IEEE VR 2020
Extensible 3D (X3D): Quick Start

http://metagrid2.sv.vt.edu/~npolys/VR2020/

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Acknowledgements

Evolving material since 2018 with:

Johannes Behr
Timo Sturm
Uwe Woessner
X3D Tutorial Outline

Technology Overview

Ecosystem

Break

Applications: VT, Navy, NIH, 3DMD, ...

Authoring
IEEE VR Workshops: X3D / VRML notables

- Mixed-Reality Interface Specification 2006
- Future Standards for Immersive VR 2007
- SEARIS 2008, 2009
- Medical Virtual Reality 2010
- Immersive Volume Rendering 2013
- Immersive Analytics 2016

Present every year @

SIGGRAPH, SuperComputing BOFs
Resources

March 12, 2020:

‘X3D’
yields 20,700 documents in Google Scholar and 8,450 in Semantic Scholar

‘VRML’
yields 87,100 documents in Google Scholar and 24,000 in Semantic Scholar.
Interactive 3D Graphics + WWW = Web3D
The Web is the Interface
The Web is Wide

Many Domains … data
The Web is Deep

Open worlds linked can composed by URL
A Rising Tide Lifts All Boats

Web3D Standards:

● 25 years of interactive 3D Graphics Innovation (& ACM SIGGRAPH Conference)
● A world-wide community
● Researchers Innovate
● Content & Applications Survive
How it Works

- International Standards Organization (ISO.org)
  - National bodies ratify technology
- World Wide Web Consortium (W3C.org)
  - Members ratify technology
- Web3D Consortium (Web3D.org)
  - Members ratify technology
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.

https://www.web3d.org/
http://www.web3d.org/standards
Interactive 3D Graphics: a first-class citizen on the WWW

Networked 3D digital assets (Web3D) linked by URLs:

- 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 XML uses a DTD and Schema
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.
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.

X3D Scene Graph

Resources & International Community

www.web3d.org

Online Examples: https://www.web3d.org/x3d/content/examples/X3dResources.html#Examples

X3D Book: http://x3dgraphics.com/

Online Slides: http://x3dgraphics.com/slidesets/index.php
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>OpenGL, WebGL, DirectX, ...</td>
</tr>
<tr>
<td>Operating System</td>
</tr>
</tbody>
</table>
The X3D graphics stack

X3D for Web Authors Vs WebGL for 3D graphics application programmers

Open Source X3D Browsers

X3DOM  http://www.x3dom.org

X_ITE  http://create3000.de/x_ite

Standalone – Instant Reality
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)
- Specifies animation and interaction behaviors
- Is 'traversed' for drawing
Renderers vs Markup

*Draw a Red Cube*

OpenGL

X3D

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

83 lines of compiled C code
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!
Scene Graph

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
More Fundamentals

- Spatial Units assumed to be meters
  (unless otherwise declared)
- Rotational Units are in Radians
- Right-handed 3D coordinate system
VRML -> X3D

Durability of interactive 3D content 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
1 Line upgrade to X3D!

‘Classic’ utf8 encoding:

A VRML.wrl file can become an X3D.x3dv file simply by changing the header line from:

VRML #2.0 to VRML #3.0
From VRML to X3D

- Introduced XML & Binary encoding
- Shaders
- Physics (Rigid Body)
- Distributed Interactive Simulation (DIS) [http://open-dis.org/](http://open-dis.org/)

From X3D 3.x to X3D 4.0

- New encodings: eg HTML5 encoding
- New Language Bindings: eg DOM API
- Physically-Based Rendering & glTF inlining

**Encodings:**
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# X3D: Encodings and Examples

MIME Types

<table>
<thead>
<tr>
<th>X3D Encoding</th>
<th>File Extension</th>
<th>MIME Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>XML</td>
<td>.x3d, .x3dz</td>
<td>model/x3d+json</td>
</tr>
<tr>
<td>JSON</td>
<td>.x3dj</td>
<td>model/x3d+json</td>
</tr>
<tr>
<td>Classic VRML</td>
<td>.x3dv, .x3dvz</td>
<td>model/x3d+vrml</td>
</tr>
<tr>
<td>VRML</td>
<td>.wrl, .wrz</td>
<td>model/vrml</td>
</tr>
<tr>
<td>Binary</td>
<td>.x3db, .x3dbz</td>
<td>model/x3d+binary</td>
</tr>
</tbody>
</table>

[https://www.web3d.org/x3d/content/examples/Basic/index.html](https://www.web3d.org/x3d/content/examples/Basic/index.html)

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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.

```xml
<?xml version="1.0" encoding="UTF-8"?>
  <head>
    <meta name="title" content='"Skeleton Complete Normals.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="TODD"/>
    <meta name="modified" content="22 December 2013"/>
    <meta name="creator" content='"Damon Hernandez, Joe D. Williams, Don Brutzman"'/>
  </head>
```

X3D model
ClassicVRML
VRML97
Canonical
X3D source
X3D model
X3DOM
.jsd (check)
.x3dj Binary
Java and x3dv source

Visit Web3D Example Archive

https://www.web3d.org/x3d/content/examples/X3dResources.html#Examples
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YouTube
Web3D Consortium Channel
https://www.youtube.com/user/Web3DMaster/playlists

Twitter
https://twitter.com/Web3DConsortium
Take-Aways

● X3D and open standards leadership helps Virginia Tech fulfill its mission everyday
● X3D supports interoperable data, unlocking value across the enterprise, application stovepipes, and hardware platforms
● X3D is durable, providing a data strategy longer than silicon valley life-cycles
Networked Graphics - using X3D DIS