X3D Graphics International Standard Version 4 Update and Online Resources

Web3D 2021 Conference

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Abstract

X3D version 4 is a major upgrade to the Extensible 3D (X3D) Graphics International Standard that supports HTML5 integration, advanced Physically Based Rendering (PBR) supporting glTF, Projective Texture Mapping (PTM), Humanoid Animation (HAnim2), enhanced spatial audio supporting the W3C Web Audio standard, plus numerous other improvements.

Available file encodings include XML, ClassicVRML, JSON and Turtle. Additionally open-source programming libraries are available in JavaScript, Java, and Python. Strict validation of models allows exceptionally high levels of Quality Assurance (QA).

This tutorial summarizes new capabilities and describes author support in modern browsers, updated tools and a growing set of examples. An emphasis on design principles illustrates how this important standard has steadily and consistently evolved for archival publication of interactive 3D graphics across the Web.

This presentation provides a regular annual progress update, and a follow-on discussion period is welcome.
Presentation Topics

X3D version 4 Architecture progress update
• Summary report of status
• ISO/IEC specifications
• Liaison relationships

Resources
• Provide synopses, snapshots and links for a wide ecology of X3D tools, examples and learning aids.
X3D4 Specification Update
Web3D Consortium Role and Relationships

Web3D Consortium is a non-profit Standards Development Organization (SDO) holding a Class A liaison relationship with ISO/IEC since 1997.

• About Web3D Consortium: https://www.web3d.org/about  (Web3D Introduction Video)

Web3D Consortium prepares, verifies and submits functional specifications to ISO, receives comments back, resolves them, and resubmits specs in accordance with ISO/IEC processes. To date these specifically include the VRML, HAnim and X3D standards. Each has corresponding, complementary volumes and parts.

• Standards Adoption Process https://www.web3d.org/standards/adoption-process

We are happy to work with all ISO/IEC working groups, SC24 WG6 is primary. Many other working groups and standardization groups hold related interest.

• Web3D Consortium Liaisons and Partnerships https://www.web3d.org/about/liaisons
X3D4 Architecture Revision is Approaching Completion

• **X3D® version 4 (X3D4)** is a major upgrade to the Extensible 3D (X3D) Graphics International Standard that provides close support for the HTML5 Recommendation, Khronos glTF Physically Based Rendering (PBR), Web Audio API and other capabilities.
  • [https://www.web3d.org/x3d4](https://www.web3d.org/x3d4)

• This work is a major update that builds upon prior versions of X3D and Virtual Reality Modeling Language (VRML). Overall development is guided by the Web3D Consortium Standards Strategy.
  • [https://www.web3d.org/strategy](https://www.web3d.org/strategy)

• This effort is driven by the X3D Graphics Working Group with many contributions from other working groups and daily community outreach.
  • [https://www.web3d.org/working-groups](https://www.web3d.org/working-groups)
X3D4 Overview References

X3D specification relationships:
• https://www.web3d.org/specifications/X3dSpecificationRelationships.png

Detailed information on X3D4 is found online at Web3D 2020 Conference site
• Tutorial: https://web3d.siggraph.org/archive/web3d2020/tutorial-2/
• Slideset: https://drive.google.com/file/d/1VCgdLaWMmZUu-TZgRAMsSobR6CC5Okt5/view
• Video:  https://drive.google.com/file/d/1zVRysi1pl7iC1nBMiVK_iXsAM93JlrLv/view

Current draft X3D4 specification:
• https://www.web3d.org/specifications/X3Dv4Draft/ISO-IEC19775-1v4-CD1
One architecture, many supporting specifications, all functionally equivalent and fully compatible

- 19775-1 X3D Architecture
- 19775-2 X3D Scene Access Interface: corresponding API requirements
- 19776 X3D file encodings
- 19777 X3D bindings for various programming languages
- 19774 Humanoid Animation (HAnim)
## X3D Graphics Standards Relationships

### Reference Standards

|---------------------|---------------------------------------------|------------------------|---------------------------------------|---------------|---------------------------------------------------------------|-------------|----------------|--------|

### Web3D Consortium Architectures, File Encodings, and Programming Language Bindings

#### X3D Graphics Architecture
- **19975-1 v4.0**
- X3D Unified Object Model (DOM)
- X3D Graphics for Semantic Web

#### X3D Scene Access Interface (SAI)
- **19775-2**
- Standalone program functionality

#### X3D XML Encoding
- **19776-1**
- .xml
- X3D ECA/JS Binding

#### X3D CBE Compressed Binary Encoding
- **19776-3**
- .cbe
- X3D EBE Efficient Binary Encoding

#### X3D JSON Encoding
- **19776-5**
- .json
- X3D JS Binding

### Example Instances

- **HTML5 CSS pages including X3D**
- **X3D scenes, model files**
- **Compressed gTF shapes**
- **X3D script, applications**
- **SAI libraries X3DUOM**
Khronos glTF v2.0 capabilities now part of X3D4

Full-coverage correspondence defined in glTF and X3D4 specifications
• Adds Physically Based Rendering (PBR) and Non-Photorealistic Rendering (NPR)
• X3D4 players can Inline glTF models, or support visually equivalent X3D models

Working on automatic X3D player support for glTF examples archive
• https://github.com/KhronosGroup/glTF-Sample-Models/tree/master/2.0#readme
• X3D4 goal is to demonstrate correct, consistent rendering throughout all examples
• Paper: “diff” testing continues for structured text, viewpoint images, animations

Formal liaison between The Khronos Group and Web3D Consortium
• Planning to match correspondences between respective metadata models
The X3D Unified Object Model (X3DUOM) definitions exactly match the X3D Architecture and are used to autogenerate other representations.

- Derived from formal X3D XML schema with added object-model annotations
- Under discussion: considering possible addition to X3D specification suite
- [https://www.web3d.org/specifications/X3DUOM.html](https://www.web3d.org/specifications/X3DUOM.html)
- (Functional descriptions are possible annex addition to 19775-1 Architecture)

To achieve a second implementation for C, C++, C# source implementations (for example) we can adapt demonstrated source-generation patterns already developed for:

- Java [https://www.web3d.org/specifications/java/X3DJSAIL.html](https://www.web3d.org/specifications/java/X3DJSAIL.html)
- Python [https://www.web3d.org/x3d/stylesheets/python/python.html](https://www.web3d.org/x3d/stylesheets/python/python.html)
- JSON [https://www.web3d.org/x3d/stylesheets/X3dToJson.html](https://www.web3d.org/x3d/stylesheets/X3dToJson.html)
- Turtle [https://www.web3d.org/x3d/content/semantics/semantics.html](https://www.web3d.org/x3d/content/semantics/semantics.html)

(which may further get submitted to SC24 as specification 19776-6)
Prominent capability additions in X3D4

• HTML5 recommended integration guidelines for authors, implementers
  • Annex L [HTML authoring guidelines](https://www.khronos.org/gltf)
• Full support for Khronos glTF v2.0 via Inline or matching X3D nodes
  • [https://www.khronos.org/gltf](https://www.khronos.org/gltf)
• Web Audio API W3C Recommendation
  • [https://www.w3.org/TR/webaudio](https://www.w3.org/TR/webaudio)
• Addition of [Projective Texture Mapping (PTM)](https://www.w3.org/TR/webaudio)
• Support for properties of point clouds and scanning requirements
• Support for [Humanoid Animation HAnim version 2](https://www.w3.org/TR/webaudio), particularly motion animation
Current Efforts, X3D 4.0 Architecture 19775-1

✓ Support achieved for glTF advanced rendering, W3C Web Audio API
  • plus integration with HTML5/CSS
✓ X3D4 new work item proposal (NP) approved by national bodies 2021
  • 8 affirmative, 4 abstain
  • ISO/IEC Committee Draft (CD) submitted, review and editing in progress
    • Over 200 “editorial” comments identified during last ballot, each being addressed
    • Only a handful of minor functional issues remain, evaluating implementations
    • HTML/CSS specification editing in GitHub version control, also productionized
✓ Necessary next milestone: finish ballot/editing, final version resubmitted
  • Then pursue programming language bindings and file encodings, at a faster pace
  • No plans to pursue v4.1 future functionality until current v4.0 work all complete
Suggested path forward for C, C++, C# APIs, namely programming language bindings ISO/IEC 19777-3,4,5

A. Share draft implementation, example scenes, and draft specification (now in GitHub) for Web3D Consortium member and public review

B. Show design patterns for expressing X3D nodes and statements in each programming language, to allow autogeneration of consistent source code libraries and provide independent 2nd implementation
   1. Rephrase: syntax for minimalist implementations matching SAI requirements
   2. Similar design-pattern approach to matching syntax for Java, Python, JSON

C. Public review period – ready to implement/evaluate/finalize?

D. Web3D member, Board of Directors approval of submission to SC24

E. Submit CD 3.3 to ISO/IEC for ballot, next draft becomes version 4.0
Human Animation (HAnim) Status

HAnim second edition approved as International Standard (IS)
- Part 1 matches original HAnim first edition (with small improvements)
- Part 2 adds Motion Animation (both interpolators and BVH-style motion files)

X3D support exactly matches functionality in latest 19774, tested OK
- Active work improving tool support and published examples
  - https://www.web3d.org/x3d/content/examples/HumanoidAnimation

Future work on HAnim will apply similar technical approaches for
- Facial and expression encodings, variety of internal organs
- Long-term goals include clothing/fashion and 3D medical records

Addition of X3D Ontology implementing Semantic Web relationships has obviated need for continued definition of alias names.
- Vocabulary synonyms, correspondences are queryable and portable across versions
  - https://www.web3d.org/x3d/content/semantics
ISO/IEC document considerations

All specifications in git version control, privately hosted by Web3D Consortium
- [https://github.com/Web3dConsortium/X3D](https://github.com/Web3dConsortium/X3D)
- [https://github.com/Web3dConsortium/HAnim](https://github.com/Web3dConsortium/HAnim)

Each draft/final version published equivalently with ISO/IEC, Web3D copyrights
- [Publicly Available Standards (iso.org)](https://standards.iso.org/ittf/PubliclyAvailableStandards/index.html)

Editorial CSS styles facilitate comment resolution by marking up HTML drafts
- Details for all issues formally tracked by Web3D Consortium in [Mantis](https://mantisweb3d.org) system
- Stable process, slow but steady progress – relentless!

Styling issue: does ISO/IEC have improved HTML document layouts? Ready to adopt.
- Consistent presentation of international standards is important for reader understanding and broad adoption worldwide. HTML style guidelines are essential for creating high-quality results.
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<td>Ensure uniform and consistent usage of root and top-level terminology</td>
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Resources
X3D Version 4 Overview

- https://www.web3d.org/x3d4
The Web3D Consortium is proud to offer free public access to the X3D4 Architecture Specification, now in Committee Draft (CD).

All major functional requirements are complete.

Editorial refinements continue throughout the ISO/IEC balloting and comment process.
Castle Game Engine *view3dscene*

- Free cross-platform VRML/X3D browser that also supports other 3D model formats (FreeBSD, Linux, MacOS, Windows)
- Best glTF support and conversion, paper in Web3D 2021 Conference
Usage:
- Click on any editable shape, and drag with mouse to move.
- Hold down Shift when clicking (and dragging) to rotate.
- Hold down Ctrl when clicking (and dragging) to scale.

Note that the collisions between avatar and objects, checked when the avatar moves (but not when objects move), work all the time for current geometry.

As a bonus, you can use dynamic shadows from everywhere.

Press key h (help) to hide/show this text at any time.
X3DOM for X3D in HTML

• High-performance X3D player in open-source JavaScript. Authors can publish X3D source within an HTML5 page that works in modern Web browsers without prior plugin installation.

• https://www.x3dom.org
X_ITE for X3D in HTML

• X_ITE is a full standard X3D JavaScript WebGL Browser for all major web browsers and operating systems. Open source.

• All X3D Examples include X_ITE presentation, linked and as default inset.

• https://github.com/create3000/x_ite and Web3D tweet
Titania X3D Authoring Tool

• Titania has everything you need to create dynamic web graphics quickly and easily. (Linux only)

• Great support for animations, interpolator timing, ROUTE connections

• https://github.com/create3000/titania/wiki

• https://twitter.com/web3dconsortium/status/943504674660925440
TITANIA X3D AUTHORING TOOL

BRING COLOURS TO YOUR LIFE.

Integrated X3D Browser

Directly view and test your scenes

Titania X3D Editor provides an integrated, powerful toolset for animation, environments, motion graphics, and virtual reality. The integrated X3D Browser makes it easy to create scenes that look equal to X_ITE. Titania allows you to view and interactively edit scenes and offers powerful tools for the execution of the scenes. Titania is completely specifiable confirm as specified by Web3D Consortium.

Advanced X_ITE Support

Works seamlessly together with X_ITE

X_ITE is the new WebGL X3D runtime for all major web browsers that implements a high-performance X3D player in pure to the JavaScript. Author can publish X3D scenes with an HTML5 page that works with web browsers without any plugin installation. It can be used as a single 3D show via X3D/HTML5 and high-quality 3D animation rendering engine. For advanced scenes simulations, live data visualization, or as easy to use WebGL game engine, Titania and X_ITE are designed to work seamlessly together.
freeWRL

• FreeWRL is an X3D/VRML open source viewer for Windows, Linux, OSX and Android. FreeWRL has had a long track record, is here to stay. X3D Components get added, problems get resolved.

• [http://freewrl.sourceforge.net](http://freewrl.sourceforge.net)
X3D Resources

• Extensible 3D (X3D) Graphics is the royalty-free open standard for publishing, viewing, printing and archiving interactive 3D models on the Web.

• https://www.web3d.org/x3d/content/examples/X3dResources.html
X3D Scene Authoring Hints

• These hints provide a collection of style guidelines, authoring tips and best practices to improve the quality, consistency and maintainability of Extensible 3D (X3D) Graphics models.

• https://www.web3d.org/x3d/content/examples/X3dSceneAuthoringHints.html
X3D Tooltips

- X3D Tooltips provide authoring hints for each node and field found in X3D Architecture Specification version 4 draft.

- [https://www.web3d.org/x3d/tooltips/X3dTooltips.html](https://www.web3d.org/x3d/tooltips/X3dTooltips.html)
Conversions, Translation Tools, Import/Export

• Extensible 3D (X3D) Graphics is the royalty-free open standard for publishing, viewing, printing and archiving interactive 3D models on the Web.
• Numerous conversion tools are available for various encodings of X3D and VRML.
• Many 3D modeling systems include X3D and VRML import/export as well.
• https://www.web3d.org/x3d/content/examples/X3dResources.html#Conversions
• https://www.web3d.org/x3d/content/examples/X3dResources.html#Export
• Blender https://www.blender.org
• CADExchanger https://cadexchanger.com
• MeshLab https://www.meshlab.net
X3D Validator

• The X3D Validator performs comprehensive Quality Assurance (QA) testing to ensure the validity of X3D3 and X3D4 graphics models.

• [https://savage.nps.edu/X3dValidator](https://savage.nps.edu/X3dValidator)
X3D-Edit 4.0 Authoring Tool for X3D Graphics

• X3D-Edit is a free, open-source Extensible 3D (X3D) Graphics authoring tool for simple high-quality authoring, editing, import/export, validation and viewing of X3D scenes.

• [https://savage.nps.edu/X3D-Edit](https://savage.nps.edu/X3D-Edit)
X3D for Web Authors

• Building and interacting with 3D graphics is a "hands on" experience. Throughout this book there are lots of examples to study and modify. Practice helps you learn how X3D works, and assists you in building your own projects. 1200 slides, 3 dozen videos, 268 X3D models.

• The book presents the essential ideas needed to understand how an X3D world is constructed. Book chapters build upon each other, progressing from simple ideas to sophisticated concepts.

• *X3D: Extensible 3D Graphics for Web Authors* assumes that you are interested in learning more about 3D graphics. Some experience with other Web technologies (such as HTML or XML) is helpful. No prior programming experience is needed.

• [https://x3dgraphics.com](https://x3dgraphics.com)
X3D Examples Archives

- The X3D Examples Archives demonstrate how X3D nodes and scenes work. Thousands of scenes are provided in all X3D encodings. You can browse them individually online or download fully complete, separately installable .zip archives. Links to thousands of X3D example scenes are provided.

- https://www.web3d.org/x3d/content/examples/X3dResources.html#Examples
X3D Specifications: Schema and DOCTYPE Validation

• These assets are commonly used for XML validation of X3D scenes, including in-depth documentation.
• Work in progress: updated JSON Schema.
• https://www.web3d.org/specifications

Recommended Validation and Implementation Assets

• X3D XML Schema x3d-4.0.xsd and documentation (latest)
• XML DOCTYPE x3d-4.0.dtd and documentation (latest)
• x3d-schema-changelog.txt and x3d.dtd-changelog.txt
• X3D Node Inventory Comparison (.pdf) shows node-by-node implementation coverage of the X3D Abstract Specification: validation using X3D Schema, X3D DOCTYPE, and X3D Schematron; X3D Tooltips and VRML97 node sets; plus selected open-source implementations: FreeWrl, X3DOM, X_ITE, view3dscene (Castle Game Engine), X3D-Edit and Xj3D.
X3D Unified Object Model (X3DUOM)

- X3D Unified Object Model (X3DUOM) is a full set of object-oriented interfaces for all nodes, fields and statements in X3D4 Architecture.
- X3DUOM enables autogeneration of source code for multiple tools.
- https://www.web3d.org/specifications/X3DUOM.html
X3DJSAIL, X3D Java Scene Access Interface Library

- X3D Java Scene Access Interface Library (X3DJSAIL) supports programmers with standards-based X3D Java interfaces and objects, all as open source.
- [http://www.web3d.org/specifications/java/X3DJSAIL.html](http://www.web3d.org/specifications/java/X3DJSAIL.html)
X3DPSAIL, Python Package x3d.py

• The x3d.py Python X3D Package supports programmers with Python interfaces and objects for standards-based X3D programming, all as open source.

• [https://www.web3d.org/x3d/stylesheets/python/python.html](https://www.web3d.org/x3d/stylesheets/python/python.html) and [https://pypi.org/project/x3d](https://pypi.org/project/x3d)

"Pythonic is a word because Python programming is... different, in many excellent ways."
X3D to JSON Stylesheet Converter

• The X3D to JSON stylesheet converts .x3d XML to .json, supporting the forthcoming JSON Encoding for X3D Graphics.

  • [https://www.web3d.org/x3d/stylesheets/X3dToJson.html](https://www.web3d.org/x3d/stylesheets/X3dToJson.html)

<table>
<thead>
<tr>
<th>Nomenclature comparison: X3D, XML, JSON</th>
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<tbody>
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<td>X3D scene graph</td>
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<td>X3D nodes</td>
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<td>Embedded source code for</td>
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<tr>
<td>Script, ShaderPart and ShaderProgram</td>
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<tr>
<td>nodes</td>
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X3DJSONLD

• JavaScript open-source codebase for X3D by John Carlson
• X3D JSON Loader (X3DJSONLD) can load different encodings of X3D models into JavaScript Document Object Model (DOM), useful for HTML scripting. X3DJSONLD also implemented server-side X3D programming using node.js, Java and Python run-time environments.

• https://github.com/coderextreme/X3DJSONLD/blob/master/README.md
• https://github.com/coderextreme/X3DJSONLD/blob/master/doc/Beginner's%20X3D%20JSON.pdf
• https://github.com/coderextreme/X3DJSONLD/blob/master/doc/X3DJSONLoaderTutorial.pptx
X3D Ontology for Semantic Web

• The X3D Ontology for Semantic Web provides terms of reference for semantic query of X3D models.
• https://www.web3d.org/x3d/content/semantics
X3D® Registered Trademark

https://tmsearch.uspto.gov/bin/showfield?f=doc&state=4801:5y2iyq.3.10
Eye candy: USNA Annapolis Maryland

• Work by Versar and Virginia Tech composing many 3D models and scans

• README, video and Web3D tweet for SIGGRAPH 2021
3D Printing: SPIDERS3D Virtual Sand Table

- **SPIDERS3D Virtual Sand Table (VST)** enables hands-on group collaboration through vertical display and 3D printing of X3D models.
Acknowledgements

Collaboration with ISO/IEC SC24 participants and organizations continues to be very helpful in all WeB3D Consortium activities.

We gratefully thank technical contributors including Myeong Won Lee, Kwan Hee Yoo, Michalis Kamburelis, John Carlson, Anita Havele, Efi Lakka, Athanasios Malamos, Christophe Mouton, Vince Marchetti, Nicholas Polys, Joe D. Williams, and all others who have helped improve both the X3D and HAnim International Standards.

We gratefully applaud everyone publishing 3D graphics on the Web. Have fun with X3D! ☺️ ☺️
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