Augmented Reality Roadmap for X3D

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Abstract

Augmented Reality (AR) and Mixed Reality (MR) operate across many display devices, ranging from small hand-held mobile phones to laptops, desktop, and full-blown walk-around CAVE spaces. There is always a combination of both 2D imagery and 3D graphics, plus a mix of the real world and virtual worlds. Numerous innovative AR activities are ongoing by many researchers, companies and study groups. Coordination and collaboration between numerous developers and standards organizations is likely necessary for AR to eventually become a seamless part of the Web infrastructure.

Web3D Consortium's X3D standard is a mature standard with several implementations and many converters. Multiple implementations and extensions for AR have been demonstrated in X3D. These efforts have been successful because X3D integrates numerous proven technologies, providing a simple and coherent way for authors to create 3D models and VR applications. X3D's extensibility provides the ability to extend the standard with new profiles and components, allowing it to "play well" when moving from simple mobile applications to bigger models and spaces and integrate with the web environment of HTML, JavaScript, and DOM,

The future consumer demand for AR applications will go beyond the current use of geo-located points of interest. Web3D Consortium is working on new paradigms to develop standards that address the larger 2D plus 3D space for AR. Currently the Consortium is harmonizing proven capabilities into best practices for AR and 3D graphics, implementable by multiple X3D viewers, and usable by content authors. X3D, a reliable and viable standard, can save considerable time for developers looking to design new AR applications.

1. Motivation: Value of the X3D Standard for AR

Extensible 3D graphics[1] a royalty free and ISO certified open standard developed by the Web3D Consortium[2] that originated from VRML, and now encoded in XML, already has capabilities to support AR and MR applications. X3D is a mature standard it unites numerous proven technologies together, providing a simple and coherent pipeline for authors to create 3D models and VR applications (X3D Examples)[3]. (See X3D Use Cases)[4]

Because there are multiple implementations and extensions for AR that have already been demonstrated for X3D (See X3D-AR Examples)[5], it is clear that we can build an AR component for X3D. It will have lightweight capabilities suitable for mobile devices, plus additional compatible capabilities that work with larger 3D scenes and spaces. We will take advantage of X3D extensibility to define component levels and profiles that capture these palettes as easily expanded extensions.

Current AR efforts include proposing X3D components for AR/MR applications and a critical lightweight X3D profile suitable for mobile devices. Many people are especially interested in lightweight AR that they can use as part of GPS-aware mobile devices. It is sometimes tempting to think of a mobile device as simply a rotatable 2D display situated within the 3D real world. However, 2D displays by themselves can be limiting and oversimplified. The X3D group is thinking in terms of the larger 2D plus 3D space that many AR authors and users want.

2. X3D Strategy for AR

Several experimental AR nodes have been proposed and implemented for X3D by Web3D Consortium members. A comprehensive list of AR nodes is being considered by the X3D AR Working Group[6] and is formally written up as the Augmented Reality (AR) component for the X3D Specification. Establishing common implementations and examples to demonstrate successful interoperability for the specification is of primary importance.

Recent work in HTML/DOM, geolocation sensor, and palettes for interactive scenes has led to a proposal for a new lightweight (Mobile) Profile for X3D. X3D efforts include identification of critical lightweight components suitable for mobile devices and AR applications.

Numerous innovative AR activities are ongoing by many researchers, companies, and standards groups. As we achieve clarity on the larger strategy for AR, we plan to outreach and collaborate with these groups in establishing an integrated and interoperable AR standards stack. We look forward to further participation and collaboration by the AR community to achieve long-term success for AR content on the Web.

2.1. X3D Relation to Reality–Virtuality Continuum

The Reality–Virtuality Continuum is often used to describe the range of functionality involved. The goals for X3D capabilities are broad by extending AR functionality beyond geolocated points of interest.

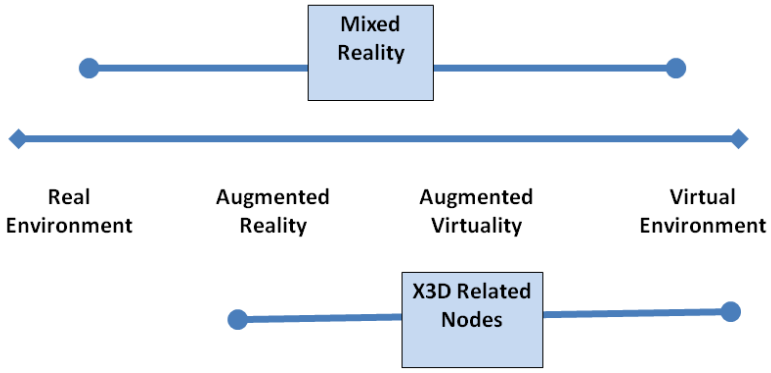

Figure 1: X3D - Reality–Virtuality Continuum[7]

2.2. Proposed AR/MR extensions for X3D

Many capabilities are possible and relevant for adding AR/MR functionality to Web-based 3D graphics. Today AR authors and users want a larger 2D plus 3D space that provide:

- High Quality Rendering
  - High Quality Real-time Rendering
  - Scalability from Smartphone to PC-Clusters
- Multimodal Interaction
  - Immersive Interaction e.g. Multi-Touch-Systems and Haptic Interaction
- Development of VR-Systems
  - Tiled Display HEyeWall 2.0 & Cave
  - Movable Screen
- Computer Vision Based Tracking
  - Markerless Tracking
  - Combination of CV & Inertial Sensors
  - Augmented Reality on Smartphones

The Web3D Consortium's AR WG is gathering requirements and typical use cases and proposing X3D components for AR/MR scenes and applications. The following list shows the functions and features under consideration for supporting AR and MR visualization in X3D:

- Adding real world view
  - Access to live video (e.g. local camera on the user's portable device)
    - Live video stream as a texture on geometry within the X3D scene
    - Live video stream as a background of the X3D scene
- Merging real and virtual images correctly
  - Access to calibration information of the camera device providing the video stream
  - Viewpoint nodes using calibration information to set projection parameters
  - Chroma keying of live video stream texture (rendering pixels in key color transparent)
- Correct occlusion between real and virtual objects
  - Depth masking with virtual representation of physical object
  - Support for depth image and depth imaging devices
- Tracking, registration and real-time interaction
  - Access to motion tracking information
  - Camera for registration between real and virtual spaces
  - Other physical objects for real-time interactivity

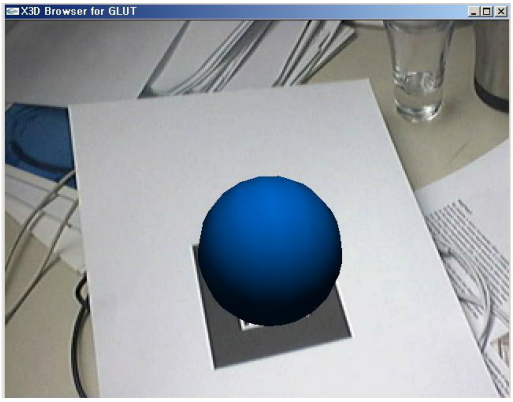


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Figure 2: Example of extending X3D to support AR[8]

The current challenge facing the X3D AR Working Group is deciding how to best merge these capabilities consistently with the X3D Specification and X3D best practices. The AR WG is currently reviewing number proposals on extending X3D to integrate, compose and deploy AR/MR functionalities.

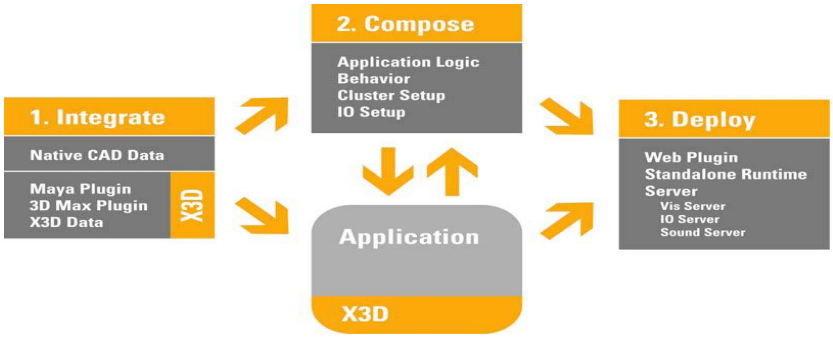

Figure 3: X3D AR Integration[9]

2.3. X3D Augmented Reality Applications

Web3D Consortium member are experimenting and implementing multiple AR/MR functionalities and applications using X3D engines. Fraunhofer IGD's instantReality, X3dom and mobileAR (instantMini) supports AR implementations from touch screen interaction to marker less tracking for 40 Device Handlers, 15 CV Trackers on Windows/Mac/Linux, iOS and Android platforms.

The X3dom AR application uses the Flash version of AR Toolkit (FLART). The InterAR Project uses X3D on C++ AR BS Contact Engine by Bitmanagement on mobile devices. Several AR/VR applications for anatomical education are developed using SenseGraphics's H3D. (See X3D AR Examples)

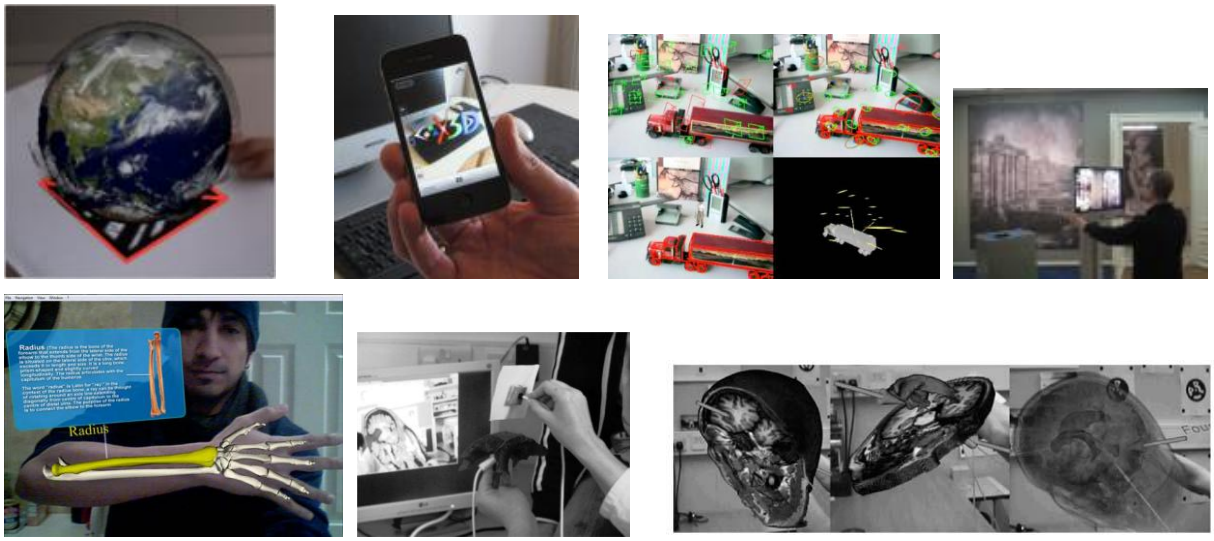

Figure 4: *X3D Applications showing their use in various AR and MR markets. The individual images show (left to right, top to bottom) (a) X3dom AR Earth, (b) Mobile AR application, (c) Markerless tracking for 3D reconstruction,* (d) iTACITUS Reality Filtering, *(e-f) AR for Anatomical Education. (Images courtesy of Fraunhofer, Bitmanagement, SenseGraphics, Bangor University and Virginia Tech)*

3. X3D is a viable and proven standard platform for implementing AR/MR

Multiple implementations and extensions for AR have already been demonstrated in X3D. X3D already has some of the AR components and now we are extending these capabilities. AR components will have lightweight capabilities suitable for mobile devices, plus additional compatible capabilities that work with larger 3D scenes and spaces. We will take advantage of X3D architecture, features and extensibility to define component levels and profiles that capture these palettes as easily expanded extensions.

3.1. Architecture and Features of X3D

X3D has been developed to meet a specific set of market and technical requirements. To meet these requirements, X3D adopts the following design objectives:

- Separate the runtime architecture from the data encoding
- Support a variety of encoding formats, including the Extensible Markup Language (XML)
- Add new graphical, behavioral and interactive objects
- Provide alternative application programmer interfaces (APIs) into the 3D scene
- Define subsets of the specification ("Profiles") that meet different market needs
- Allow for the specification to be implemented at varying levels of service
- Eliminate, where possible, unspecified or underspecified behaviors

X3D is a scenegraph (see X3D Architecture)[10] for interactive delivery of virtual environments which includes: Meshes, lights, materials, textures, shaders, integrated video, audio, Animation, Interaction, Scripts & Behaviors. Encodings include: XML, VRMLClassic and Compressed Binary. Application Programming Interfaces include: ECMAScript (JavaScript) and Java. X3D Version 3.3 includes examples for Volume rendering, CAD and Geospatial support.

3.2. X3D's layered Components and Profiles

The X in X3D stands for Extensible. X3D is highly modular in order to allow both authors and implementers to choose the palette of capability they might need for a given application area. This flexibility is a major virtue which lets the 3D content declare how much implementation support is needed. The X3D specification defines a rich set of 281 nodes[11], which are grouped in 35 components and 7 profiles. A "Components"[12] is typically a set of X3D nodes, which may be organized into levels. Each level is defined by a set of nodes. A "profiles"[13] consists of a collection of components and levels of each component. Components can be individually extended or modified or new components can be added to introduce new features, such as streaming.

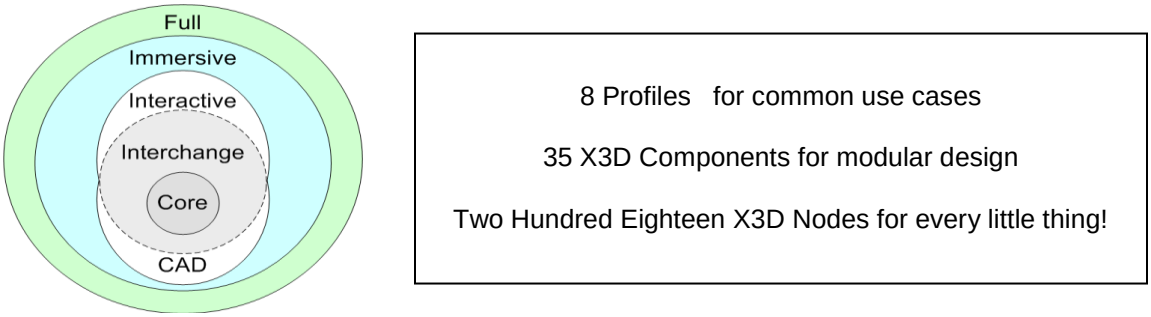

Figure 5: X3D Profiles, Components and Nodes [14]

For comparison purposes, 68 nodes are in the X3D Interactive profile which is lightweight and already runs on mobile devices. Approximately 10 new nodes are being considered for an AR component. This is an area of active work: minimizing software footprint while maximizing user capability. See Modular X3D[15].

The modular architecture of X3D allows increased functionality for immersive environments and enhanced interactivity or focused data interchange formats for applications within a small downloadable footprint.

3.3. X3D Lightweight/Mobile profile

A lightweight profile is valuable for author creation of simple but dramatic content. This approach allows a small-footprint and efficient operation of X3D on mobile devices, easy export from other formats, and a simple vocabulary for new authors. This Small footprint can be achieved by reducing the current geometric modeling, high-quality rendering, and lighting options. This extension, optimization, and refinement process can unlock carefully chosen X3D capabilities for important new areas:

- Mobile applications
- Lightweight HTML web pages
- Augmented Reality (AR)

Heavyweight advanced capabilities for mixed reality; CAVEs etc. are defined and kept separate from lightweight/Mobile profile but available in the other AR-related X3D components.

3.4. Integrating X3D into HTML (X3dom)

The traditional way to embed an X3D scene into a webpage uses a plug-in that needs to be installed by the user. The plug-in approach has always been an issue for web developers and users. Several efforts have been initiated by Web3D on how to integrate X3D with HTML. Our goal is to bring 3D to Web developers by fully integrating 3D content into HTML documents. Web3D and Fraunhofer[16] IGD's recent efforts – X3dom, integrating X3D with HTML and the DOM, have proven this capability. X3dom's design goals are to have a live X3D scene in your HTML DOM, allowing you to manipulate the 3D content by only adding, removing, or changing DOM elements. No specific plug-in or plug-in interface is needed. It also supports HTML events on 3D objects. X3dom uses three basic approaches to display an X3D scene inside an HTML page without a plug-in. (See X3dom Fallback model)[17].

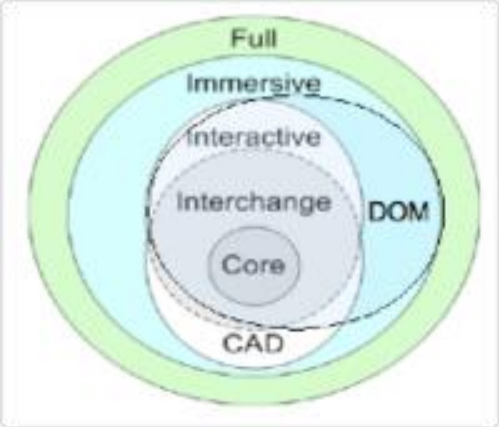

Figure 6: X3dom profile [18]

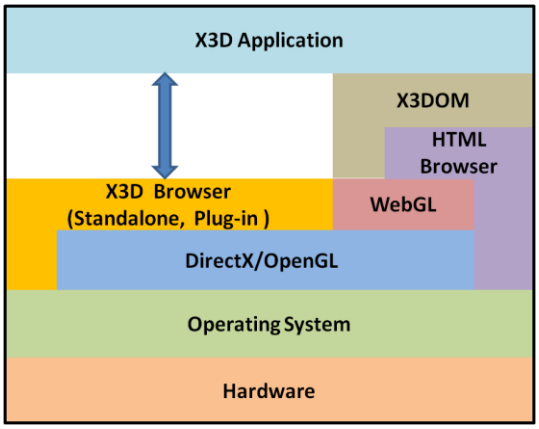

Figure 7: X3D Graphics Stack[19]

X3D is a step above Web3GL, OpenGL and DirectX in complexity, it is much easier to author. Our goal with X3D and X3dom is to bring 3D graphics to the widest possible audience: the Web.

The X3dom model (See X3dom Showcase)[20] provides an experimental environment to develop an integration model for declarative 3D in HTML and has triggered several discussions in the HTML and X3D communities, and is working to become a part of the HTML standard supported by every major browser.

X3D along with JavaScript and HTML can be a viable solution for a larger 2D plus 3D AR/MR experience.

4. X3D Adoption and Interoperability with other AR and Web Standards

X3D is a royalty free ISO standard. X3D has adoption (See X3D Adoption)[21] in many industries and markets with many implementations and converters. It brings together many proven technologies, providing a simple and coherent pipeline for authors to create 3D models and VR applications, without license fees or any danger that a company might drop support. (See X3D Examples)

For the past 10 years the Web3D Consortium has been extending its standardization activities through formal collaborative efforts with the ISO, OGC, DICOM and W3C standards organization. (See Web3D Collaborations)[22] Several discussions at the 2011 Web3D Conference, SIGGRAPH 2011, ISO-SC24 and OGC meeting about the recent developments in AR Standards continue to improve and refine our strategy on interoperability with other standards.

ISO Standards Committee (SC24) which administers X3D review as an International Standard has established a new Working Group for Augmented and Mixed Reality. The group proposes an AR content model as an extension of a virtual world with provisions for representing the physically-sensed objects. The ISO JTC1/SC24 report[23] by Dr. Gerry Kim summarizes the group's findings of the current state of the art in AR/MR and proposals on standardization AR/MR functionalities.

Recent discussions at OGC's ARML SWG meeting mainly focused on geo-located point of interest's AR applications targeted for mobile platforms. This work will eventually result in an AR standard built on KML, an OGC standard. Web3D and OGC have successfully worked together formally under a MOU agreement since 2006. Our common goal is to advance standards-based, interoperable web-enabled 3D geospatial content sharing, modeling and visualization. Our collaboration with OGC will continue to provide interoperability with OGC and X3D standards for AR capabilities.

The “Declarative 3D” W3C Community Group is working on integrating 3D with HTML and the DOM. Efforts include in-depth consideration of X3dom as one possible exemplar solution. The Declarative 3D effort has strategic importance for Web3D and indeed for all 3D graphics, especially since X3D is already a portable interchange format for a wide variety of models and technical approaches. We intend to establish a solid foundation for X3D to properly support 3D graphics for the native Web page, which definitely includes enhancements for AR capabilities and experiences. The group is developing a Declarative 3D AR use case for the W3C AR Community group.

In recent DICOM meetings, a specification roadmap has been developed to leverage the ISO X3D scenegraph. This delivers the highest-benefit, least-risk path for real time 3D visualization of medical images. A MedX3D Profile[24] will be specified in ISO 19775. This profile will include a base set of scenegraph functionality plus a number of components that target the specific needs of medical imaging presentation also used in anatomical AR/MR applications.

5. How to come to Fruition - Invitation to Participate

Much work has been accomplished already towards integrating AR capabilities in X3D.Current efforts are focused on harmonization of AR options, lightweight deployability, heavyweight consistency, and interoperability with AR and Web standards. As we achieve clarity on the larger strategy for AR, we plan to continue outreach and collaborate with all AR standards groups in establishing compatibility of X3D with other AR models. There is much work yet to be done to achieve synergy. Now is the time for serious AR developers to consider these essential challenges and get involved.

Web3D Consortium membership is open to companies, government agencies, educational institutions, and individuals. All X3D Specification capabilities can be implemented on a royalty free basis. We look forward to further participation and collaboration by the AR community to achieve long-term success for AR content on the Web.

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