X3D-Edit Authoring Tool for Extensible 3D (X3D) Graphics

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Abstract. XML-based languages provide a wide variety of new capabilities for authoring, processing and validating graphics scenes. *X3D-Edit* is an authoring tool for Extensible 3D (X3D) Graphics scenes developed using IBM's *Xeena*, an XML-based tool-building application. XSLT stylesheets provide rapid translation of XML-based X3D scenes into VRML97 syntax or pretty-print HTML pages. Use by several dozen students and development of numerous examples has led to the development of context-sensitive tooltips and demonstrated good effectiveness overall. The use of XML both for scene design and tool construction provides numerous benefits, including improved author productivity and content stability.

1. **Purpose and Basic Usage**. X3D-Edit is a graphics file editor for Extensible 3D (X3D) that enables simple error-free editing, authoring and validation of X3D or VRML scene-graph files. Context-sensitive tooltips provide concise summaries of each VRML node and attribute. These tooltips simplify authoring and improve understanding for novice and expert users alike. Figure 1 shows the X3D-Edit interface for a typical "Hello World" example, shown in Figure 2 with spinning globe and animated text.

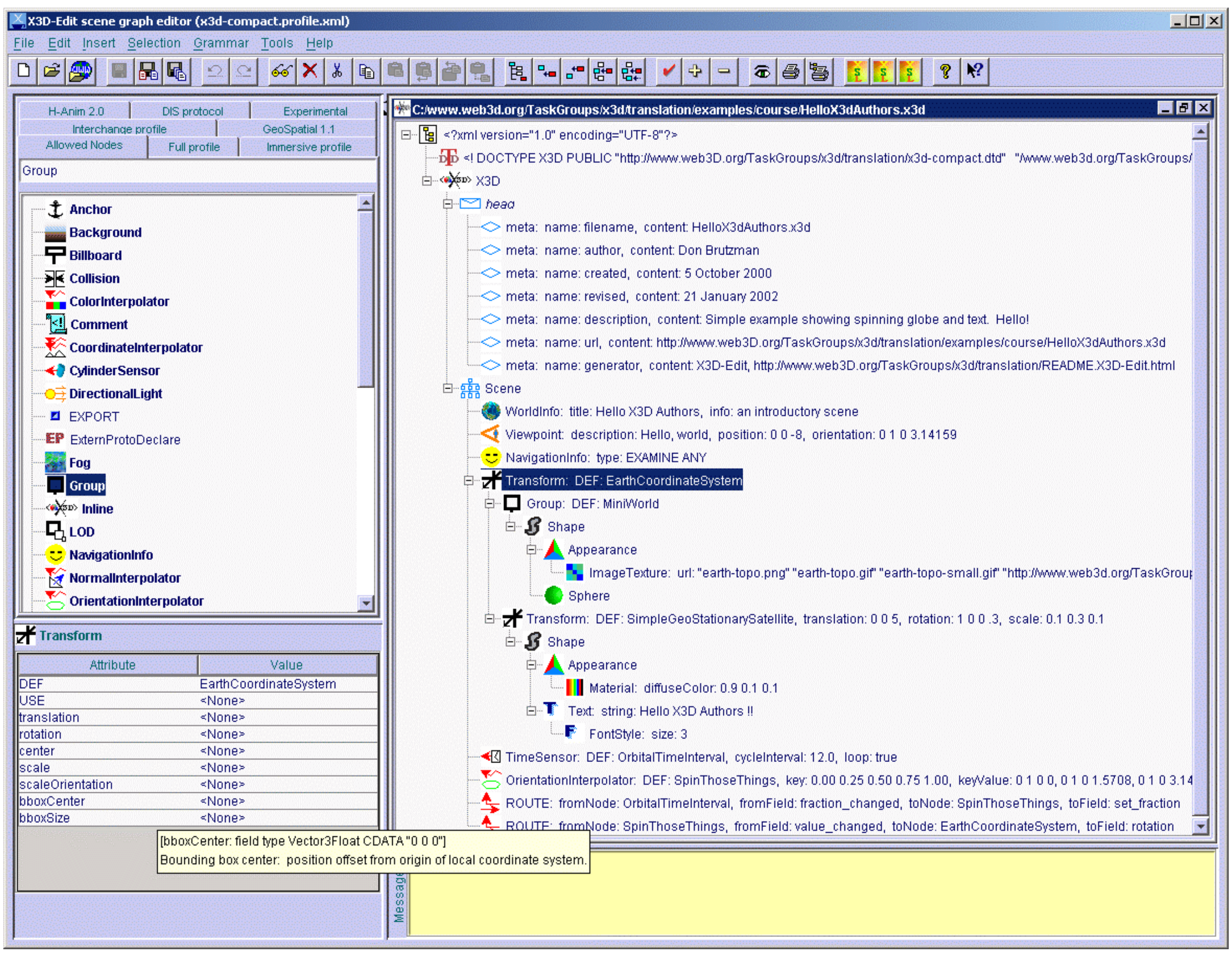

Figure 1. X3D-Edit screen layout for example scene, showing context-sensitive tooltip for bounding box center.

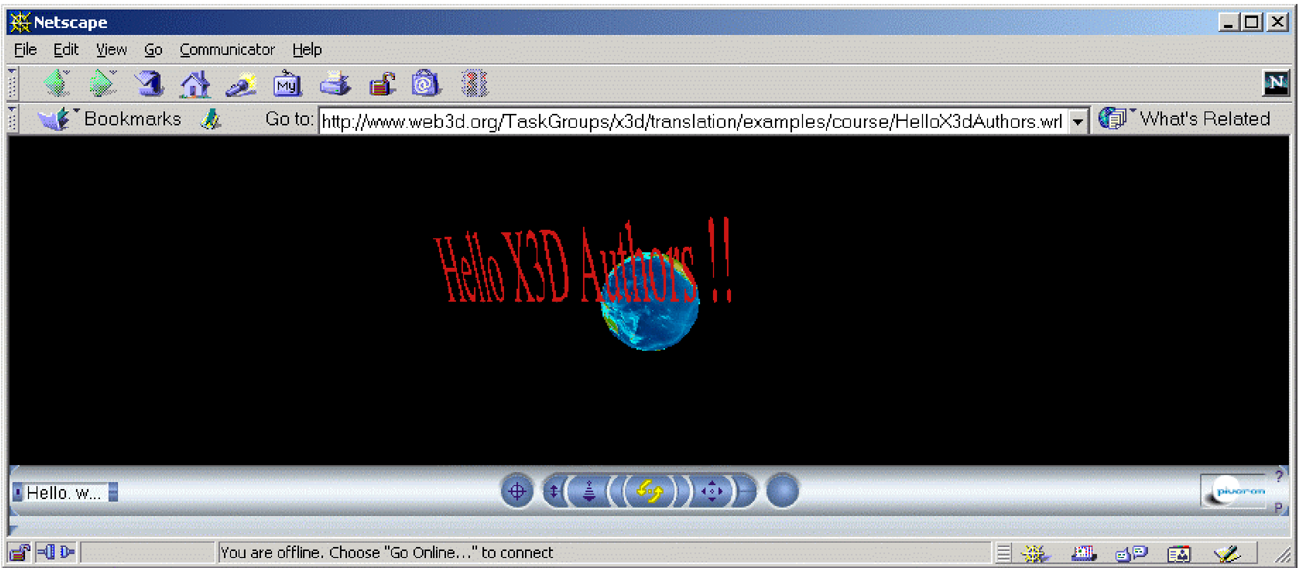

Figure 2. Animating text of an X3D "Hello World" scene, converted into VRML encoding and launched into a Web browser's standard VRML plugin.

2. **VRML/XML Quicklook**. X3D is a scene-graph architecture and encoding that improves on the Virtual Reality Modeling Language (VRML) international standard (VRML 97, ISO/IEC 14772-1:1997). X3D uses the Extensible Markup Language (XML) to express the geometry and behavior capabilities of VRML. Now entering its third generation, VRML is well known as a highly expressive 3D interchange format that is supported by large numbers of tools and APIs (Lansdale 2002). In addition to being able to express diverse geometry and animation behaviors, scripting (in Java or EcmaScript) and node prototyping provide excellent support for scene-graph extensions. Despite intermittent industry support, VRML has persisted and remains the most widely supported nonproprietary scene format.

The Extensible 3D (X3D) specification is an exciting new area of work, expressing the geometry and behavior capabilities of VRML using the Web-compatible tagsets of the Extensible Markup Language (XML). Scene graph, nodes and fields respectively correspond to document, elements and attributes in XML parlance. The X3D Task Group is designing and implementing the next-generation Extensible 3D graphics specification (www.web3D.org/x3d.html). XML benefits are numerous: customized metalanguages for structuring data, easily read by humans and computer systems, validatable data constraints, etc. XML is license-free, platform-independent and well-supported (Bos 2001). Together these qualities can ensure that the VRML ISO standard is extended to functionally match the emerging family of next-generation XML-based Web languages.

X3D attributes include far simpler validity checking of content, componentized browsers for faster downloads, flexible addition of new hardware extensions, a lightweight Core Profile, and better script integration. Numerous (over 2000) example scenes exercises most 3D and animation aspects of these scene-graph specifications, demonstrates syntax checking during autotranslation to VRML encodings, and provides a challenging conformance/performance site for demonstrating exemplar high-end content. Both VRML-based and XML-based syntax are valid ways to encode the information in an X3D scene.

3. **IBM's *Xeena* Tool Builder and X3D-Edit Design**. IBM's *Xeena* tool (IBM 2002) is an interface-building tool written in Java that uses designer-produced XML profile configuration files to create customized tree-based editors for arbitrary XML languages. This is a powerful approach that has enabled extensive development and testing of X3D's XML encoding, which corresponds to the functionality of the VRML encoding. Thanks to a Java implementation, the tool is reasonably platform independent with successful results reported under Windows, Macintosh and Linux.

Authoring-tool features available through *Xeena* configuration are numerous. Student authors consider the user interface (shown in Figure 1) intuitive and powerful. Design of actual functionality flows from the design of XML-encoding relationships for X3D itself. The primary determinant of node relationships is determined by the rules expressed in the X3D Document Type Definition (DTD), which is the classical method for defining XML tagsets. As a result, the tool always creates well-formed scene graphs, and new nodes only fit into the scene graph where allowed. Componentization rules allow subset validation for X3D scenes conforming with the VRML 97, Core and other profiles. Adding node-specific icon images further improves scene-graph authorability and author comprehension.

While modifying a tree view of the scene graph, authors can automatically translate each X3D scene into the VRML encoding and launch plugin-enabled Web browser to view results. A huge set of publicly available X3D scenes provides well-documented exemplars, including translated X3D versions of all examples in the *VRML 2.0 Sourcebook* (Ames 97). An independent NPS effort named Scenario Authoring and Visualization for Advanced Graphics Environment (SAVAGE) has utilized and tested most of these constructs. We have further seen significant improvements in our ability to teach the principles of 3D graphics, enabling students in any major to become effective authors with no prior programming experience. Our teaching experiences are documented further in papers on development of the Kelp Forest Exhibit (Brutzman 2002).

Node-selection panels provides full X3D-Edit support for numerous X3D extensions, including:

- Distributed Interactive Simulation (DIS) Profile nodes specified by the DIS-Java-VRML Working Group http://www.web3D.org/WorkingGroups/vrtp/dis-java-vrml
- GeoSpatial Profile nodes from GeoVRML 1.0 specification http://www.geovrml.org/1.0/doc
- (Currently draft) Humanoid Animation (H-Anim 2001) Specification and backwards-compatible support for H-Anim 1.1 profile (http://ece.uwaterloo.ca:80/~h-anim/spec1.1)
- Non Uniform Rational B-Splines (NURBS)
- LatticeXvl parametric surfaces (http://www.latticeXvl.com)

4. **Stylesheet Conversions**. The Extensible Stylesheet Language for Transformations (XSLT) is used for conversions from X3D form to various other encodings. For example, converting the original X3D source scene using stylesheet *X3dToVrm97l.xsl* produces the VRML scene shown in Figure 2. A similar stylesheet *X3dToHml.xsl* is used to convert source X3D scenes into pretty-print HTML output. This is a helpful capability to ensure that users can obtain color-coded documentation regardless of their system's XML-editing capability. The Xeena/X3D-Edit interface for HTML conversion appears in Figure 3. An excerpt HTML-styled output appears in Figure 4.

5. **Tooltips and Internationalization (I18n)**. A particularly powerful capability that derives from using Xeena is the availability of tooltips for each element and attribute. Tool tips provide authoring hints that pop up in context of use, helping authors learn and understand how VRML/X3D scene graphs really work. A typical tooltip consists of a few concise sentences describing purpose, allowed values, example use and caveats. Originally derived from the VRML 97 specification, the tooltips have been repeatedly refined based on student questions and recommendations. An example tooltip for the bboxCenter attribute of the Transform node is shown popped up in the lower right-hand quarter of Figure 1.

Tooltips are now a valuable resource in their own right. The English-language profile has been translated into French and German, enabling creation of X3D-Edit variants that edit syntactically identical scenes but provide customized tooltips in alternate languages. Tooltips are further available as standalone documents, organized by nodes and formatted for ready reference using a tooltip-generation stylesheet.

Multilingual tooltips are available as the following web pages.

- http://www.web3d.org/TaskGroups/x3d/translation/X3dTooltips.html
- http://www.web3d.org/TaskGroups/x3d/translation/X3dTooltipsFrench.html
- http://www.web3d.org/TaskGroups/x3d/translation/X3dTooltipsSpanish.html

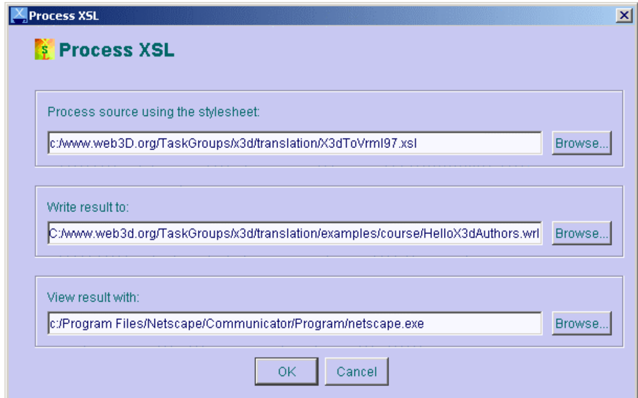

Figure 3. Stylesheet interface to invoke *X3dToVrml97.xsl*, converting X3D source scene to VRML encoding.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "http://www.web3D.org/TaskGroups/x3d/translation/x3d-compact.dtd"
             "/www.web3D.org/TaskGroups/x3d/translation/x3d-compact.dtd">
<X3D>
  <head>
      <meta name='filename' content='HelloX3dAuthors.x3d'/>
      <meta name='author' content='Don Brutzman'/>
      <meta name='created' content='5 October 2000'/>
      <meta name='revised' content='21 January 2002'/>
      <meta name='description' content='Simple example showing spinning globe and text. Hello!'/>
      <meta name='url' content='http://www.web3D.org/TaskGroups/x3d/translation/examples/course/HelloX3dAuthors.x3d'/>
      <meta name='generator' content='X3D-Edit, http://www.web3D.org/TaskGroups/x3d/translation/README.X3D-Edit.html'/>
  </head>
  <Scene>
    <WorldInfo title='Hello X3D Authors' info='an introductory scene' />
    <Viewpoint description='Hello, world' orientation='0 1 0 3.14159' position='0 0 -8'/>
    <NavigationInfo type='EXAMINE ANY'/>
    <Transform DEF='EarthCoordinateSystem'>
        <Group DEF='MiniWorld'>
            <Shape>
                <Appearance>
                    <ImageTexture url='"earth-topo.png" "earth-topo.gif" "earth-topo-small.gif"
                        "http://www.web3d.org/TaskGroups/x3d/translation/earth-topo.png"
                        "http://www.web3d.org/TaskGroups/x3d/translation/earth-topo.gif"'/>
                </Appearance>
                <Sphere/>
            </Shape>
        </Group>
        <Transform DEF='SimpleGeoStationarySatellite' rotation='1 0 0 0.3' scale='0.1 0.3 0.1' translation='0 0 5'>
            <Shape>
                <Appearance>
                    <Material diffuseColor='0.9 0.1 0.1'/>
                </Appearance>
                <Text string='Hello X3D Authors !!'>
                    <FontStyle size='3'/>
                </Text>
            </Shape>
        </Transform>
    </Transform>
    <TimeSensor DEF='OrbitalTimeInterval' cycleInterval='12.0' loop='true'/>
    <OrientationInterpolator DEF='SpinThoseThings' key='0.00 0.25 0.50 0.75 1.00'
        keyValue='0 1 0 0, 0 1 0 1.5708, 0 1 0 3.14159, 0 1 0 4.7123889, 0 1 0 6.2831852'/>
    <ROUTE fromNode='OrbitalTimeInterval' fromField='fraction_changed' toNode='SpinThoseThings' toField='set_fraction'/>
    <ROUTE fromNode='SpinThoseThings'     fromField='value_changed'    toNode='EarthCoordinateSystem' toField='rotation'/>
  </Scene>
</X3D>
```

Figure 4. HTML presentation of X3D source, produced from XML encoding by *X3dToVrml97.xsl* stylesheet.

6. **Construction of Example Archives**. The rapid page-generation capabilities of XSLT and the inclusion of document metadata via HTML-like "meta" tags are powerful capabilities. This combination enabled the development of archive-generation stylesheets.

Archive design for lots of content is accomplished as follows. First, file and directory names are carefully chosen to be concise, descriptive and without abbreviations. Camel-case capitalization is applied to the first letter of each word (e.g. *UniversalMediaPanoramas*). An XSLT stylesheet is then able to automatically build tables of contents, chapter contents and individual scene pages to present all content in an intuitive, cross-referenced fashion. An example scene page appears as Figure 5.

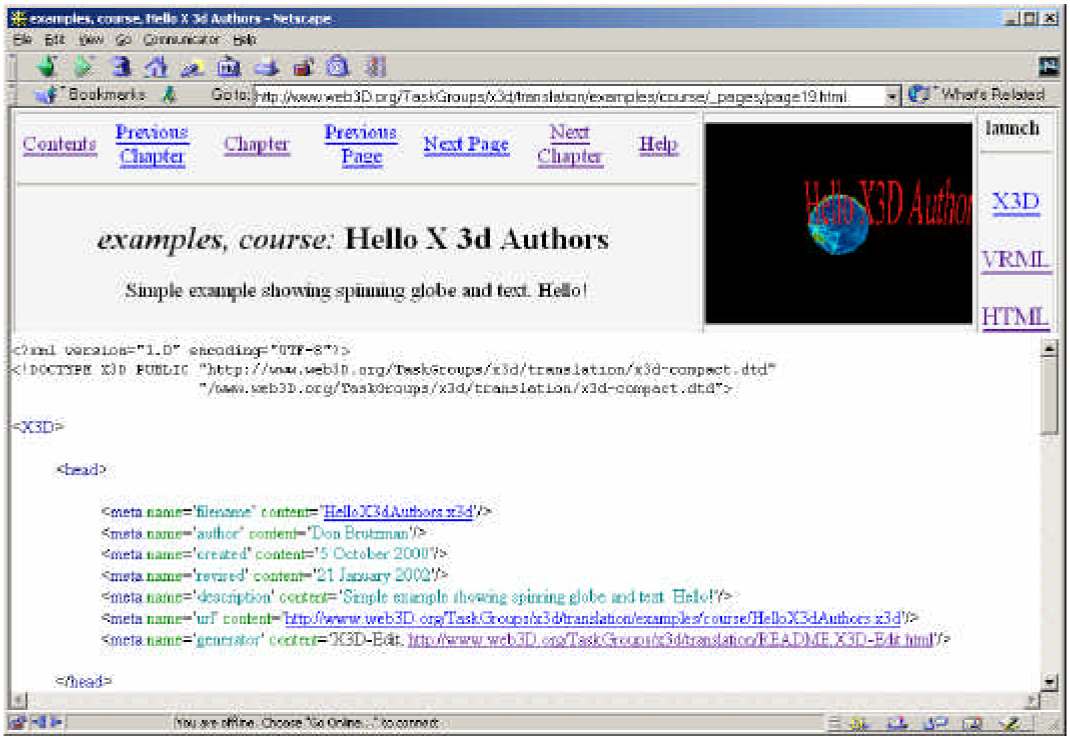

Figure 6. Catalog pages are rapidly autogenerated to account for large archives of example scenes.

Archives of example scenes are available as follows.

- **X3D Examples** are at http://www.web3D.org/TaskGroups/x3d/translation/examples/contents.html
- **X3D versions of VRML 2.0 Sourcebook examples** are at http://www.web3D.org/TaskGroups/x3d/translation/examples/Vrml2.0Sourcebook/contents.html
- **VRML/X3D Conformance Suite Examples** are at http://www.web3D.org/TaskGroups/x3d/translation/examples/Conformance/contents.html
- **NPS Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) library** is at http://web.nps.navy.mil/~brutzman/Savage/contents.html

7. **Conclusions and Future Work.** X3D-Edit is an effective authoring tool that has significantly improved our ability to author effective 3D scenes and teach the principles of 3D graphics to new students. The Extensible Markup Language (XML) provides significant capabilities for scene validation, effectively eliminating most of the "garbage in, garbage out" pathologies that might otherwise exist undetected in large content archives. Future work includes merging all node-relationship rules, complex types and multilingual tooltips into a single XML-based X3D Schema that will provide similarly strong functionality in any XML Schema-based editing tools.

8. **Acknowledgements.** The author and the Web3D Consortium gratefully acknowledge the support of IBM in licensing *Xeena* for unrestricted X3D development and use, and further thanks the IBM Haifa team for technical support. Tooltip translations were performed by Frederic Roussille of Ecole National des Ingenieurs de Tarbes (ENIT) France, and Guadalupe Muñoz Martín of Escuela Superior de CC. Experimentales y Tecnología, Universidad Rey Juan Carlos, Madrid España. Tooltip inputs were provided from dozens of hard-working NPS graduate students. All contributions are greatly appreciated.

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VRML 97 International Specification (ISO/IEC 14772-1), December 1997. Available at http://www.web3D.org/technicalinfo/specifications/vrml97/index.htm

Extensible 3D (X3D) Graphics, working group home page, http://www.web3D.org/x3d.html

World Wide Web Consortium (W3C), Internationalization (i18n) home page, http://www.w3.org/International

10. Biographical Information

Don Brutzman is a computer scientist and Associate Professor working at the Naval Postgraduate School. He holds a B.S.E.E. from the U.S. Naval Academy in 1978, qualified as engineer aboard nuclear submarines, and earned a Ph.D. in Computer Science from the NPS in 1994. He is a member in the Undersea Warfare Academic Group, the Modeling Virtual Environments & Simulation (MOVES) Institute, and the NPS Center for Autonomous Underwater Vehicle (AUV) Research. His research interests include underwater robotics, real-time 3D computer graphics, artificial intelligence and high-performance networking. He is a member of the Institute of Electrical and Electronic Engineers (IEEE), the Association for Computing Machinery (ACM) Special Interest Group on Graphics (SIGGRAPH) and the American Association for Artificial Intelligence (AAAI). He is a board member of non-profit Sea Lab Monterey Bay, which is designing and building a youth-oriented year-round residential science camp. He is a founding member of the non-profit Web3D Consortium Board of Directors and leads the Extensible 3D (X3D) Working Group for the VRML 200x Specification. He represents Web3D as the Advisory Committee Representative to the World Wide Web Consortium (W3C). His research work includes the development of underwater robot software, in combination with comprehensive virtual-world modeling of underwater hydrodynamics, sonar and robot hardware response. He organized and led the SIGGRAPH Online 2001 team, designing and developing a huge audio/video/Web/XML information architecture. As MOVES Technical Director for Networked Virtual Environments and 3D Visual Simulation, he currently directs the construction and integration of internetworked physically based models for large-scale virtual environments through development of X3D and the virtual reality transfer protocol (vrtp).