabcentral/fileexchange/32207-matlab-3d-figure-to-3d--x-html>

- **R (vrmolgen):**

- <http://ico2s.org/software/vrmolgen.html>

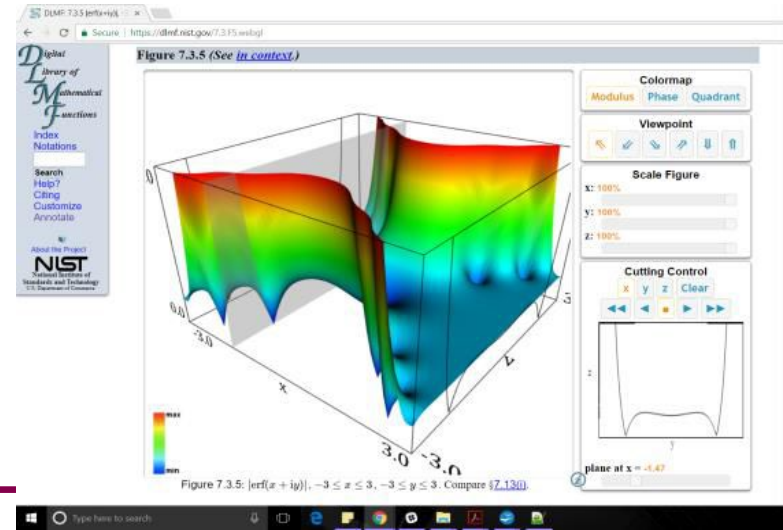
- **mayavi:**

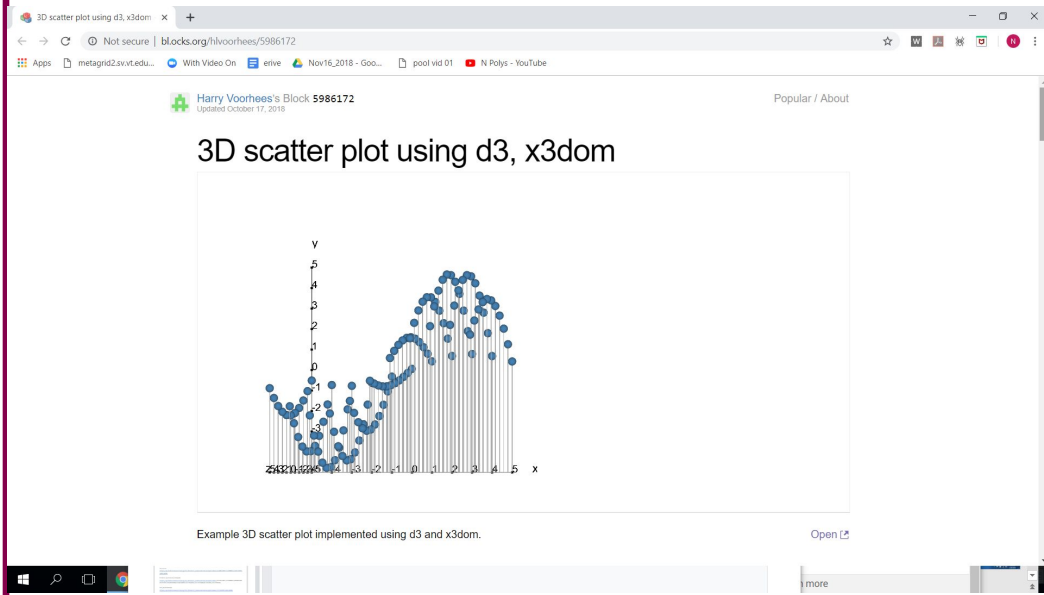
- the open source Python tool Mayavi has a builtin save function that exports to X3D such as `mlab.savefig('./fig.x3d')` <http://docs.enthought.com/mayavi/mayavi/>

Online Reference Library of Mathematical Functions National Institute of Standards Technology (NIST)

DLMF: <https://dlmf.nist.gov/>

See Graphics pages
and click the
3D icon





<http://bl.ocks.org/hlvoorhees/5986172>

<https://www.datamaplab.com/posts/d3-x3dom-tutorial-part-1/>



X3D Charting HL7: Population

D3 + X3DOM + HTML5

Sinusitis:

[https://syntheticmass.mitre.org/fhir/Patient? has:Condition:subject:code=444814009,75498004,36971009,40055000](https://syntheticmass.mitre.org/fhir/Patient?%20has:Condition:subject:code=444814009,75498004,36971009,40055000)

Chronic pulmonary disease:

[https://syntheticmass.mitre.org/fhir/Patient? has:Condition:subject:code=195951007,47938003,106001000119101,196001008,135836000,313296004,313297008,87433001,313299006](https://syntheticmass.mitre.org/fhir/Patient?%20has:Condition:subject:code=195951007,47938003,106001000119101,196001008,135836000,313296004,313297008,87433001,313299006)

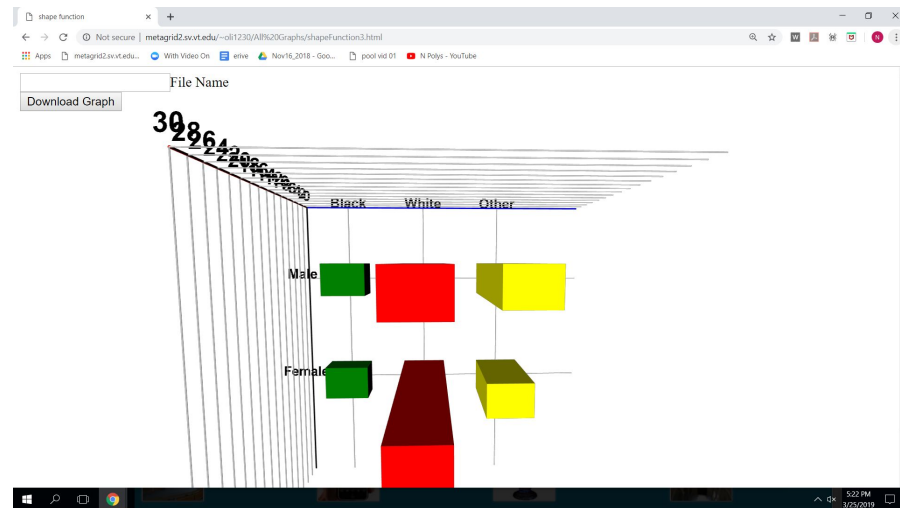
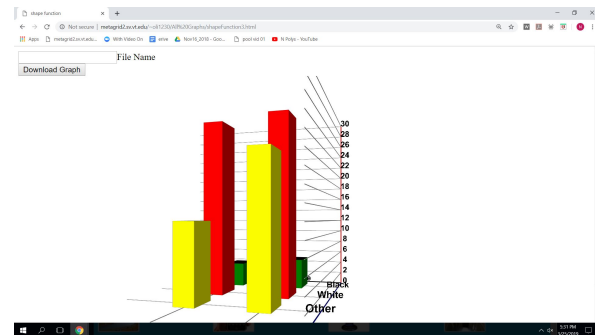
Simple Diabetes:

[https://syntheticmass.mitre.org/fhir/Patient? has:Condition:subject:code=73211009,44054006](https://syntheticmass.mitre.org/fhir/Patient?%20has:Condition:subject:code=73211009,44054006)

Oliver Stein

VT CS Undergrad Independent Study :

- Take FIHR JSON query result & plot X3D in the Web Browser
 - Synthetic Mass FIHR endpoint
 - Javascript
 - X3DOM + D3
 - Patient populations with Diabetes, Sinusitis
CPD
 - Frequency by race and gender



Open Standards make it work



www.web3d.org

- Portability
- Durability
- IP independence
- International recognition and support



Industry Standards unify communities

web|3D
CONSORTIUM



OGC[®]
Open Geospatial Consortium, Inc.

W3C[®] WORLD WIDE WEB
consortium

KHRONOS
GROUP

 DICOM[™]
Digital Imaging and Communications in Medicine

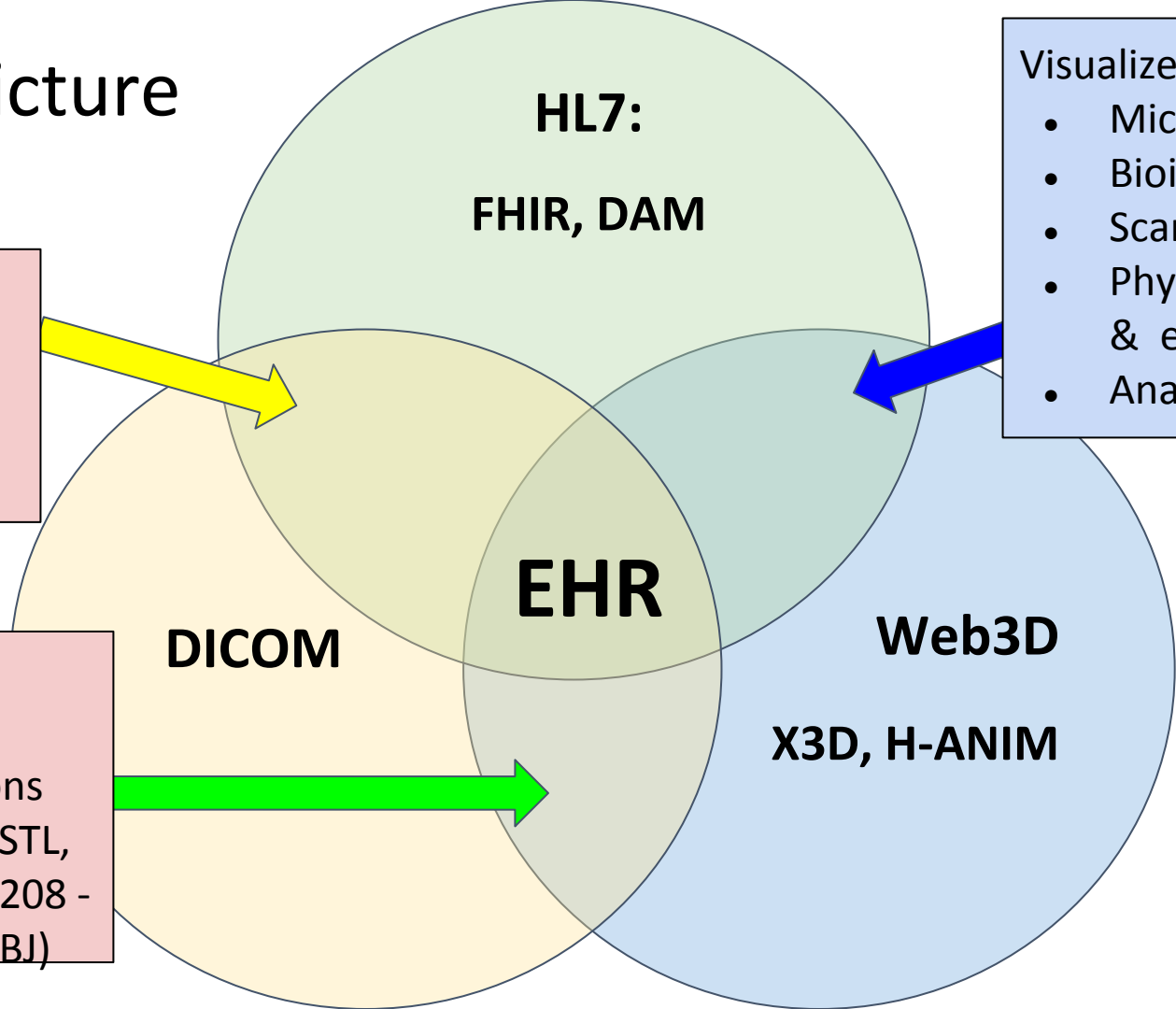


 VIRGINIA
TECH

EHR Big Picture

- Patient Imaging
- Treatments
- ...

- Volume viz
- Meshes
- Segmentations
- 3D printing (STL, supplement 208 - X3D, 3MF, OBJ)



- Visualize:
- Microscopy
 - Bioinformatics
 - Scanning
 - Physical Therapy & ergonomics
 - Analytics

Pipelines to Exchange Views on the Patient

HL7 FHIR Endpoint

Health Records:

- DAMs
- DICOMs
- X3D as scene or url

Use-case driven mappings

lossless ; cross-referenced

- Codes -> Anatomy
- SampledData timeseries
- Surgical Planning
- X-Ray-Proton Therapy
- Body Scans
- Therapeutic VR
- Physical Therapy
 - Exercise data
 - Motivational VR
- ...

Extensible 3D (X3D)

XML
(dtd, xsd)

JSON

Binary

utf8

ECMASCRIPT

Java

*Components
per use case*

Display Modalities

Desktop - Mobile

- Metadata, urls

VR-MR-AR

- Metadata, urls

3D Printing

- Metadata, urls

...

GIS

- Metadata, urls

Human Animation

- Metadata, urls

Path Forward

X3D in HL7:

- XML & JSON payloads of X3D content in FHIR
- DAM-specific integrations

HL7 in X3D:

- Metadata vocabularies & reference practice
- Using 3D Semantic Interaction to explore high-dimensional HL7 information



The Web Is the Interface



Tons of Tools...

- Blender
- MeshLab
- Modo
- 3DS Max
- Maya
- Rhino
- Paraview
- Agisoft
- ARCScene
- Creoform
- Unity
- PointFuse....

export ISO Web3D!

- Titania (Linux)

<http://create3000.de/>

- X3D-Edit

<https://savage.nps.edu/X3D-Edit/>

- AOPT (w/
InstantPlayer)
- XML & stylesheets
- ...

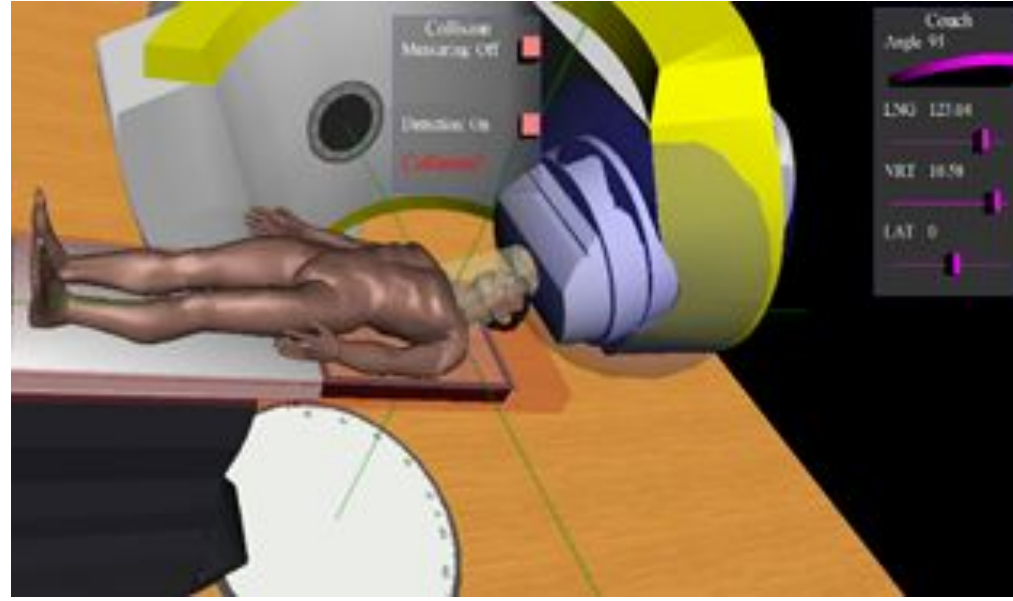
- 3DPrint Exchange
- POSTGIS

<https://postgis.net/>

- ...
- Okino Polytrans
- Safe Software (FME)
- ...

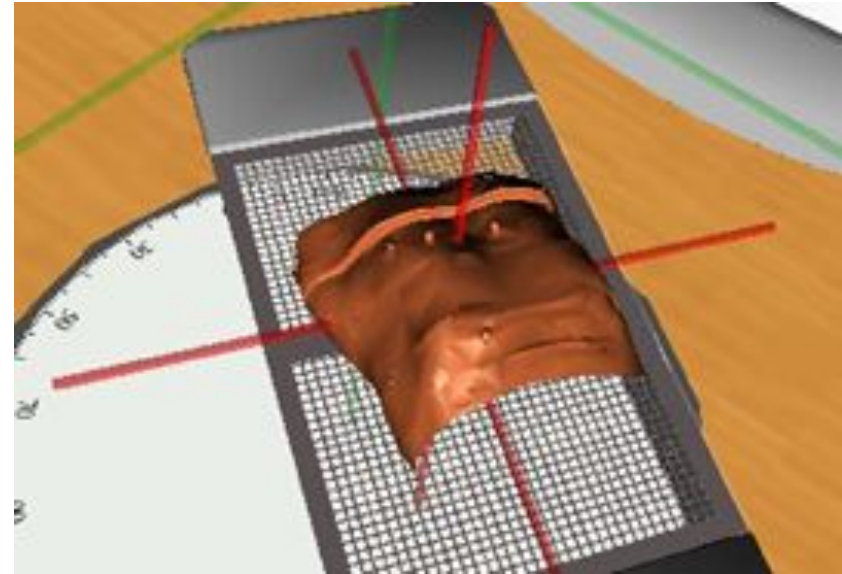
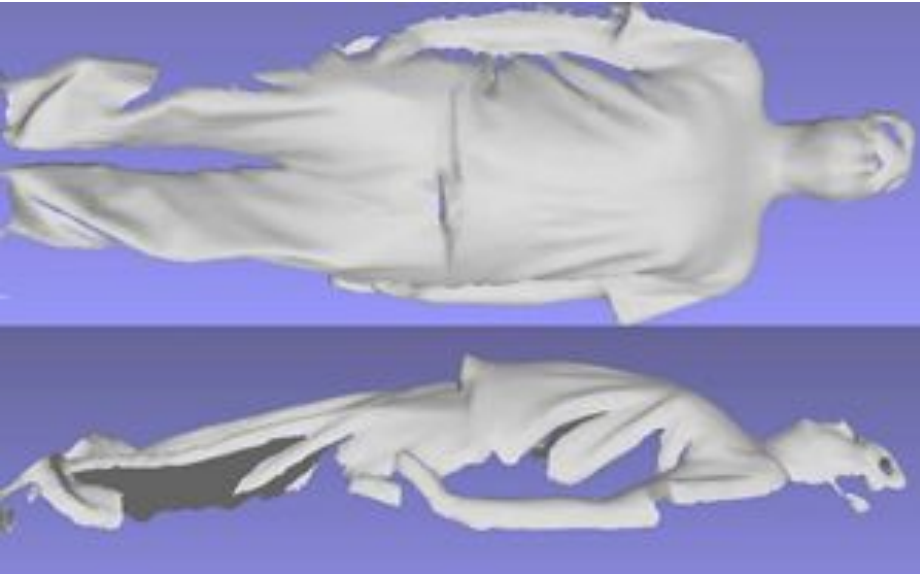
Safety and Radiation Therapy

X3D simulation of X-Ray therapy: Felix Hamza-Lup



Safety and Radiation Therapy

Patient CT data and real-time boundary representation for the 3DRTT simulator (3DRTT.org)





High spatial and
temporal resolution
body scans

www.3dmd.com

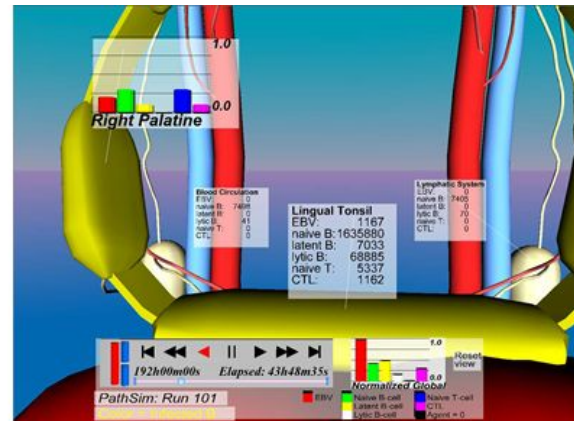
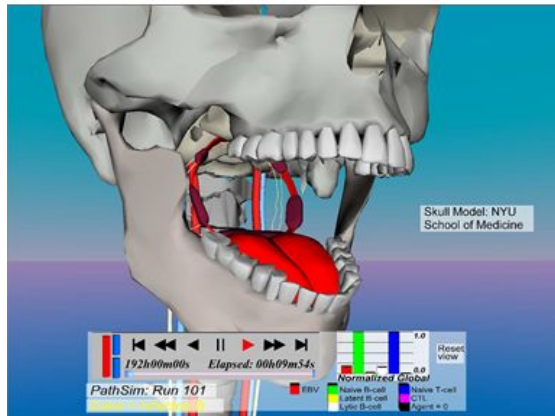




<http://people.cs.vt.edu/~npolys/DNA/index.xhtml>

Bioinformatics & Analytics

- [Physics of DNA](#)
- Agent-based immune system
- MPI_Blast results
- Network visualization



Compute the Cure (MPI-Blast)

Genomic query
results in X3D:

Alignments

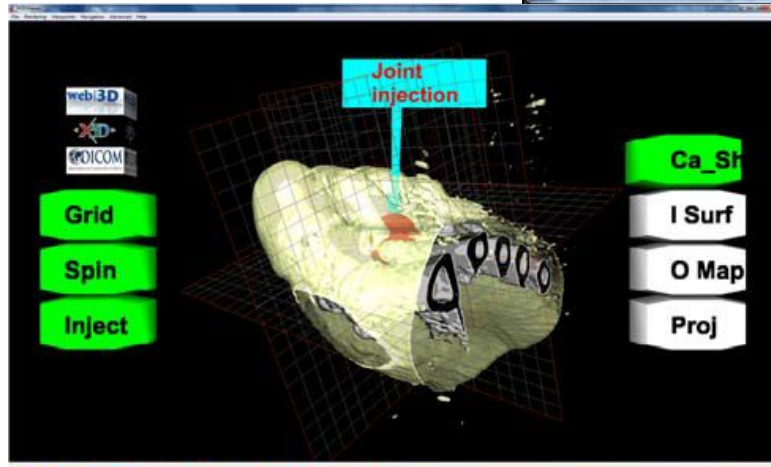
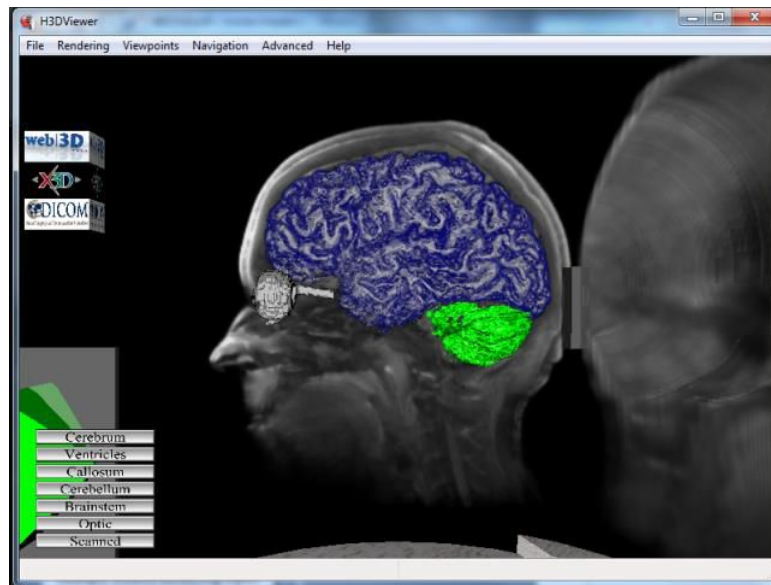
(i.e. for treatment
compatibility
studies)

With Wu Feng et al



Part 2

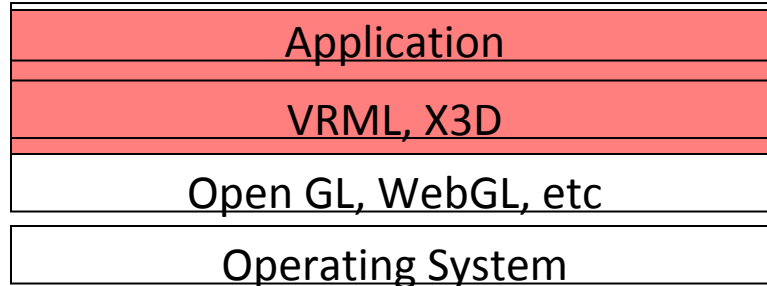
1. Web3D Standards
2. The Scenegraph
3. Tools
4. Examples



X3D Scenegraph

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*



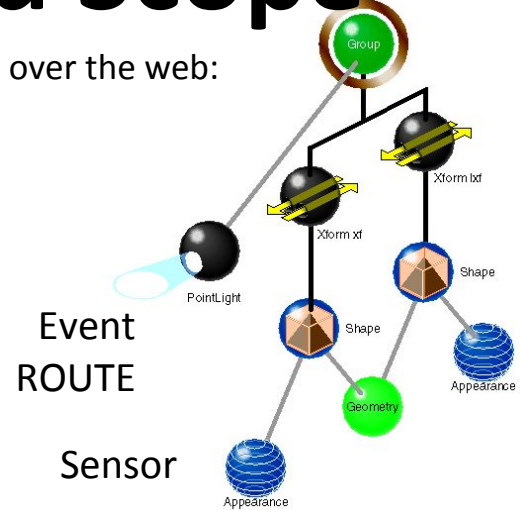


ISO-IEC Standard Scope

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

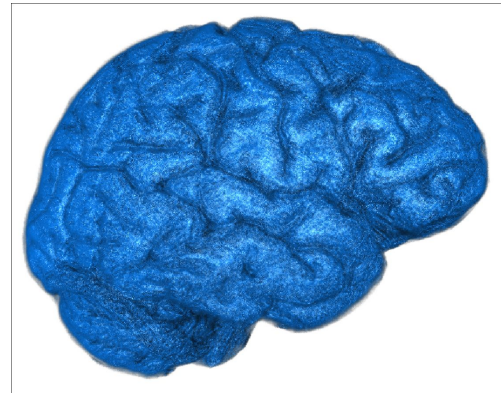
3.3 examples for Medical Imaging, CAD and Geospatial support!



Interactive 3D Graphics: a first-class citizen on the WWW

Networked 3D digital assets:

- Objects and components
- Appearances & materials
- Environments
- Animation and Timeseries databases
- Metadata & web-aware referencing
- Interaction semantics



A Hypertext Markup for 3D: Extensible 3D (X3D)

- Like HTML, X3D has a content model that enables the spatial layout of media elements (images, audio, video, text) and links
- Like HTML, X3D is platform - independent
- Like HTML, X3D can be scripted with JavaScript
- Like XML, X3D is extensible using DTD and Schema

Renderers vs Markup

Draw a Red Cube

OpenGL

83 lines of compiled C code

X3D

```
<X3D>  
  <Scene>  
    <Shape>  
      <Appearance>  
        <Material diffuseColor='1 0 0'>  
      </Material>  
    </Appearance>  
  <Box></Box>  
</Shape>  
</Scene>  
</X3d>
```

VRML -> X3D

Durability of 3D information across industry epochs:

- 1994: VRML 1.0
- 1997: VRML 2.0
- 2002: VRML 2.1
- 2005: X3D 3.0
- 2006: X3D 3.1 ; H-Anim 1.0
- 2008: X3D 3.2
- 2013: X3D 3.3
- 2018: H-Anim 2.0

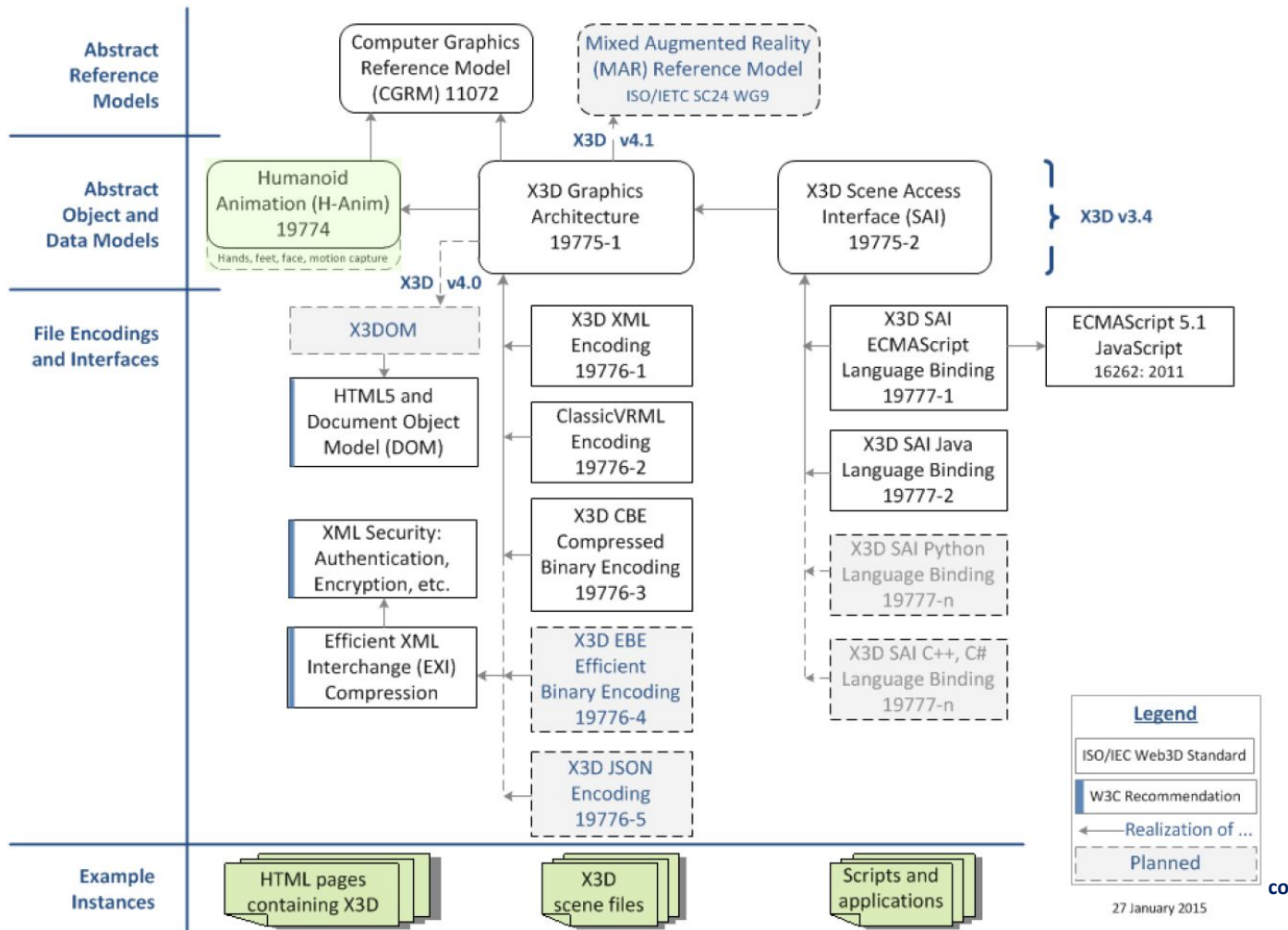
Encodings:

- *XML,*
- *utf8,*
- *binary,*
- *JSON*

Bindings:

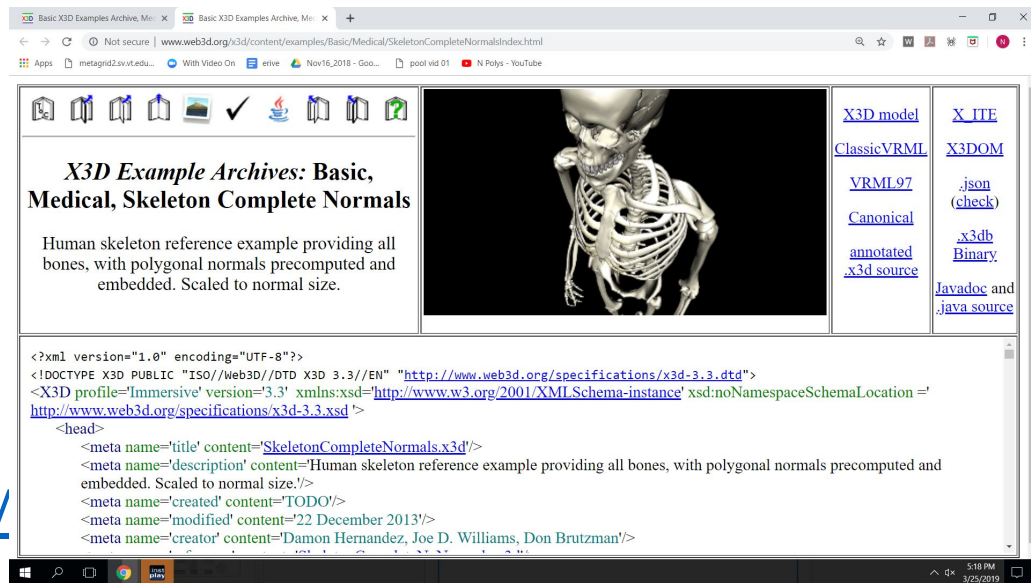
- *Javascript,*
- *Java,*
- *C#,*
- *C++, C,*
- *Python*

X3D Graphics Standards: Specification Relationships



X3D: Encodings and Examples

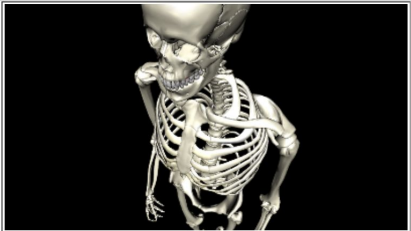
www.web3d.org/x3d/content/examples/Basic/Medical/



The screenshot shows a web browser window with the URL www.web3d.org/x3d/content/examples/Basic/Medical/SkeletonCompleteNormalsIndex.html. The page content is as follows:

X3D Example Archives: Basic, Medical, Skeleton Complete Normals

Human skeleton reference example providing all bones, with polygonal normals precomputed and embedded. Scaled to normal size.



Navigation links on the right side of the page include: [X3D model](#), [X_ITE](#), [ClassicVRML](#), [X3DOM](#), [VRML97](#), [.json \(check\)](#), [Canonical](#), [.x3db](#), [annotated](#), [Binary](#), [.x3d source](#), [Javadoc](#) and [.java source](#).

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.3//EN" "http://www.web3d.org/specifications/x3d-3.3.dtd">
<X3D profile="Immersive" version="3.3" xmlns:xsd="http://www.w3.org/2001/XMLSchema-instance" xsd:noNamespaceSchemaLocation="http://www.web3d.org/specifications/x3d-3.3.xsd">
  <head>
    <meta name="title" content="SkeletonCompleteNormals.x3d"/>
    <meta name="description" content="Human skeleton reference example providing all bones, with polygonal normals precomputed and embedded. Scaled to normal size."/>
    <meta name="created" content="TODO"/>
    <meta name="modified" content="22 December 2013"/>
    <meta name="creator" content="Damon Hernandez, Joe D. Williams, Don Brutzman"/>
  </head>
</X3D>
```

X3DOM.org

<https://www.x3dom.org/examples/>

More Fundamentals

- Spatial Units assumed to be meters
(unless otherwise declared)
- Rotational Units are in Radians
- Right-handed 3D coordinate system

1 Line upgrade to X3D!

'Classic' utf8 encoding:

A VRML.wrl file can become

an X3D.x3dv file

by changing the header line from :

VRML #2.0

to

VRML #3.0



simply

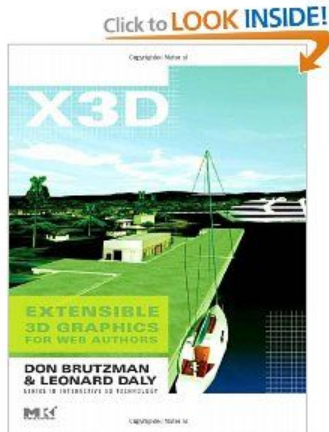


Runtime APIs

- ISO-IEC Standard specifies JavaScript and Java language bindings
- C#, C++, and Python bindings in Web3D standardization pipeline
- In the WWW context, the DOM is a JavaScript API to HTML & X3D documents and their runtime

X3D Book & Online Resources

- <http://www.x3dgraphics.com/>
- Digital copy in U Libraries



Extensible 3D Graphics For Web Authors

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



HTML5 – WebGL – X3D Toolkits

See examples and tutorials of each
open source tool:

1. **X3DOM** <https://www.x3dom.org/>

Supports WebVR; Chrome Extension

2. **X_ITE** http://create3000.de/x_ite/getting-started/

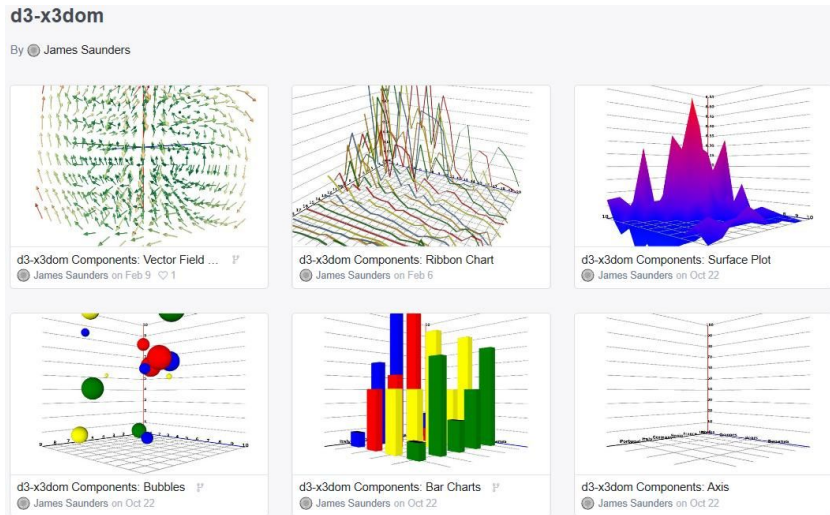
D3 + X3DOM

Github!

<https://github.com/x3dom>

<https://github.com/jamesleesaunders/d3-x3dom>

<https://www.datamaplab.com/posts/d3-x3dom-tutorial-part-1/>



Tools

- Rendering X3D
- Exporting X3D
- Processing X3D



X3D Rendering Engines (*selected*)

WebGL Open Source:

X3DOM, X_ITE

OpenGL/ DirectX Commercial:

InstantReality

Octaga

BS Contact

OpenGL/ DirectX Open Source:

Castle Game Engine 3D

FreeWRL

Xj3D

V-Slam

COVISE

H3D

X3D + HTML5

Two open-source implementations, Javascript WebGL libraries

Interpret and render X3D documents with interaction:

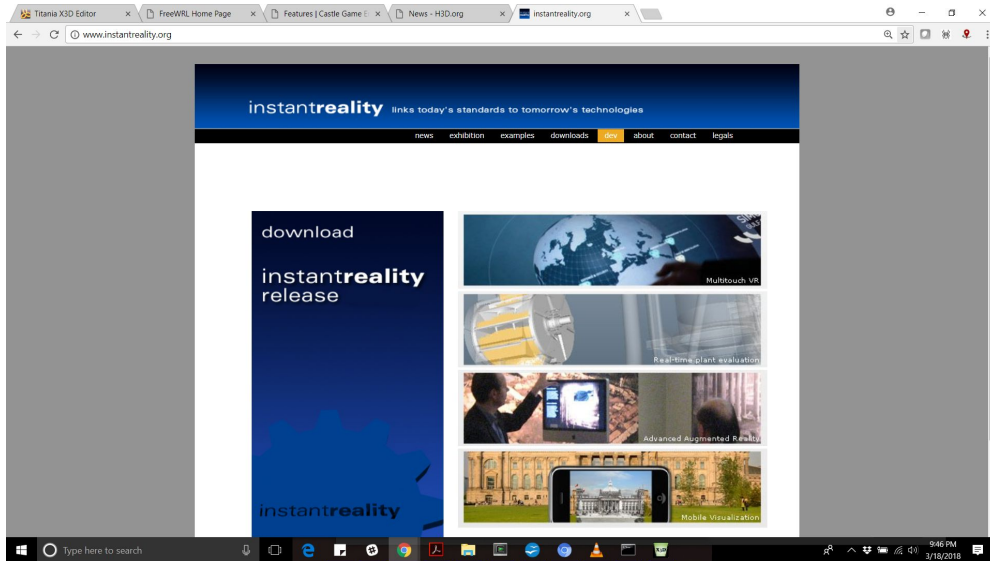
- X3DOM - www.x3dom.org
- X_ITE - create3000.de/x_ite

x3dom
Instant 3D the HTML way!



Instant Reality

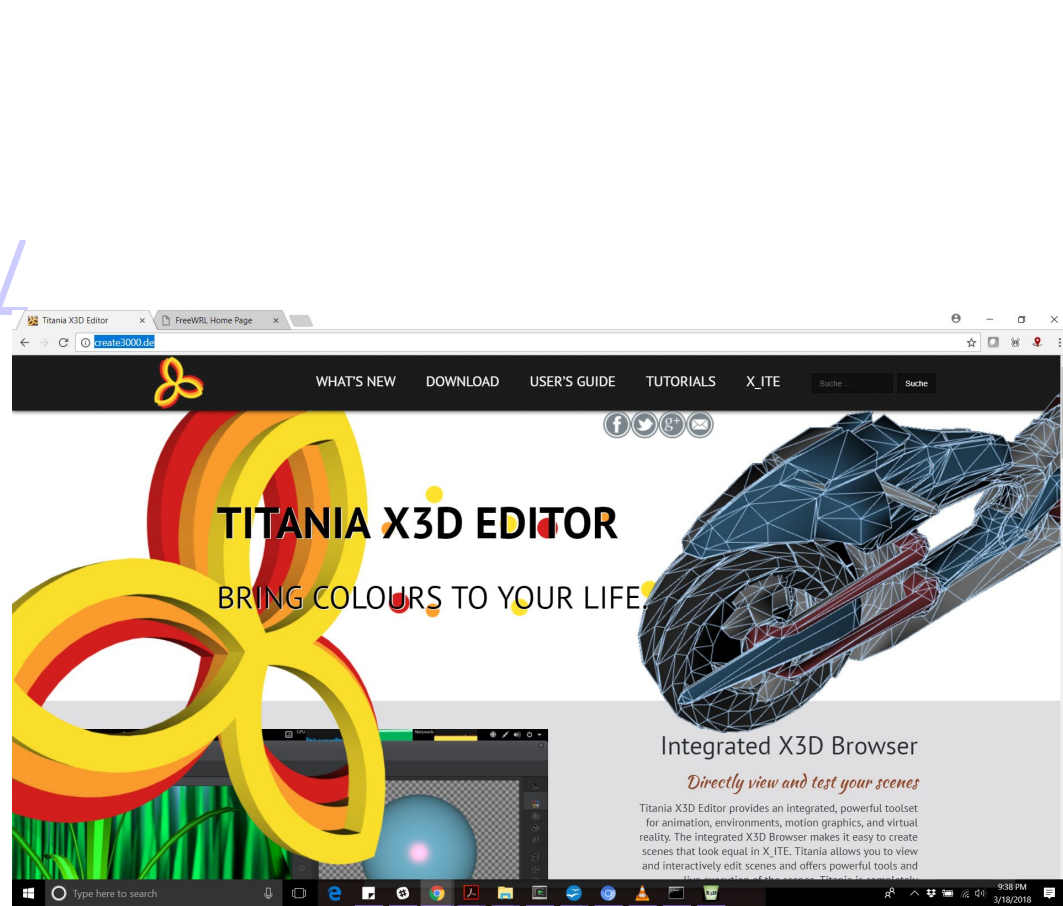
<http://www.instantreality.org/>



X_ITE and LINUX X3D Editor

TITANIA

<http://create3000.de/>



Castle3D Game Engine

<https://castle-engine.io/>



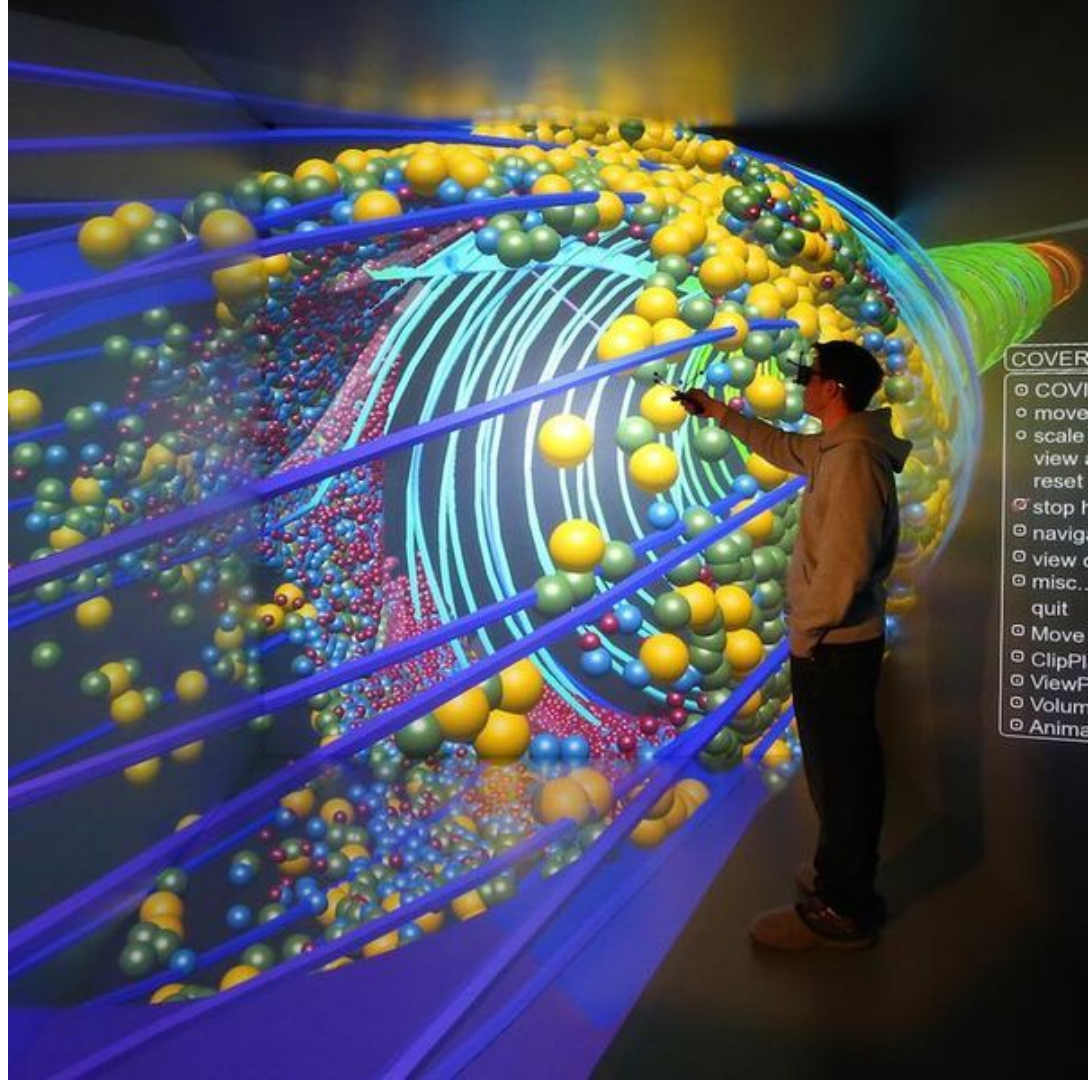
FreeWRL

<http://freewrl.sourceforge.net/>



Covise/OpenCover

<https://github.com/hlrs-vis/covise>





H3D.org - Haptics

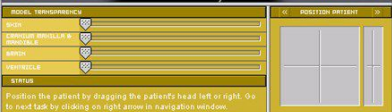
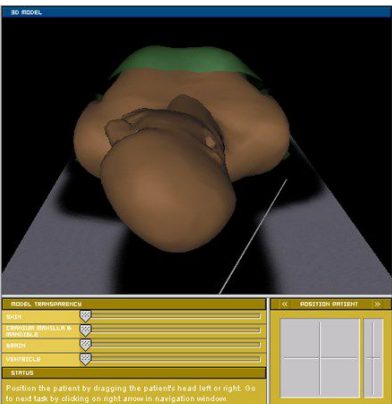
X3D + Volume Component (MEDX3D)



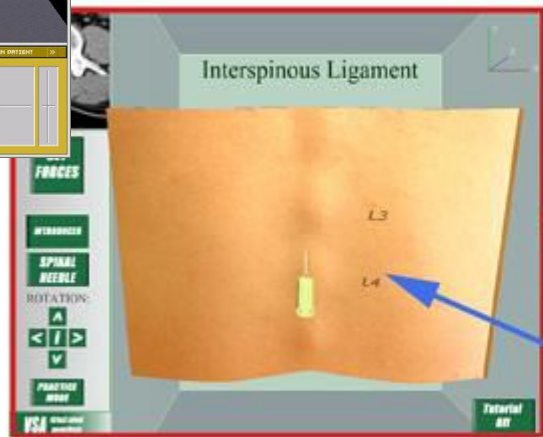
The screenshot shows the H3D.org website with the following content:

- Header:** H3D.org Open Source Haptics
- Left Navigation Menu:**
 - Login
 - Username:
 - Password:
 - Remember me
 - User Login
 - Lost Password?
 - Register now!
 - Main Menu
 - Home
 - Downloads
 - H3D Wiki
 - Documentation
 - Forum
 - News
 - H3D.org Feeds
- Main Content:**
 - Download the latest H3DAPI here!
H3DAPI 2.3.0, the latest of H3DAPI versions, is released on 13th June 2014 and can be [downloaded here!](#) Haptics programming has never been easier.

 - New features in H3DAPI 2.3.0:
 - Performance improvements for graphics rendering and start up time.
 - Quite a lot of new functions accessible from python.
 - Many new nodes such as GaussianFilterShader, GeometryGroup, PlaybackDevice, NoiseTexture and RazerHydraSensor.
 - See [changelog](#) for changes in H3DAPI 2.3.0
 - Download the latest H3DViewer here!
The latest version of H3DViewer, which is our X3D browser can be obtained through the links below.
 - Windows 32 bit
 - Windows 64 bit
 - OSX 10.6.8
- Right Sidebar:**
 - What is H3DAPI.org?
H3DAPI.org is the community website for H3DAPI, the open source haptic API. For more information about H3DAPI, please visit [SenseGraphics](#).
 - If you would like to download H3DAPI, please [register here](#) for an account on H3DAPI.org where you can download the latest version of the API.
 - H3DAPI on YouTube
See our videos!
 - H3D Powered By:


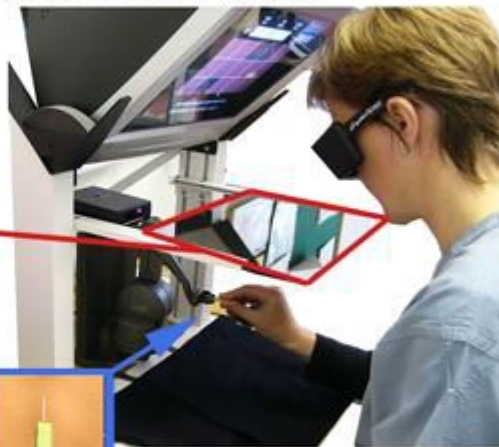
Rehearsal & Consent



Virtual Environment



Immersive Workbench



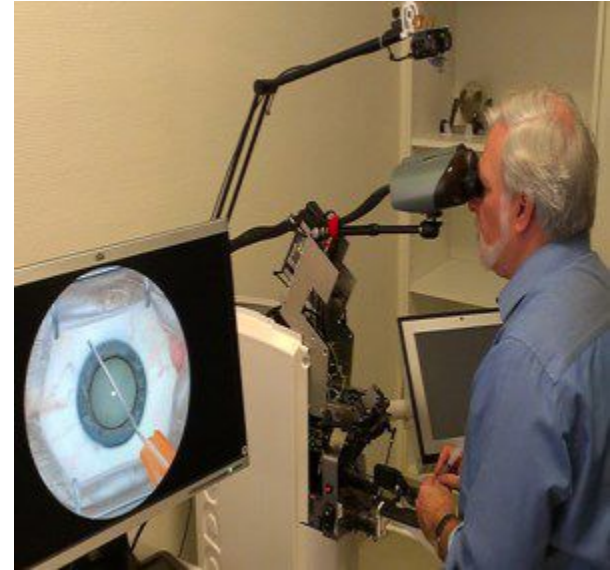
Virtual Needle



Surgical Simulation

X3D as a platform for Haptic simulation and Medical training

- H3D.org
- Nigel John's trainers:
 - Eye surgery simulator
 - Ventricular catheterization training
- MMVR 2014 workshop (cite?)
- "Quantizing the Void" paper (cite)



X3D Volume Rendering

Videos:

- DICOM, NRRD, TIFF:

- <https://www.youtube.com/watch?v=ml7zfrH6A9U&t=37s>

- Segmentations and Interaction Mashup:

- <https://www.youtube.com/watch?v=ZO3jWjW9soE>

- Cell images with corresponding surfaces:

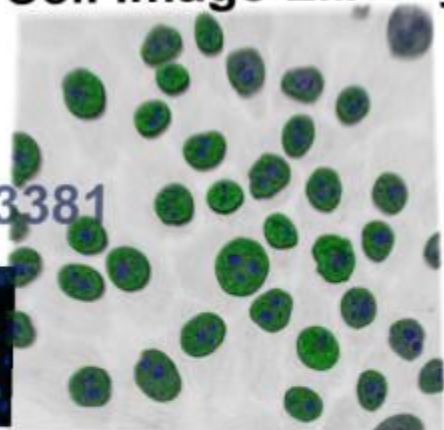
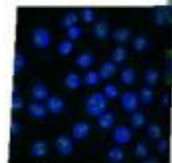
-

- <https://www.youtube.com/watch?v=srpiEBvbG-Q&list=UUoQkIIQuVbdKEBqgefLbhzw>

- Many publications

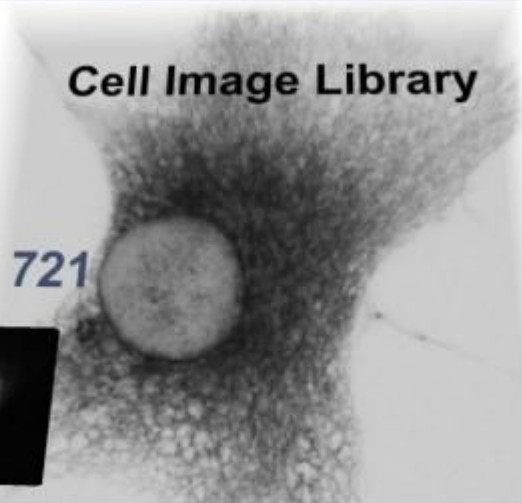
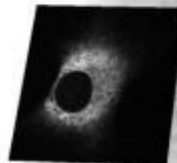
Cell Image Library

CIL: 13381



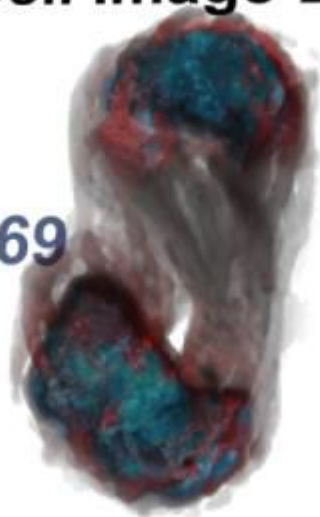
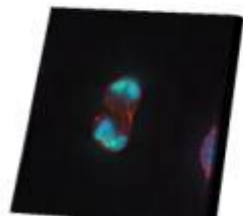
Cell Image Library

CIL: 721



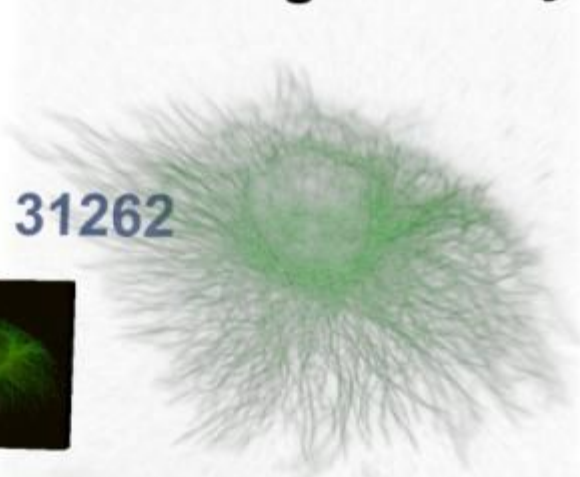
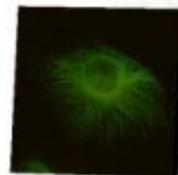
Cell Image Library

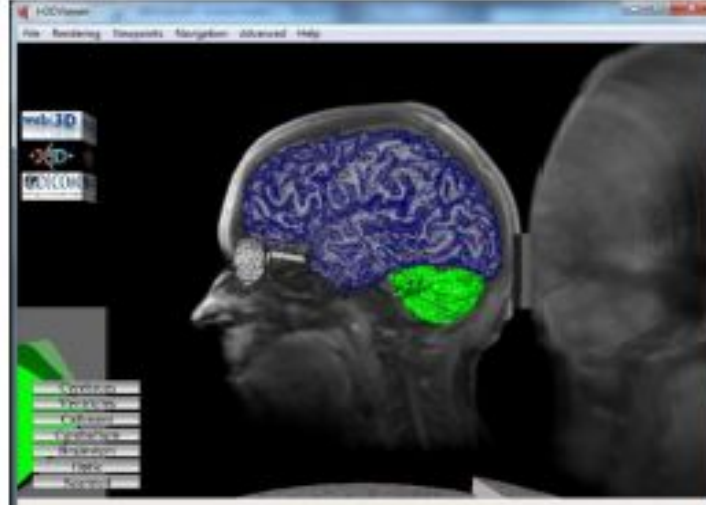
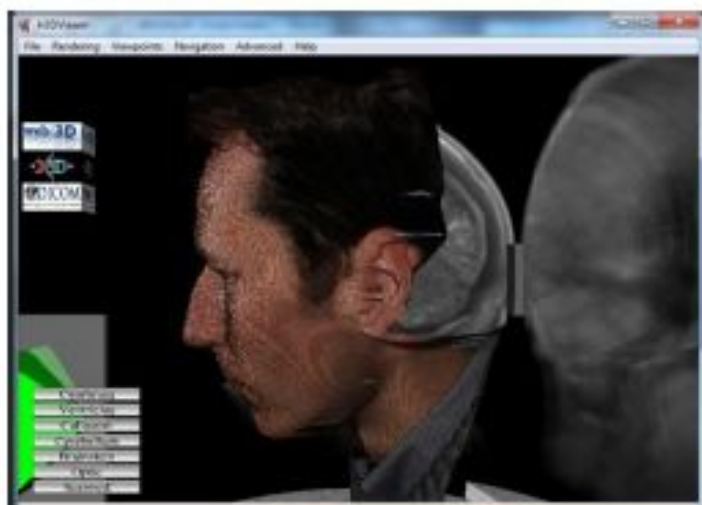
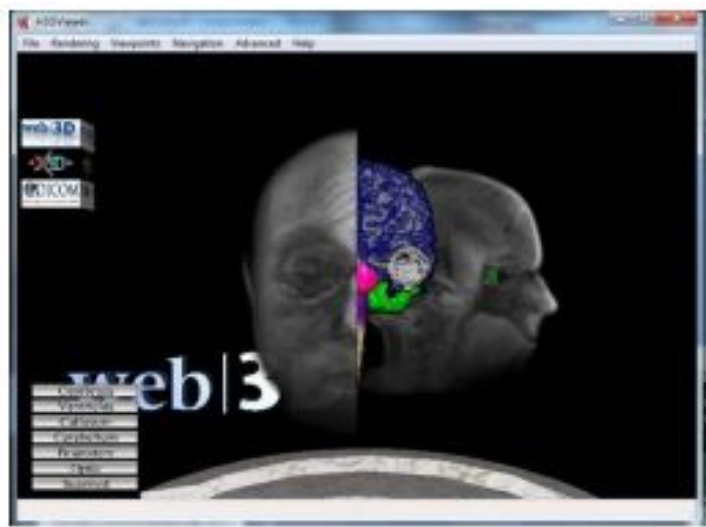
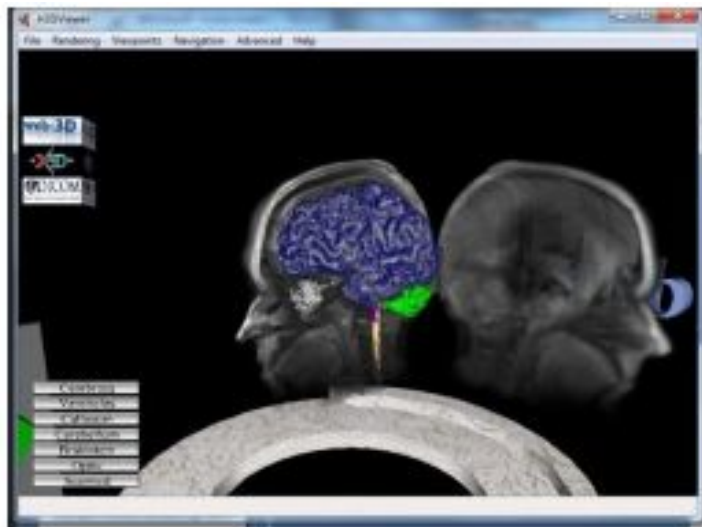
CIL: 12169



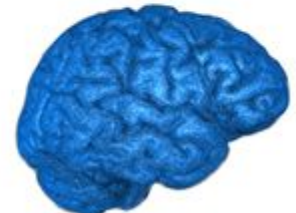
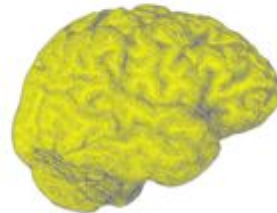
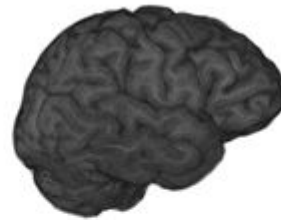
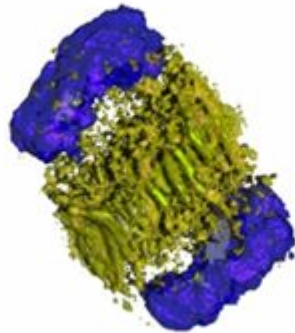
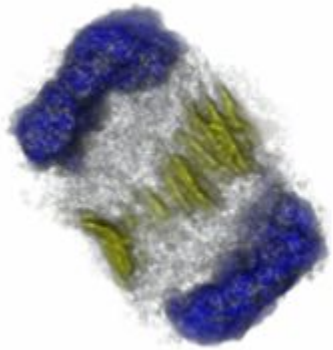
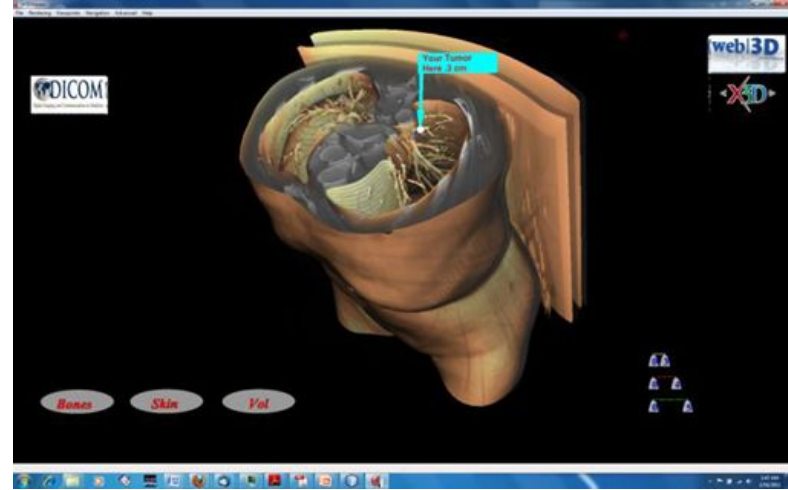
Cell Image Library

CIL: 31262





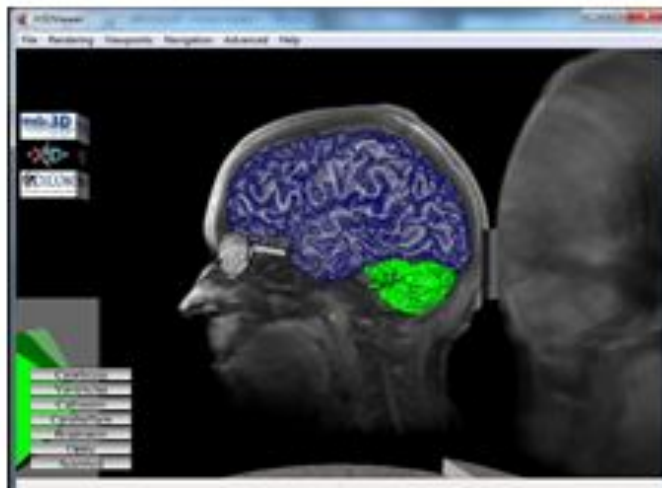
More X3D Volume Rendering



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>
```



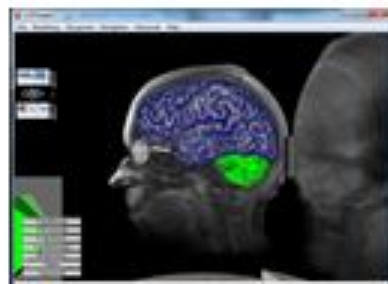
Example Volume Rendering Styles

(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>
```





X3D Volume Rendering

- Composable Render Styles covering the state of the art
 - Formalizes parameters and transfer functions for 3D rendering & blending
 - [BoundaryEnhancementVolumeStyle](#)
 - [CartoonVolumeStyle](#)
 - [ComposedVolumeStyle](#)
 - [EdgeEnhancementVolumeStyle](#)
 - [OpacityMapVolumeStyle](#)
 - [ProjectionVolumeStyle](#)
 - [ShadedVolumeStyle](#)
 - [SilhouetteEnhancementVolumeStyle](#)
 - [ToneMappedVolumeStyle](#)
 - ***Greatest Common Denominator***



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 Rendering : X3D + HTML5 + WebGL

Web3D Member collaboration: Vicomtech

Python Scripts to produce ImageTextureAtlas for browser-based rendering

<http://volumerc.org/demos.html>

<https://github.com/volumerc>

... RAW, DICOM, NRRD, TIFF, PNG

Access

3D Everywhere

- Workstations
- High-Resolution projection
- WWW
- Web3D
- Mobile
- WebVR (HMDs)
- Device-specific interaction



Virginia Tech Visionarium Spotlight

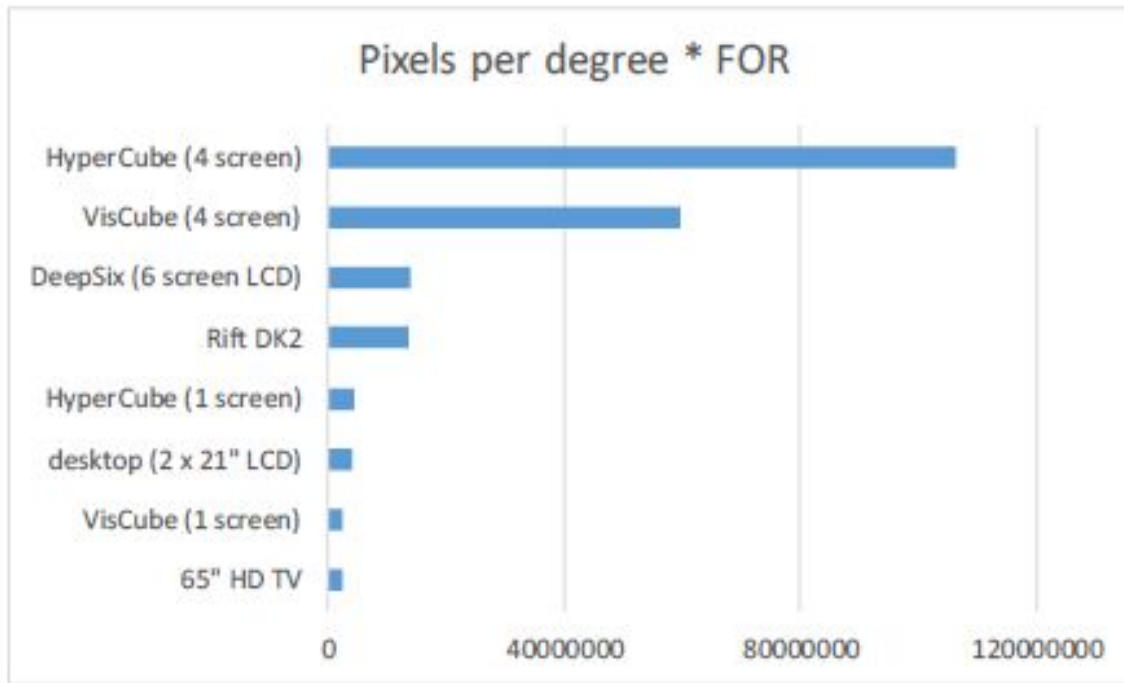
3D Blacksburg
www.3dblacksburg.org

Access: WebVR

- X3D and HTML5 files
- Uses the browser as the platform
- Many headsets



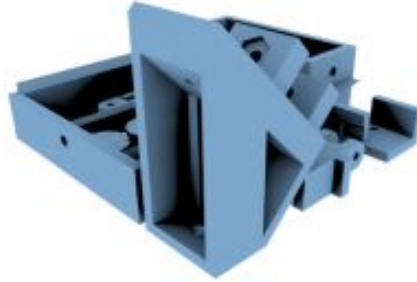
Display Bandwidth



Metric for Total Display Bandwidth

Access: 3D Printing

- 3D Printing
- CURA
- Netfabb
- Shapeways
- Lulzbot



support X3D for 3D Printing!

Exporting X3D

Tons of Tools...

- Blender
- MeshLab
- Modo
- 3DS Max
- Maya
- Rhino
- Paraview
- Agisoft
- ARCScene
- Creoform
- Unity
- PointFuse....

export ISO Web3D!

- Titania (Linux)

<http://create3000.de/>

- X3D-Edit

<https://savage.nps.edu/X3D-Edit/>

- AOPT (w/
InstantPlayer)
- XML & stylesheets
- ...

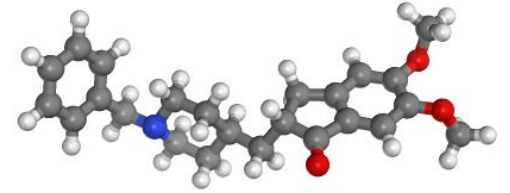
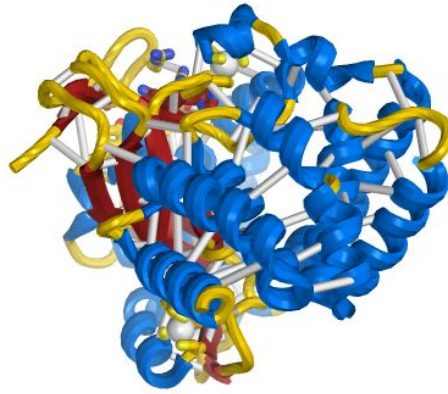
- 3DPrint Exchange
- POSTGIS

<https://postgis.net/>

- ...
- Okino Polytrans
- Safe Software (FME)
- ...

Molecules

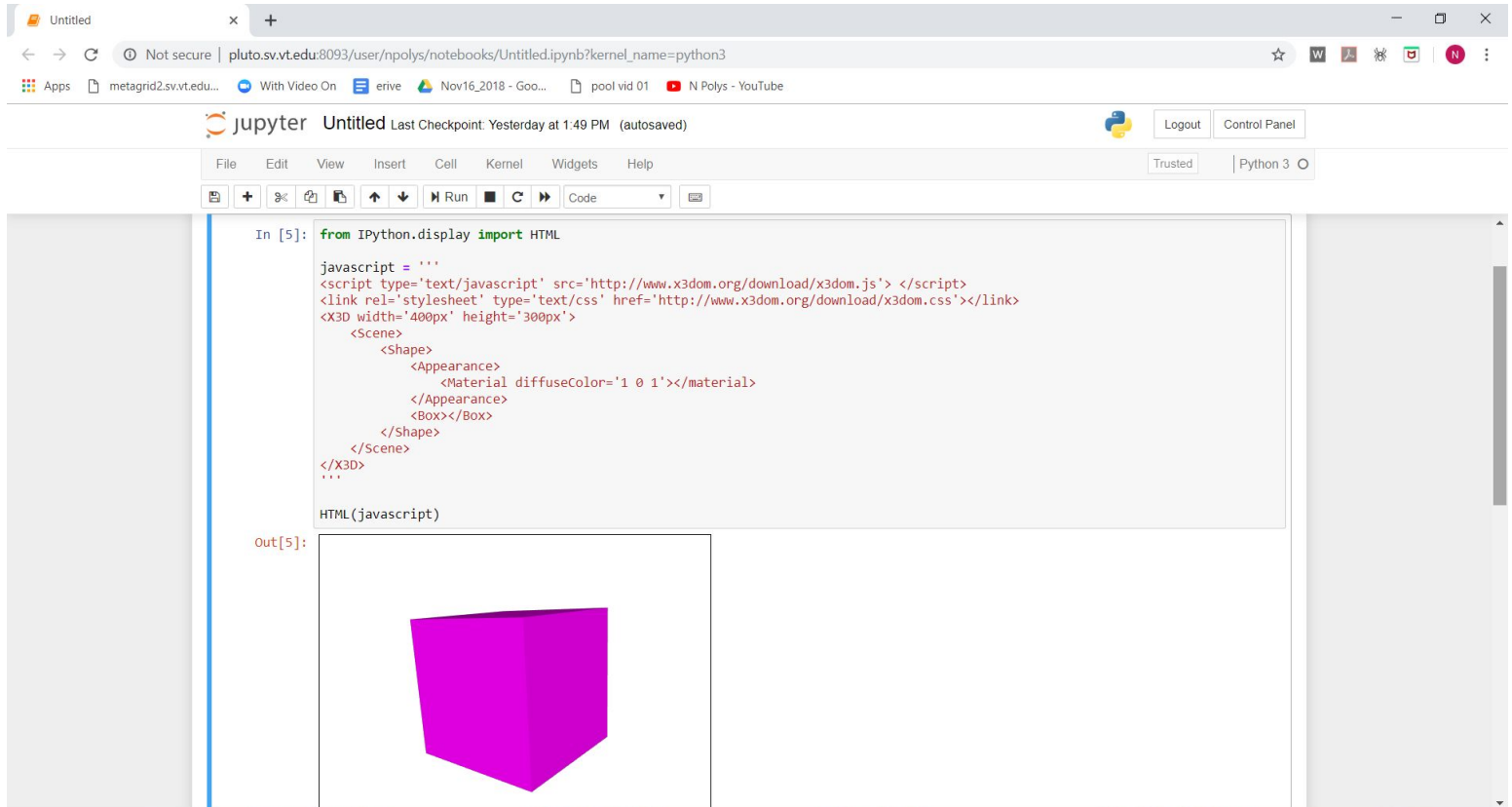
- Chimera
- VMD
- *Mol
- CML
- ...



Processing X3D

- Okino's NuGraf / PolyTrans
- Blender
- MeshLab
- Safe Software's FME
- Your own Scripts and compiled programsany language!!!

X3D from Python in Jupyter Notebooks



The screenshot shows a Jupyter Notebook interface in a web browser. The browser address bar shows the URL: `pluto.sv.ttu.edu:8093/user/npolys/notebooks/Untitled.ipynb?kernel_name=python3`. The Jupyter interface includes a menu bar (File, Edit, View, Insert, Cell, Kernel, Widgets, Help), a toolbar with icons for file operations and execution, and a code editor. The code cell contains the following Python code:

```
In [5]: from IPython.display import HTML

javascript = '''
<script type='text/javascript' src='http://www.x3dom.org/download/x3dom.js'> </script>
<link rel='stylesheet' type='text/css' href='http://www.x3dom.org/download/x3dom.css'></link>
<X3D width='400px' height='300px'>
  <Scene>
    <Shape>
      <Appearance>
        <Material diffuseColor='1 0 1'></material>
      </Appearance>
      <Box></Box>
    </Shape>
  </Scene>
</X3D>
'''

HTML(javascript)
```

The output of the code cell is a 3D visualization of a purple cube, displayed within a rectangular frame. The cube is rendered in a perspective view, showing its top, front, and right-side faces. The background of the output area is white.

Processing image stacks to ImageTextureAtlas

Required for WebGL volume rendering (with X3DOM)

Arguments:

```
python convertPNG.py <InputFolder> <OutputFileName> [width] [height]
```

Usage example:

```
python convertPNG.py ./data/slices/ ./ouput/atlas 512 512
```

Can also generate a GradientAtlas and multiple output resolutions!!

See the project's github Wiki for details and required python packages

Join Us!

www.web3d.org

npolys@vt.edu