Web3D Quickstart & X3D v4

Web3D 2019 Tutorial

Nicholas Polys, Virginia Tech USA
Don Brutzman, Naval Postgraduate School
Interactive 3D Graphics

+ WWW

= Web3D
## Topics

<table>
<thead>
<tr>
<th>Applications</th>
<th>Implementations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO Scenegraph</td>
<td>X</td>
</tr>
<tr>
<td>WWW eb3D</td>
<td>X</td>
</tr>
<tr>
<td>x - Reality</td>
<td>X</td>
</tr>
</tbody>
</table>
Immersive Web3D: ISO-IEC X3D, VRML
Web3D Integration, HTML5, 3D Printing
The Web is the Interface
History of Web3D Standards

1994  Virtual Reality *Markup* Language v1.0 efforts
1997  Virtual Reality *Modeling* Language (VRML) v2.0
2000  **Non-profit Web3D Consortium** established to protect open specifications
2000s Extensible 3D (X3D) adds XML to Classic VRML Encoding v3.0
2008  IEEE VR workshop on Future Standards (Polys, Behr, Brutzman)


2011  W3C Declarative 3D Community Group and continuing efforts.

The Web is Wide

Many Domains … data
Something in Common?

Vis.arc.vt.edu

Instantreality.org

3dprint.nih.gov
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!
Web3D.org
Specifications, Resources, Community
VRML -> Web3D Conference Proceedings
● 24 Years in the ACM Digital Library

Google Scholar search:
● ‘Extensible 3D’ 109,000 hits;
  19,500 hits for ‘X3D’
● ‘Virtual Reality Modelling Language’ 258,000 hits;
  80,300 hits for ‘VRML’
The Extensibility of VRML and X3D has been proven in 17+ years of academic papers where leading-edge graphics techniques have been tested and proposed for standardization.

**X3D yields 20,200 documents in Google Scholar and 4,440 in Semantic Scholar;**

**VRML yields 84,600 documents in Google Scholar and 13,100 in Semantic Scholar.**
The X3D suite of ISO-IEC Standards provides a system for the storage, retrieval and playback of real-time graphics content embedded in applications, all within an open architecture to support a wide array of domains and user scenarios.

http://www.web3d.org/standards
What is X3D (Extensible) 3D?

- Originated from ISO-IEC VRML
- A File Format *and* Runtime API (Javascript, Java, …)
- Multiple encodings (file formats): XML, VRML, JSON, based on the same abstract scenegraph content model
- Includes shaders, animation, interaction, geometry, texturing, lighting, camera
- Extensible - Capabilities added through scripting and node prototyping.
What is X3D (Extensible 3D)?

- Large set of nodes for describing interactive 3D scenes
- **Profile** and **Component** structure promotes interoperability
  - 8 Profiles for common use cases [X3D Profiles]
  - 35 X3D Components for modular design [X3D Components]
- 233 X3D Nodes for every little thing! [X3D Nodes]
- Implementations on multiple platforms: WWW, mobile, immersive
- Domain components - Design, 3D Printing, Medical, Geospatial, Humanoid Animation, AR and VR
- Multiple commercial and open source implementations

http://www.web3d.org/x3d/what-x3d
Web3D Consortium Overview

Web3D.org: Open Standards for Real-Time 3D Communication

- Founded in 1997, an international, non-profit, member funded, standards development organization
- Developing the ISO specification X3D for interactive 3D graphics on the Web
- Our members span from Academia, research, industry, government, and professionals
- A community of technologists, artists and enterprises
- National recognition (e.g. US National Archives)
Web3D.org  Interoperability

Web3D Consortium has MOU and Liaison agreements with multiple standards bodies to develop open interoperable 3D solutions

Converging with other standards
The Greatest Common Denominator

1997 era VRML worlds runs in:

- 2018 HyperCube ....
- Samsung GearVR, DayDream Apps
- HTML5
- ...

21 years of asset durability

And reproducibility !!!
VRML is X3D…

A text editor:

Change the first line of your *.wrl from:

#VRML V2.0

To:

#VRML V3.0

... save as *.x3dv

but X3D is so much more!
YouTube
Web3D Consortium Channel
https://www.youtube.com/user/Web3DMaster/playlists

Twitter
https://twitter.com/Web3DConsortium
Standards make the Web go round!

Runtime approaches:

1) Installed engines import, export render X3D and VRML with different node Profiles

2) Javascript Polyfills ('native' in browser):

- X3DOM: [https://www.x3dom.org/](https://www.x3dom.org/)
- X_ite: [http://create3000.de/x_ite/](http://create3000.de/x_ite/)
X3D Engines

- Instant Reality
- Covise/OpenCover
- GearVR
- Castle3D
- FreeWRL
- H3D (Haptics, py)
- Coin3D
- Titania
- OctagaVS
- Xj3D
- BS Contact
- ... 

(July 2019)

**HTML5 + WebGL Javascript Polyfills:**

- X3DOM
- X_ITE
- NIH 3D Viewer
- Smithsonian X 3D
- Three.js
- ...
Instant Reality

http://www.instantreality.org/
Covise/OpenCover

https://github.com/hlrs-vis/covise
X_CITE and LINUX X3D Editor

TITANIA

http://create3000.de/
Castle3D Game Engine

https://castle-engine.io/
FreeWRL

http://freewrl.sourceforge.net/
H3D.org - Haptics

X3D + Volume Component (MEDX3D)
Major development work: **Samsung GearXR**

**Why implement X3D in GearVR**

- Samsung began this effort February, 2016
- X3D is a widely supported file format
  - Exported by 3DS Max, Blender, Maya, Moto
    - Or exports VRML and converts to X3D
- No other file format had similar capabilities.
  - Interactivity via JavaScript
  - Declarative format easy to edit / visualize the scene.
- GearVR is not just a VR game console like Sony PSVR
  - We are a phone, web access device, camera, apps platform
  - X3D enables web applications:
    - Compliments the game influence in GearVR from Unity, Unreal.
    - Enables new VR web apps including: Google Maps, Facebook, Yelp JavaScript API’s.
V-Slam.org

Open Source Unity – based X3D browser

- tested O-Snap X3D with Hololense!

Bring your business online in 3D!
Javascript libraries for rendering X3D w WebGL:

X3DOM
X_ITE
x3dom
Instant 3D the HTML way!
X3DOM.org // Overview

- Integrates 3D content seamlessly into your webpage
- Access & manipulate Nodes per DOM-API
- No Plugins needed
- Simply include a javascript file
- Open-Source
- Free for non-commercial and commercial purposes
1.8.0: 10-year Anniversary Release!

**Gltf Inlines:**

X_ITE X3D BROWSER

HAVE YOU SEEN THIS?

Getting Started

X_ITE is a new 3D JavaScript library entirely written in JavaScript and uses WebGL for 3D rendering.
ISO-IEC Standard Scope

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- Scripts
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3.3 examples for Medical Imaging, CAD and Geospatial support!
X3D Scene graph

Resources & International Community

www.web3d.org


Book:

http://x3dgraphics.com/

Online Slides: http://x3dgraphics.com/slidesets/index.php

Online Examples: http://www.web3d.org/x3d/content/#Examples
X3D & VRML Scene Graph

- Transformation
  - Directed Acyclic Graph
- Worlds by URL#Viewpoint
- Bind-ables
  - NavigationInfo {}
  - modes: WALK, FLY, EXAMINE, ...
  - Default to lexical order
  - Modifiable through Script and SAI / EAI
  - Background, Fog,
  - Viewpoint
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*

<table>
<thead>
<tr>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRML, X3D</td>
</tr>
<tr>
<td>Open GL, etc</td>
</tr>
<tr>
<td>Operating System</td>
</tr>
</tbody>
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Scene Graph

- Lives above the rendering library
- Specifies object and environmental properties:
  - Lights
  - Camera
  - Transformation and Grouping of Shapes (parent - child)
  - Geometry and Appearance (materials, textures, shaders)
  - Environmental effects (e.g. Fog, Backgrounds)
- Manifests animation and interaction behaviors
- Is 'traversed' for drawing
Scenegraph

Lots of tools export:

- Virtual Reality Modeling Language (VRML)
- Extensible 3D (X3D)

... lots of other proprietary formats; can be converted with commercial translation tools, open source tools, or your own Scripts!

Target X3D Profiles and Components for different node sets (functionality)
Behavior Graph

- How events flow through the system
  - ROUTEs
- The 'Event Cascade' per timestep / frame
  - Animations (keyframe)
    - Interpolators
    - Sequencers
    - Timesensor
  - Interactions
    - ROUTE sensors to Event Utilities
    - Or write a Script {} to process events w logic
Scripting

- In-scene logic
- Build an X3D file with scripts (perl, python, ...)
  - Read a CSV
  - Re-project GIS
  - Pointclouds
  - ...
- Build the scenegraph at runtime with Scripts
  - Java, Javascript
  - DOM
  - JSON
Lights

- Have attributes:
  - position, orientation/direction, on/off, intensity, color, range, attenuation, ...

- DirectionalLight

- PointLight

- Spotlight

- Scoping rules
  - Siblings
  - global
Cameras

- Binding Stack
  - Current at top
  - Forward and Back in the Stack (Pg-Up, Pg-Dn)
  - Listed in Browser
  - Scripted

- Viewpoint: **perspective camera**
- OrthoViewpoint: **orthographic camera**
Transformation & Grouping

- Transform
- Group
- LOD
- Switch
- Billboard
- Collision
- Anchor

Scenegraph scopes lights and sensors
Shapes

Consist of geometry and appearance data:

- **Material**, **ImageTexture**, **Shaders**
- **Primitives** *(Box, Cone, Cylinder, Sphere)*
- **ElevationGrid**, **Extrusion**
- **IndexedFaceSet**, **IndexedLineSet**
- **PointSet**
- **Carries** **Color**, **Normals**, **Coordinate**, **indices**
- ‘**ComposedGeometry**’ component includes triangle fans and strips
Environment nodes

Bindables:

- BackGround
- TextureBackground
- Fog
- LocalFog
Animation

- Keyframe or Scripts
- Keyframes:
  - Interpolators
  - Sequencers

For each field type you want to animate: position, orientation, scalar, integer, color, coordinate

ROUTE TimeSensor.fractionChanged to *Interpolator key

ROUTE *Interpolator keyValue to node’s field
Going Immersive @ VT

Instant Player Engine files:
- Stereo Windows and Screens
- 3DUI as Javascript

InstantIO components:
- ART head, wand data
- DTK/TrackD (Intersense)
- Navigator
Extensible 3D (X3D)

- Components and Profiles collect a structured nodeset (scene graphs)
  - Geometry, appearance, lighting
  - Animation, multimedia (sound, video)
  - Interaction and application logic
- File format with multiple encodings: XML, UTF8, Binary, JSON
- Runtime API for a Unified Object Model with multiple programming language bindings (JavaScript, Java, C#, C++, Python, ...)
- Widespread support through multiple commercial and open-source engines and VRML heritage
- ISO-IEC Standard
Tons of Tools...

- Blender
- MeshLab
- 3DS Max
- Maya
- Rhino
- Paraview
- Agisoft
- ARCScape
- Creoform
- Unity
- ...

**export**

- 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
- ...
- ...
Immersive X3D Examples

- Samsung GearVR, Google Pixel
- WebVR + X3DOM
- Multi-projector CAVEs (same X3D file)
- Variety of implementation efforts
- Annual Web3D Conference
- VR Hackathons
- The eTrout project
3D Graphs and Plotting with X3D

- **MatLab:**

- **R (vrmlgen):**
  - http://ico2s.org/software/vrmlgen.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/](http://docs.enthought.com/mayavi/mayavi/)
Interactive X3D Graphing

https://dlmf.nist.gov/

Molecules

- Chimera
- VMD
- *Mol
- CML

...
Design & Planning examples

Exhibits

Landscapes
Design & Planning II

- Virtual Tours
  - photospheres
  - Structure.io scans

- Town Planning (Sketchcup + X3D Blacksburg)
Smart Buildings

http://icat.vt.edu/mirrorworlds/

- VT Moss Arts Center
- Telepresence platform
- Multi-user online building
https://youtu.be/ybi77t6WNO8
3dprint.nih.gov

- Molecules
- Cells & tissues
- Anatomical models
- Prosthetics
- Labware
- ...

NIH 3D PRINT EXCHANGE
3D Printing Support

- CURA,
- Netfab,
- Shapeways,
- ...

Native support of X3D for 3D Printing
(including color and metadata)!

Can always convert to STL with tools like:

- Blender
- Meshlab,
- 3DPrintExchange
- ...

Immersive Displays

Gallery @ vis.arc.vt.edu

http://www.youtube.com/user/VTVisionarium

Youtube Channel!
SAFAS
Space Frame designer & Structural Simulator:

Creation and Visualization via Web3D Service

- CAVM stereo wall ->
- VisCube, HyperCube
CORNET 3D

https://www.youtube.com/watch?v=i8rqwmEDIU
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.*
Scientific Visualization: CFD

*Immersive X3D via Paraview*

[Video Link]
https://vimeo.com/255413564
Online Vis - Sim Services

VRS - RAPID

https://www.youtube.com/watch?v=1Q2ytjBrmXc&t=1s
Volume data

● Cell Image library
● Fossils (CT)

● Zoology (Prof Hoffmann, Bonn)
  ○ http://vnhm.de/
● VICOMTech:
  ○ MIRROR4All
  ○ https://github.com/VolumeRC/AtlasConversionScripts
Fossils and Evolution


Surfaced:

X3DOM Volume Rendering (cont’d)

- RadarVolumeStyle + ClipPlane
  - [https://examples.x3dom.org/example/RadarVolumeStyle/](https://examples.x3dom.org/example/RadarVolumeStyle/)
Smithsonian Heritage + metadata in X3D

Smithsonian Mammoth in X3D with embedded Metadata

- National Museum of Natural History
- Mammutthus primigenius (Bibronuch)
- Skeletal Morphology: Complete skull and skeleton
- Geological Age: Quaternary; NMNH - Paleobiology Dept.
- Common name: mammoth
- Taxonomy: Animalia Chordata Mammalia Proboscidea Elephthioids
- USNM Number: V23792
- OBJ model downloaded from: https://3d.si.edu/browser

Smithsonian Buddha in X3D with embedded Metadata

- Freer Gallery of Art and Arthur M. Sackler Gallery
- Buddha draped in robes portraying the Reclining of Existence
- Origin: probably Henan province, China
- Period: Northern Qi dynasty 550-577
- Type: Sculpture, Stone
- Accession Number: F1823.15
- https://www.si.edu/specifs/F1823
- OBJ model downloaded from: https://3d.si.edu/browser

Nicholas Polys (VT) & web3D.org

Virginia Tech
Innovate the Future

web 3D consortium

X3D: web3D.org
X3DOM: X3DOM.org
GIS

- ESRI
- OGC / Geoserver / PostGIS


- GDAL

X3D Blacksburg

Environmental Awareness  E.g.  https://youtu.be/ZlXbsR4KSzc

- Terrain
- Imagery, openstreetmap
- Town buildings
- Campus buildings
- Sketchup buildings
- Frog scans
- ...
X3D Blacksburg

- n-D City model
- Enterprise scale GIS infrastructure
- International standards:
  - Web3D (X3D)
  - OGC (Sensor Web)
- Integrates sensor feeds and crowd-sourced content
X3D Blacksburg
X3D Blacksburg Mirror World
Town & Building LODs

X3D shared multi-user VT Campus

X3D Immersive
Catawba GIS & tree LOD

http://metagrid2.sv.vt.edu/~npolys/Fusality_Summer2016/catawba_deer_hunting_x3d/

Drone Lidar Pointclouds

200-300 GB .las files

Stroubles Creek, Catawba Lidar ... -> binary X3D

http://metagrid2.sv.vt.edu/~npolys/Fusality_Fall2017/home.html
Pipeline Risk

vis-a-vis Geology

http://metagrid2.sv.vt.edu/~npolys/NRVPipeline/Pipeline_in_NRV_binc.html
GLTF

Use with Inline, ExternalShape, or convert:

- **X3DOM:**
  - https://examples.x3dom.org/x3dom-inline-gltf-2/

- **X_ITE:**
  - http://create3000.de/users-guide/components/rendering/indexedtriangleset/
Another encoding of X3D!:

- [http://www.web3d.org/x3d/content/#Examples](http://www.web3d.org/x3d/content/#Examples)

... Easy for Javascript!
X3D Evolution Strategy for VR

1. X3D v4.0 specification integrates with HTML5, DOM
   a. Currently working through “how precisely do we do that in the specification”
   b. These capabilities will ensure technical alignment with WebVR is possible via Web browser (Fraunhofer and VT already demonstrated WebVR 1.1 with X3DOM)
   c. Demonstration work with Samsung, others has proven particularly helpful
   d. Similarities to SVG and other W3C examples are being examined and utilized whenever possible

2. X3D v4.1 adds VR, AR, MAR
   a. Add any missing WebVR technical requirements: hooks into X3D Scenegraph (SAI)
   b. Consider X3D WebVR Profile for content authors and VR-experience generators
   c. Next add Augmented Reality (AR) and Mixed Augmented Reality (MAR) features according to ISO/IEC SC24 WG9 Mixed Augmented Reality (MAR) abstract reference model
   d. 2+ open-source implementations, public evaluation, content examples, specification approval
   e. Deep-dive testing to date indicates no “show stoppers” and X3D participation continues
Web3D Consortium Strategic Roadmap for X3D

VR, AR, MR, xR
- Identify Member projects
- Track industry efforts
- Define gaps, new goals in X3D standards
- Extend X3D to support full range of Mixed and Augmented Reality (MAR)

X3D 4.0
- HTML encoding and DOM binding: Design, Specification, Implementation, X3D v4 /HTML examples
- Maintain alignment: W3C HTML5, DOM updates

X3D 4.1
- ISO MAR Reference Model efforts
- Compare/contrast, align with WebVR/XR
- ISO/IEC Mixed Augmented Reality (MAR) Reference Model implemented in X3D for VR/AR

Web3D products provide a coordinated set of steadily evolving ISO/IEC standards

In development
In planning
Ongoing Specification Development Activity

- Continued dialogue on mailing lists and at community events!
- Continue open proofs and development of X3D and HTML5, WebVR
- Web3D Specifications Development, Implementation and Evaluation
  - Multiple file encodings and programming languages within X3D Unified Object Model
  - **X3D 4.0 aligning with HTML5 and DOM**
    - Expand on CSS design efforts to date, confirm full alignment with HTML5 and DOM
    - Add glTF inline / import
  - **X3D 4.1 aligning with VR/AR/MR capabilities**
    - ISO-IEC Mixed Augmented Reality (MAR) Reference Model
    - Augment X3D node set to integrate additional WebVR parameters
    - Design, implement, evaluate WebVR Profile for X3D
- Web3D working groups are quite active. Participation and liaison are welcome.
Join Web3D!

- Deploy Web3D systems and content
- Communicate on Web3D public Listserves
- Comment on Specifications
- Slack
- Public / Member wiki
- Professional / Student memberships
- Member Area
Contact

www.web3d.org

npolys@vt.edu
https://www.youtube.com/watch?v=GY2Bq0op-Kc
X3D on the tubes (source: VT)

https://youtu.be/SDM97VpArSY
https://youtu.be/DO35QIAPrtg
https://youtu.be/9C6T_JYj6Lg
https://youtu.be/JI9iL2a-pmw
https://youtu.be/p8nER5wb6cA
https://youtu.be/5V9RAd-JUas