VIRTUAL REALITY AS AN INTERFACE TO GIS: FOCUS ON WWW

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ABSTRACT

Geographic Information Systems (GIS) traditionally handle very complex datasets and operations; therefore the interface design is a hard task. Most GIS software has a CAD background and as they are highly graphic; a GIS interface has always been a Graphical User Interface (GUI) and 3D online GIS requires a special GUI.

"Virtual Reality "(VR) is an environment where the human perception of a simulated environment is as close to the perception of the real world as possible. There are significant developments, but it is a new technology and will need to evolve much more before it can claim to satisfy the human perception fully. In any case, the nature of today's VR practice creates a natural desire to make this environment more giving than the natural, by adding more information, because it is possible. To use the VR as an interface to a rich database (as in GIS) is one obvious outcome of this thinking.

There are several proposals and test implementations of using cave- or Head Mounted Display (HMD)-based VR as an interface for GIS systems. The cave environment and the HMD devices have their limitations though, they are not accessible to everyone (they are still very expensive). The public version of VR, however much the quality of the experience goes down, can be seen as the Virtual Reality Modeling Language (VRML) models. This is for obvious reasons; like the powerful communication environment it lives in, WWW, and that it does not require any special devices for a simplified VR experience (1)(2)(3)(4)(5)

In this paper, we will present a review of the current literature on VR and GIS combinations and an implementation of a VRML/X3D model with some interactive features to present the potential use of VRML as a 3D GIS interface.

Note: This is a modified version of another paper published by the same author in the Journal of Surveying Science in Finland (30).

1. INTRODUCTION

When you look at the title of this paper, you meet three concepts mentioned: Virtual Reality, GIS and WWW. "Interface" can also be seen as a concept, but differently from the first three, this one cannot exist as a stand-alone application. We will, in any case, try to give a definition of each of these 4 terms, and then show what is the intersection between the four to come together in one sentence.

1.1 Definitions and Relationships

1.1.1 Virtual Reality (VR)

A technology that began in military and university laboratories more than 20 years ago, may be called Artificial Reality, Cyberspace, or Synthetic Reality. VR is a computer-created sensory experience that allows a participant to believe and barely distinguish a "virtual" experience from a real one. VR uses computer graphics, sounds, and images to reproduce electronic versions of real-life situations (6).

Virtual reality is the simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height, and depth and that may additionally provide an interactive experience visually in full real-time motion with sound and possibly with tactile and other forms of feedback.

The simplest form of virtual reality is a 3-D model that can be explored interactively at a personal computer, usually by manipulating keys or the mouse so that the content of the image moves in some direction or zooms in or out.

Virtual reality can be divided into:

- The simulation of real environments such as the interior of a building or a spaceship often with the purpose of training or education
- The development of an imagined environment, typically for a game or educational adventure

Popular products for creating virtual reality effects on personal computers include Bryce, Extreme 3D, Ray Dream Studio, trueSpace, 3D Studio MAX, and Visual Reality. The Virtual Reality Modeling Language (VRML) allows the creator to specify images and the rules for their display and interaction using textual language statements (7).

1.1.2 Geographic Information System *(GIS)*
A GIS enables you to envision the geographic aspects of a body of data. Basically, it lets you query or analyze a database and receive the results in the form of some kind of map, or retrieves the information from the database when an object is selected on a map/model. Since many kinds of data have important geographic aspects, a GIS can have many uses: weather forecasting, sales analysis, population forecasting, and land use planning, to name a few (8).

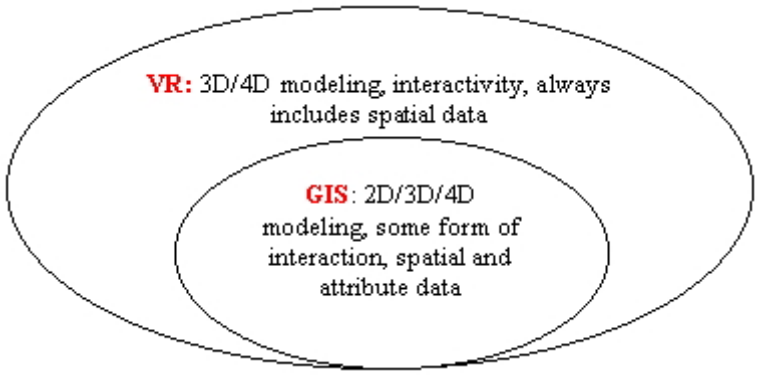

Figure 1. VR, in some way, is closely related to GIS. *It will always include spatial data*, and you can interact with the objects. In GIS, typically the dataset is closer to traditional "maps", but still it is about a form of interaction with the objects within the dataset. If one thinks of VR as some form of extended GIS, the query or analysis results could be returned to the user as a feedback (motion, sound, force, smell – nothing with the taste so far) from the object in the environment, as well as in a text-box or a menu-driven set of results.

1.1.3 World-Wide-Web (WWW)
The World-Wide-Web, also abbreviated as W3, The Web) An Internet client-server hypertext distributed information retrieval system which originated from the CERN High-Energy Physics laboratories in Geneva, Switzerland (9).

1.2 Interface
As a noun, an interface is either:

- A user interface, consisting of the set of dials, knobs, operating system commands, graphical display formats, and other devices provided by a computer or a program to allow the user to communicate and use the computer or program. A graphical user interface (GUI) provides its user a more or less "picture-oriented" way to interact with technology. A GUI is usually a more satisfying or user-friendly interface to a computer system.
- A programming interface, consisting of the set of statements, functions, options, and other ways of expressing program instructions and data provided by a program or language for a programmer to use.
- The physical and logical arrangement supporting the attachment of any device to a connector or to another device.

As a verb, to interface means to communicate with another person or object. With hardware equipment, to interface means making an appropriate physical connection so that two pieces of equipment can communicate or work together effectively.

1.3 All terms in one
At this point we can look back at the title of this paper and ask how the relationship between all these terms can be established. Now we have all the definitions.

GIS, typically deals with geographic data. VR deals with any kind of data. In GIS, typically the queries and analysis will result into either text-like results, or as 2 or 3D graphics, sometimes animations, if time is included as a dimension. In VR, the queries are typically of a different nature, input through interaction (e.g. touch the light switch) and output as feedback (e.g. the room lights up).

In a VR environment the input can be just like in a CAD environment too, but, additionally, it allows other perceptually driven methods. The input and the output both are directed to human motion and senses. The movements of human body (head, eyes, arms, hands, torso etc) can be tracked and the scene is re-drawn based on the changing orientation of the human. Visual, audio and haptic (seeing, hearing, touch-feeling) have been explored and the early results are proven

to have a powerful effect on people: a very promising human-computer interaction environment. Of the remaining two external human senses, the smell is being studied (though yet with small success) but the taste seems to be left out of the research so far.

In using the VR environment as an interface to GIS, we also imagine an endless new ways of communication with the database in hand. The thought becomes rather obvious, and has been considered by many in the field until now.

1.4 Why WWW

The reason we include the WWW in the picture, is the obvious effect of it in human communication. If the VE (Virtual Environment) is in a cave, or uses HMD, the possibilities with tracking and adding other more powerful effects are advantageous. But to create a community larger than a handful of privileged researchers would bring in more and faster development, plus the results reach to many, many more people. Of course it limits the actual VR experience, but nevertheless it is a VR experience, at least a visual one, and responds to mouse and keyboard inputs.

2. CURRENT TRENDS

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. Some of the alternative approaches can do some of the things better than VRML, but they have disadvantages too. To mention a few, Java3D (11), 3DML (12), 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 do 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, Java as an EAI (External Authoring Interface), HTML plus SQL combinations.

Online 2D GIS applications have been in use before VRML was known. All kinds of intelligent maps, which could tell the shortest path, or the location of a certain object (a building, a road, an office) were welcomed by public. 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.

2.1 GIS on the Web

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 (13). 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 (14). There is also a research platform, which is called OpenGIS Consortium, and it 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." (15)

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.

2.2 Traffic on the Internet

A cross-platform (platform independent), standard and open source and light weight environment, as an interface is desirable for reaching all WWW users.

WWW is a wonderful medium, but the insufficient-bandwidth is still a big obstacle (which in fact has created the famous "world wide wait" joke). GIS is a powerful tool, but it is too complex for WWW's traffic limitations. VRML is

exciting, but it lives over add-ons, which currently cannot cover the whole scope of GIS functions. An online VR-GIS is only scratching the surface of its potential.

The basic WWW architecture (which is the client/server approach), 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 (16). This means that each transaction requires a new connection from client to server. This is one of the weak points of Internet. (17)

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. Java, for example, 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. 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, several active working groups and several on-going projects, which are going to be introduced in the following section, are fighting the disadvantages.

2.3 3D Vector Data on the Internet

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.

2.3.1 VRML/X3D

Following two paragraphs are taken from VRML97 specifications (18):

“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 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.”

2.4 What is X3D

Adopted from (19). 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).

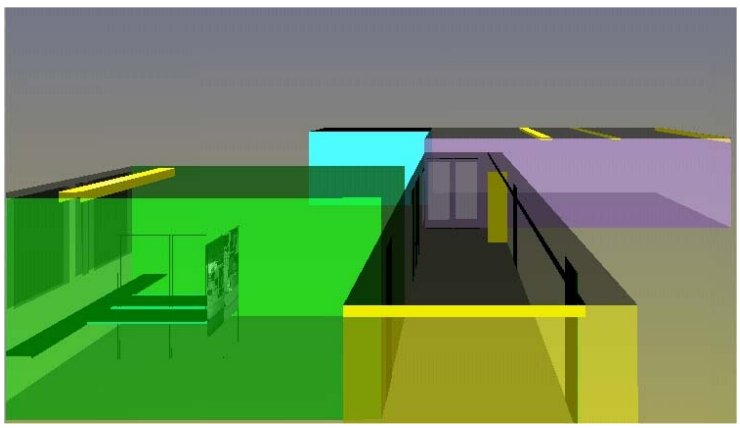

Figure 2. Model creation using reverse engineering techniques

The model shown in Figure 2 above was created using photogrammetric reverse engineering techniques utilizing the libraries of CAD software. See (21) for the details of model creation phase. Later it was edited into VRML and some interactive features were added.

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 (20).

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).

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. Remains the development of user friendly and 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 (22).

Several researchers suggest solutions to the addressed problems and using VRML as an interface is one of the attractive solutions because of the popularity and extensibility of VRML.

3.1 VRML as an interface

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 (23), 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 (23)(24)(25)(26)(27)(28).

4. CONCLUSIONS

Providing a heavy set of data on the network with complex calculations is a difficult task. The network computers, and the connection speed -especially if the ambition is to use the Internet- is often unpredictable. There are a lot of good reasons to try to this on an environment like WWW, but setting the standards to the lowest bandwidth and lowest CPU/memory combinations also bring around many problems to deal with.

A fast, accurate and efficient visualization with interactive features is the first step. As the non-networked virtual environments continue developing, remaining features will follow with innovations for the Internet too. Current techniques provide us with a VR experience, like the VRML language and its interactive features. An accessible, simple 3D interface for a complex GIS database is already possible, though with numerous development needs.

The data traffic problem will always be there, but a number of approaches to solve this problem also exist: the streaming (incremental downloading), *vrtp* (Virtual Reality Transfer Protocol) and AOIM (Are of Interest Management), (see 29).

5. ACKNOWLEDGEMENTS

This research is partly supported by Finnish Cultural Foundation.

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