# An Analysis of VRML-based 3D Interfaces for Online GISs: Current Limitations and Solutions

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## Abstract

The fast developments in the information technology reflects also on the GIS community and new opportunities give new challenges to the research and development groups. As a result of these developments, 3D data can already be processed efficiently and better methods are being explored increasingly. At the same time, the Internet has matured in many senses since it was first publicized and it is being actively used in the developed and developing world despite the fact that it has a number of disadvantages mainly regarding the data traffic. Regardless of its disadvantages, it can be said that WWW is the most popular and powerful networked information system to date. [1]

It is evident that a combination of the 3D graphics, geospatial data processing or GIS and internet is demanded at this stage of the technological development. More clearly, an Online 3D GIS is at demand. Yet there still are a number of limitations in existing technology and, to solve them, new approaches are being sought continuously. In this paper you will find a discussion of whether it is worth to try to utilize VRML/X3D as an interface for an online GIS system or not.

The discussion is based on a literature survey.

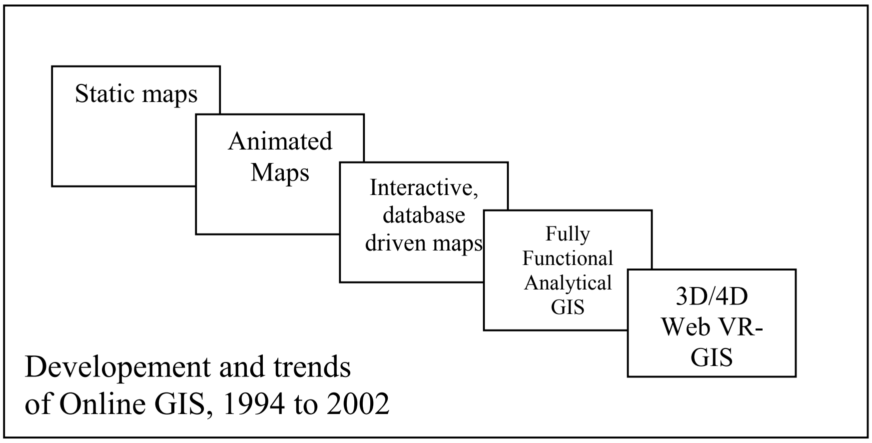
**Keywords:** 3D-interfaces, VRML, GIS, WWW

## 1. Introduction

### 1.1. Conceptual Development

Exchange of spatial data between remote interest groups was no less exciting than being able to exchange e-mails when it first came out. If possible, we would want to have a fully functional CAD (Computer Aided Design) software online, so we would not be limited to visualization. A smart, interactive, online map, even in 2D, makes life much easier for an end-user. More information (e.g. 3$^{rd}$ dimension) and more interactivity are required both by the end-users and spatial data professionals. (Coors et al., 1998, Huang et al., 2001)

The development from static maps to animations, then to interactive database-driven maps, and finally to a fully functional analytical GIS on the World Wide Web has been followed by the GI community over the past decades.




If the utopia of this development is a fully location independent Virtual Reality experience through some invisible electromagnetic signals someday, today a 4D online or mobile GIS on rather visible and limited fiber cables will also be a step forward.

Today, there are *developing* technologies to make internet applications as effective as possible, and VRML is one of them whose focus is on the 3D graphics. There indeed are not many widely accepted alternatives for publishing 3D vector graphics on the WWW. Tough some alternative approaches can do some of the things better than VRML, they also have disadvantages. To mention a few; Java3D [2], 3DML [3], PGML (Precision Graphics Markup Language), VML (Microsoft's vector graphics format), Flash vector graphics and some others are available. VRML, as an ISO standard too, seems to be the most popular format of all, according to many of the authors publishing research papers in 3D web graphics.

On the other hand, VRML browsers does not offer much interaction. Other than a few in-built interactive functions, it mainly stays in the domain of visualization. More interactivity is possible using CGI or Java scripts, HTML plus SQL combinations.

Online 2D GIS applications have been in use before VRML was known. All kinds of intelligent maps, which can tell the shortest path, or where a certain object (a building, a road, an office) is, were welcomed by public, and this was possible only with digital maps. Even further, a smart map which can tell you also *where you are* without you having to tell it to the map, was now possible with some GPS data given to the mobile device: e.g. a palmtop or a laptop computer (better if connected to the network via a wireless device like a mobile phone), or as the tests continue, the mobile phone itself. The mobile phones combined with GPS receivers started to come out. Most of them have a specially designed interface, mostly with a larger screen than the conventional mobile phones. These technologies are being developed right now, but almost all are tested using 2D graphic data.

As the real world is 3D (more precisely, 4D), to have the map/model of the objects in 3D will help the perception, interpretation and navigation. A support with a 2D bird's view can sometimes be important to percept the relative location of the focused object. The time dimension can sometimes be important too, to interpret and understand the presented data.

A multimedia environment provides new possibilities of linking diverse visual material and sound with maps *(Artimo (now Virrantaus), 1994),* and as a result of this, it is possible to talk about Virtual Reality. Yet VR has not got the smell, touch and taste included in the imitated world, although smell and touch are being explored in some scientific research. Current VR systems are, in essence, visual models, which includes motion and sound.

That visual model is a map of our environment – in scientific visualization it might be of a microscopic entity, scaled to be visible, if it is a model of your room, you can walk in it in real size, if it is the model of the solar system you can scale it down so you can see where their relative positions are and what happens if they move in certain directions over time.

This is exactly what traditional maps were doing, only today, it is possible to "fool" the perceptions of a healthy person as if s/he is really falling of a cliff and make her/him sea-sick, just by projecting the model in the right scale and presenting it in right speed. Of course, making people sea-sick is not the purpose, it is rather to help them use the map/model to gain more information about their environment.

At large the scientific community and the potential consumers have shown interest in multi-dimensional visualization, geospatial data, virtual reality and internet – all technologies are available and a merge of them using VRML/X3D might bring an easy-to-use, commonly accessible solution.

**1.2. Technological Developments**

Commercial GIS Software producers, almost all, have some tools for online services. In addition to those, there are many digital/multimedia maps online supported by some kind of database, and a number of non-commercial GIS software/applications can also be found on WWW.

Of the commercial GIS software producers, ESRI's ArcView with Internet Map Server, Aurodesk's MapGuide, MapInfo's MapXtreme, Caliper's Maptitude and Intergraph's GeoMedia might be mentioned as some of the more commonly known examples. In all these though, the provided spatial information is mostly in 2D.

A number of open-source initiatives, some non-profit, are also active as it can be seen in [4]. GRASS is probably the most complete one, and it has a GRASSLinks, which is being developed by a volunteering group as the rest of the GRASS after it was made public in 1995 [7].

Within this paper, by a further presentation of VR-GIS combinations, VRML-GIS combinations, limitations that internet brings, limitations that VRML or VRML browsers bring and how people are dealing with these limitations will be discussed. At the end, a small case is presented and some conclusions are drawn - open for discussion.

## 1.3. Standardization

For obvious reasons, standardization is a core issue in the internet. ISO, The International Standards Organization does publish standard formats for WWW as well as other areas.

Of the standard developers, two organizations are mentioned as key role players as relevant to GIS; Object Management Group (OMG) and GIS specific Open GIS Consortium (OGC). *(Green, D., Bossomaier D., 2002)*

OMG is a consortium of computer software vendors and other interested parties (800 members as reported at www.omg.org). CORBA (Common Object Request Broker Architecture) has emerged as a result of their work.

OpenGIS Consortium is a more GIS specific standard developer organization and is defined as follows by the consortium itself:

"OGC is an international industry consortium of more than 220 companies, government agencies and universities participating in a consensus process to develop publicly available geoprocessing specifications. Open interfaces and protocols defined by OpenGIS® Specifications support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT, and empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications." [5]

For platform-independency, a number of GIS developers seems to prefer Java-based solutions, but combinations of web technologies like CGI, SQL, CORBA, HTML are equally encountered.

VRML97, is an ISO standard that was suggested by The Web3D Consortium and X3D is being developed in the same path.

**Expectations**

From a technology researcher's point of view, using a commercial software that is not open source would be acceptable only for routine tasks, depending on the nature of the research, of course. A cross-platform (platform independent), standard and open source and light-weight approach is more suitable for research and for reaching all WWW users.

From a commercial point-of-view, the picture is of course different. Although the commercial organizations can benefit from open-source initiatives, they would not have non-profit investments. Combining this fact with the current marketing policies, it is best for them if they can keep their customers dependent on their own data format and/or platform.

From the user's point of view, it would be best if everything could be free, complete, quick and served door-to-door. Of course a technical support desk behind the released software is a comfort. 3D geospatial information, along with all kinds of information, should be telepathy-enabled please.

### 1.4. Bandwidth

The expectations are high, and different research development communities are working hard to fulfill them. But the reality is that there are many limitations to each component in our discussion. In simplified and informal language, in summary pros and cons are as follows:

WWW is great, but the bandwidth lord is not always so generous to everyone (which in fact has created the famous “world wide wait” joke). GIS is great, but it is too complex for WWW’s traffic limitations. VR is great, but it was not there, neither it was anticipated by GIS developers in the beginning, so it lives over add-ons which currently cannot cover the whole scope of GIS functions. And an online VR-GIS (of course in minimum three dimensions), is only scratching the surface of its potential.

#### 1.4.1 Client/Server approaches

The Web project was initiated to construct a distributed hypermedia system. The model consists of interconnected machines serving information to clients. The model has three key aspects, which are HyperText Transfer Protocol (HTTP), HyperText Markup Language (HTML) and Uniform Source Locator (URL).[1]

The basic WWW architecture, is based on the client/server model of distributed systems [8].

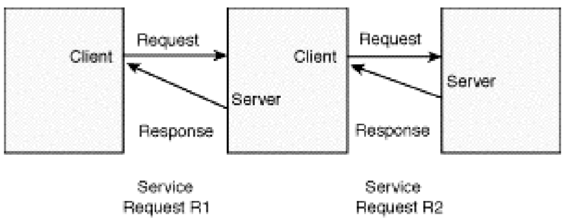



Figure: Taken from [8]. Shows the conceptual client/server architecture.

In the model, a *client* process makes a request to a *server* process, normally running on a different machine and using a network such as the Internet for communication. The server process receives the request, establishes a connection with the client, performs the desired function, returns the result to the client, and breaks the connection. [8]

In other words, this means that each transaction requires a new connection from client to server. This is one of the weak points of Internet. [1]

Client/Server approach is one of the three distributed computing models along with File Transfer Model and Peer-to-Peer Model. There is also a non-distributed model known as Terminal Host Model or Mainframe Model.

A number of other approaches are present and being developed to fill the gaps and/or make the transactions faster, such as thin and thick clients.

Java, for example, employing a thin client technique, makes the browser load a dedicated program (Applet) which then performs the actual tasks (in case of a database, using JDBC, an acronym for Java Database Connectivity). Java has become popular within the web-programmers community, basically because it is seen as platform independent along with some other attractive attributes. It also gets a share of criticism that it is not for very large applications and it bears some security risks.

Another approach is to use external viewers/plug-ins – as thick clients do. This is what VRML does. It asks the user download a VRML browser. The main advantage of this method appears to be the transaction management, because, using a dedicated viewer fully satisfies transaction management and concurrency control. It also allows a simple structure.

The biggest disadvantage to this approach is that it lacks integration of a database with WWW. It also is in a way platform-specific, because it is dependent on the browser. In case of VRML, the disadvantages are being dealt with by several active working groups and several on-going projects which are going to be introduced in the following section.

## 2. 3D GIS

### 2.1 Vector Data

The spatial data that was possible to access on WWW was, once, only raster. The vector data came later. The 3D vector data on the internet, seems to be mentioned in literature with the start of VRML.

### 2.2. VRML/X3D

In 1994, Tim Berners-Lee invited Mark Pesce to present a paper at the First International Conference on the World Wide Web. Pesce and partner Tony Parisi had developed Labyrinth, a prototype three-dimensional interface to the Web. His presentation sparked a consensus: the conference attendees agreed there was a need for a common language to specify 3D scene descriptions. [9]

Work on the VRML specification began immediately following the WWW Conference. Brian Behlendorf set up an electronic mailing list to facilitate discussion of the specification for VRML. Within a month, there were over a thousand members. The list membership quickly agreed upon a set of requirements for VRML: platform independence; extensibility; and the ability to work over low-bandwidth (14.4 kBps modem) connections. [9]

Soon after that there was VRML 1.0, and in 1996 VRML 2.0 emerged. In 1997, as mentioned earlier, this became an international standard (ISO) and was called VRML97. At the time of this writing, it is waiting to become as a new standard with the name X3D, there will be new features which makes the language more extensible.

### 2.2.1 Virtual Reality Modeling Language

Following three paragraphs are taken from VRML97 specifications:

"The Virtual Reality Modeling Language (VRML) is a file format for describing interactive 3D objects and worlds. VRML is designed to be used on the Internet, intranets, and local client systems. VRML is also intended to be a universal interchange format for integrated 3D graphics and multimedia. VRML may be used in a variety of application areas such as engineering and scientific visualization, multimedia presentations, entertainment and educational titles, web pages, and shared virtual worlds.

VRML has been designed to fulfill the following requirements:

> *Authorability* Enable the development of computer programs capable of creating, editing, and maintaining VRML files, as well as automatic translation programs for converting other commonly used 3D file formats into VRML files.
>
> *Composability* Provide the ability to use and combine dynamic 3D objects within a VRML world and thus allow re-usability.
>
> *Extensibility* Provide the ability to add new object types not explicitly defined in VRML.
>
> *Be capable of implementation* Capable of implementation on a wide range of systems.
>
> *Performance* Emphasize scalable, interactive performance on a wide variety of computing platforms.
>
> *Scalability* Enable arbitrarily large dynamic 3D worlds.

VRML is capable of representing static and animated dynamic 3D and multimedia objects with hyperlinks to other media such as text, sounds, movies, and images. VRML browsers, as well as Authoring tools for the creation of VRML files, are widely available for many different platforms." (*[10], The VRML Consortium Incorporated 1997)*

VRML allows for a flexible definition of 3D worlds and objects. Apart from 3D geometric models, a VRML world can contain (scripted) programming. Programming in VRML can either be done through the use of 'Script'-nodes or by using the so called External Authoring Interface, in both cases the programming model of VRML is event based. *([10], The VRML Consortium Incorporated 1997, Ballegooij et al., 2001)*

VRML has for years been the language of choice to bring objects to the web. It contains of 54 nodes and is purely polygon based. *(Wolters, 2002)*

The language, has the potential to describe the behavior of objects, provide links to other documents on the Web, represent interrelations that can be used to retrieve and visualize 3D spatial information and thus serve as an interface to 3D GIS. *(Zlatanova, 1999)*

***What is X3D?:*** As the X3D times are soon, a brief description should be added in this section. Adopted from *Wolters*, *2002*. X3D is, XMLized VRML; it has layered architecture: core consists of 18 nodes (no audio support) and it is an expanded set of full VRML nodes (level2 extensions with more advanced functionality).

### 2.2.1.1. A VRML sample

```
#VRML V2.0 utf8

# by Arzu Coltekin, 2002
# This is a model of Photogrammetry Lab 3rd floor, Helsinki Univ. of Tech.

DEF camera_1 Transform {
  children [
    Transform {
      translation -800 -200 5190.58
      rotation 0 -1 0 -3.14159
        children [ Viewpoint {
          position 0.0 0.0 0.0
          orientation 0  1 0 3.14159
          fieldOfView 0.785398
        } ]
    }
  ]
}
DEF closer_look Transform {
  children [
    Transform {
      translation -900 200 3500
      rotation 0 -1 0 -3.14159
        children [ Viewpoint {
          position 0.0 0.0 0.0
          orientation 0  1 0 3.14159
          fieldOfView 0.785398
        } ]
```

**Figure**: A Sample VRML Code. All VRML97 files will start with the highlighted (first) line shown in the above picture. This is an ASCII text, which means it can be edited on any text editor. It is not compiled, but interpreted.

Within the existing 54 nodes of VRML, a lot can be done for visualization. For more precision requirements, GeoVRML working group (of W3C) has published GeoVRML1.0 as an extension to VRML. GeoVRML has additional nodes: *GeoCoordinat, GeoElevationGrid, GeoLocation, GeoLOD, GeoPositionInterpolator.* For descriptions of these see *Reddy et al. 2001*.


**Figure:** This model was created using photogrammetric reverse engineering techniques utilizing the libraries of a CAD software. See *Çöltekin et al, 2000* for the details of model creation phase. Later it was edited into VRML and some functions were added. Using this model as an interface, it is possible to get more information about the surroundings.

## 3. GIS Interfaces

As GIS traditionally handles very complex datasets and operations, the interface design is a hard task. Most GIS software has a CAD background and as it is highly graphic, a GIS interface has always been a GUI (Graphical User Interface) and 3D online GIS requires a special GUI.

On the Web, achieving high interaction between the client and the server is painful. This problem can be approached by the development applications based on Java, plug-in, activeX technologies, although only Java offers full compatibility between different hardware platforms. What remains is the development of user friendly, yet powerful interfaces. While several GIS vendors propose good tools for visualization, the query part of the interface is mainly limited either to a set of menus, or to a text window where the user types in queries in a formal language. Neither of these solutions is acceptable: formal languages are far too difficult for non-specialists, while menu-based interfaces do not fully exploit all the information sources. *[Szmurlo et al., 1998]*

Several researches suggest solutions to the addressed problems and using VRML as an interface is one of the attractive solutions because of the popularity –therefore accesibility- and extensibility of VRML/X3D.

### 3.1. VRML as an interface

There are several proposals of using cave- or head mounted display(HMD)-based VR as an interface for GIS systems, but as the cave environment, or the HMD devices are not accessible to everyone and that they are very expensive, its public version –for obvious reasons- was going to be VRML. [See Raper et al., 1993, Rhyne 1997, Kraak et al.,1999, Kim et al., 1999, Chou et al, 2000]

One of the basic features in VRML is to allow a hyperlink (called “anchor”) to another object or to an HTML page from an object in the scene. As adding text or multimedia is also integral to VRML, it is easy to tell user which objects carry links to further information, either by sound or by text. This feature than can lead the user to a CGI script and allow her to make queries from a database that is in the server (or in connection with the server). This would be a simple and fast, but also, for most purposes, insufficient solution.

Several researchers suggested new nodes to VRML (Coors et al., 1998), and many others have employed Java based solutions for more complex tasks, though keeping the VRML as main graphical interface. Some others have used CGI for database connectivity, or CORBA as a middleware in combination with Java. [See Germs et al., 1999, Coors at al. 1998, Huang et al. 1999, Huang et al, 2001, Acevedo et al. 2001, Zlatanova et al.1998]

## 4. Conclusions and Future Work

Going into the terrain and walking around, pointing at an object around you and getting the precise information you are looking for, meantime, physically you are sitting on a chair: a scene from a science fiction movie. Well, that much can be provided. One can even meet a family member in a virtual room, that seems to be technologically possible, given that both sides have proper technical setting, but that is not quite the same in terms of “feeling the presence” of another person in the room.

However, the first part might be provided in a desktop version, less “feeling” of reality, but nonetheless virtual reality it is. Given that we just carried a well functioning GIS system and placed it behind a VRML interface.

The data traffic problem will always be there, but as the streaming (incremental downloading), *vrtp* (Virtual Reality Transfer Protocol) and AOIM (Are of Interest Management, (see *Wathen et al., 2002*) are active, there is hope.

Another promising development is the open-source Blaxxun VRML browser [11]. More open source browsers might mean more possibilities for the programmers to build functions from within the browser.

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