Earth's Avatar – the Web Augmented Virtual Earth

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Introduction

Young Alice deftly flies down Yarra valley tagging key sites and information nodes for her field trip report. She pauses for a moment as a TV picture window pops up, triggered by in-picture keywords and watches her favorite soap idol in a crucial relationship scene. With the onset of 3D technology, dreams of a Virtual Earth (VE) with rich media experience have fired imaginations already primed by science fiction writers. Not long after Web3D developed, people excited by the idea of 3D models online, created virtual cities, models of their house or local area and even the whole Earth. In 1998, Vice President Al Gore described a vision of a Digital Earth (DE) where the virtual world would be online for the good of mankind.

We survey VE and related projects including the earlier DE initiatives. The main focus will be on open, high interoperability systems with virtual (3D + some form of immersion) representation. However, on the latter aspect much of the digital representation of Earth has concentrated on traditional two-dimensional visualisation. Since traditional 2D systems dominate we include those that we consider key open systems and especially those with wide industry support. Apart from the fact they both use geographical information, the traditional systems and any future VE system will likely share common GIS standards and web services frameworks. Therefore these two types of systems will be closely related in terms of geographic, communications and services components.

We find that work VE-like systems began strongly with the DE initiative and then subsided after about 4 years. At that time there was a reduction in the level of political support and funding plus large changes in relevant organizational structures. Some VE work continued in various guises but most effort since that time has gone into the more traditional 2D geographical systems. We provide an up-to date snapshot of VE and related traditional GIS projects, technology and standards with a bit of a look into the future.

The purpose of this survey is to provide the background information to guide our choices for standards and technologies to build an open source Web Augmented Virtual Earth (WAVE) platform.

Science Fiction

No survey of this nature could overlook the science fiction that has spurred the imaginations of so many who labor in the field of VR. The writings of Neal Stephenson, William Gibson and William Shatner (to name a few) created a small ripple at first but this quickly spread into a vast and varied cyber culture. Neuromancer, Snow Crash, Teklab and Virtual Light, for example, all create a vision of people who live part in the physical world and part in a digital virtual world – not always one of pure fantasy but often a kind of extension of the world they live in. It is this extension, or augmented double of the planet that will be the focus of our work on WAVE. Gelernter's Mirror Worlds [Gelernter 1993] is possibly the most closely aligned concept to our augmented Earth vision. However, first we must review the past evolution of VE initiatives.

Evolution of Virtual Earth Initiatives

Isolated "worlds", produced in isolation

VRML Cities and models of houses have been put online for many years now and this continues to happen. San Francisco and a number of other cities were put online by Planet 9 studios. Unfortunately nearly all these models are not accessible now (because they are in the older vrml1.0 format or because the links are broken). One of their models for Sydney is still available at [2]. The images and models are very basic and a better one is being built by Ping (see [3]). At some stage such models became known of a "worlds" – a harkening to the immersive characteristics of 3D models that the user freely navigates within. In fact, the most significant technology for 3D immersive content on the web was the Virtual Reality Modeling Language (VRML) which used files with a ".wrl" extension (wrl for "world"). VRML gained broad and intensive interest and although the interest and hype has died down it is still in fairly wide use amongst applications that provide 3D content on the web.

The Irish Space project, an Irish Museum VR piece by volunteers, created models of the whole planetary system as an educational experience for children.

During this time the Rez project [1] also created simple, whole-Earth models in VRML and GeoVRML, putting them online over the last 4 years. The Rez project is an ongoing web3D multiresolution geographic modeling project.

More extensive models and Digital Earth work

Mark Pesche, one of the founders of VRML, created a model of the whole Earth with weather update information overlaid. This model was notable for being one of earliest (possibly *the* earliest) online Web3D models of the Earth.

After the Digital Earth initiative started organizations began specifying the requirements to realize his vision and develop prototypes. Some serious inroads were made into realizing the foundation technologies for an online database of the Earth, accessible via a web browser and with some graphical visualization. Some were 2D, a few 3D. By 2000 these efforts were starting to be working prototypes. During this time the National Spatial Data Infrastructure (NSDI) was developed and a then a global version (GSDI) was adopted by other countries round the world.

The Stanford Research Institute (SRI) lead the development of a geographics enhanced version of VRML, called GeoVRML. The GeoVRML working group is a Web3D Consortium working group who developed the GeoVRML specification and an implementation in Java+VRML. The GeoVRML specification received wide applause and some industry support. It became adopted as one of the specifications and technologies, along with VRML, forming part of the DE initiative.
GeoVRML later became part of the amended ISO VRML specification, known as Amendment 1.

SRI also developed the TerraVision system, a server and client for modeling the Earth in 3D with additional objects and information and viewing it over the web. This became part of SRI's Digital Earth prototype.

At the same time one of the other big protagonists of Web3D, the Naval Postgraduate School (NPS), developed an implementation if the military standard Distributed Interactive Simulation (DIS) protocol in VRML and Java. GeoVRML became part of their visualization platform.

The Interagency Digital Earth Working group (IDEW) developed the Digital Earth Reference Model (DERM), Web Mapping Testbed (WMT), and Digital Earth Alpha Version (which I cannot find any links or images of).

The political will, industry funding and effort for DE subsided after the third meeting of the DE Community and as a consequence of AL Gore failing to gain the Presidency. The DE project *transitioned* into Geospatial Applications and Interoperability (GAI) working group of the Federal Geographic Data Committee (FGDC) who developed the GIRM - Guide for interoperable geospatial applications - which is a high level guide for implementers of DE systems to select the right standards for interoperability.

Much of the responsibility for continuation of the DE vision appears to have fallen on the shoulders of the Open GIS Consortium (OGC) – an international industry consortium of more than 230 companies, government agencies and universities [4]. However, OGC follows the traditional 2D GIS approach in the main and does not appear to put much weight behind the original DE vision. OGC has developed the Web Map Server (WMS), Geographic Modeling Language (GML) and a suite of other specifications (see later).

The GAI, OGC and other organizations like SRI continued to build on the DE idea beyond 2000. This meant there was still impetus behind the original vision, but it had transformed to a broader, if not stronger base.

The DE project official website is [5]. On this site a number of testbed links were provided. Of these, only the NASA one: viewer.digitalearth.gov is a working link to a real application. The others either fail when you try and access them or show online documentation only. Some refer to offline applications or testbeds: such as one in the Smithsonian museum.

Summary of relevant geographic and geo-VR systems

Digitalearth.org

An up-to-date site for GIS systems, not directed at VR but a lot of recent open source initiative is showing up there (e.g. the Java based OpenMap, GeoServer, GeoTools). Digitalearth.org is a weblog formed early 2003 (feb 11th 2003). It is *not* an organisation or affiliate of the DE initiative. It is a collaboration between The Open Planning Project (TOPP) and the Geodata Alliance and also people who participated on the geoenabler, geoAll and digitalearth.gov sites. Of note, TOPP have developed an open source Java GIS server called GeoServer and Java Client. GeoServer is integrated with a spatial database system based on Postgresql, but there are plans for supporting other databases.

Terralib

Terralib (www.terralib.org) is an open source GIS from Brazil's National Institute for Space Research. It written in C++ and just recently made open source. It is designed to store all data in a spatial relational database.

Vtp

The Virtual Terrain Project (VTP) at www.vterrain.org is a truly 3D project. It is written in C++ and can be used for visualizing both real world data and synthetic terrain. A number of areas of the Earth have been modeled, such as California, New York, Oahu, etc. The project's stated ultimate goal is a whole VE type system.

Terravision II

Terravision II is the latest version of SRIs terrain visualisation system that is now open source. Its GeoWeb extensions were an enabling technology for an open, global coordinated geographical infrastructure but are not open source. Probably the best example of an open VE system to date, Terravision II has no current wide industry support even though based largely on open standards and now open source. Indeed, there is no VE system enjoying wide industry support. Even so, Terravision was a fantastic project with some truly impressive looking results as reported in [Leclerc 2000a].

NASA – a notable non-VE site

NASA made available a large database of 2D Earth images and has created a number of videos of 3D models of parts of the planet or the whole Earth. There are three dedicated Earth NASA sites: Earth's Observatory[6], the Visible Earth [8] and Blue Marble [6]. The Earth's observatory site allows users to build their own animated globe (or animated flat earth) based on a variety of selectable environmental parameters. You can also see satellite image snaps of areas of interest, such as increased pollution effects from El Nino or an image of the Kimberly in northwest Australia. The blue marble site is dedicated to the most detailed whole earth satellite imagery that has been made freely available so far. The Visible Earth site has over 5000 more detailed snapshots from satellites, showing areas of Earth as they are: such as pictures of the smoke from fires over the Amazon. However, there are no online 3D immersive Earth models for users to explore.

NASA's DE Web Map viewer ([9] link from the government DE site) portal provides 2D information with zoom and pan much like other 2D geographic portals. It implements OGC WMS Implementation Specification 1.1.2 (January 2002).

OpenMap

OpenMap is an open source JavaBeans based programmer's toolkit by BBN Technologies [18]. It can be used to build applications and applets to access and manipulate geospatial information from legacy databases. The client for this system has both 2D and 3D (through an "orthographic" projection option) views. However, the 3D view, which shows the Earth as a globe, is always top-down – essentially little more than the standard 2D top-down view. You cannot navigate freely in a full 3D immersive environment: the controls are limited to zooming in and out and panning.

Other products

Keyhole's EarthViewer3D

A proprietary technology but worth a mention here because it is one of the closest to an online, immersive 3D Earth. Using its nVidia-based viewer, it proves easy to use, fast and effective. This is an example of creating a VE repository and making it available (at a price) for the general user and then seeking applications. Although Keyhole claims their system it is in use by targeted audiences such as Real Estate, … etc, it is also an example of an augmented Earth with a wide net cast to also capture incidental or unintended uses.

EarthViewer3D is full 3D at low altitude and appears to be modeled on a smooth sphere at higher altitudes. There is a personal/home version and a pro version. The home version can be purchased for $US89 and cannot be used for commercial purposes. The pro version is $US599 and it is "not intended for home/personal use".

CubeWerx – www,cubewerx.com/demo/cubeview/cubeview.cgi

This is a 2D system, not really a VE - it is an online 2D map server, a "Spatial Data Warehouse". The main points to note are that it is an OGC compliant WMS, Cascading web download server, OGC compliant Web Feature Server, Spatial Data Warehouse. The top window works for Shuttle Radar Topography Mission (SRTM) topology. It does not work properly (top map window always blank). Initially you get a world map image bit it is easy to lose and you are left with a blank window. Once lost, the image stays lost (e.g. after being covered by another window). No save topology function – just save image.

Federal Geographic Data Committee National Geospatial Clearing House

This clearing-house is a collection of over 250 spatial data servers. One of these servers, for example, is run by ESRI. On the site there is an ESRI NSDI Wizard (a Java applet), which walks the user through to accessing the data they want (if available). The site provides for four "topics" and elevation information is included (2D overlays).

Earth Today (www.nasm.si.edu/earthtoday

This site shows "Our Dynamic Planet" which is just an online presentation with images or animated images. Not an interactive site at all.

The GLOBE program

GLOBE is a portal for worldwide network of students, teachers and scientists with an environmental mandate [15]. Sponsored by NASA, NSA, US EPA and US Department of State it is a primary and secondary school-based education and science program.

This project is more in the spirit of DE because students can publish to the GLOBE program. However, this falls short of the idea of publishing to the portal for others to then view: they only contribute data for scientists to analyze.

This site allows users to create their own maps from the information available – including nice printer friendly versions or cube foldable versions.

Many countries have schools involved in the program (including Australia). They can collaborate, propose activities and join existing activities. Online forums are provided for these.

There is even a "DE – GIS" activity, however it is viewed in common GIS terms – i.e. more in the terms of 2D GIS mapping rather than including 3D VR. There are many participants from all over the world. Last updated project discussion 2000.

An interesting thing is this site has a 3D viewing option where you can choose a VRML plugin and view the globe in 3D. It is a simple sphere view with a basic texture map – a far cry what the VE concept – but a beginning!

Military

There are a few military and military-oriented commercial systems that provide – at some considerable expense – 3D Earth modeling with detailed information and object embellishments. These include some fully VR interfaces such as the EDGE product family by Autometric [20]. However this survey is concerned with open and free access systems. The main military proponent of such open systems is the NPS.

NPS is continuing its use of geo web3d in some of its training and simulation systems. NPS is developing the Extensible Modelling and Simulation Framework (XMSF). The XMSF is a composable set of standards, profiles and recommended practices for Web-based modeling & simulation (M&S) [Brutzman 2002].

Examples of NPS's applied Web3D are a reconstruction of the USS Cole disaster [Brutzman 2002] using SAVAGE, 3D visual operations orders for military, helicopter patrol mission planning, army military patrol training with virtual avatars, terrorist incident simulation, Web3D GIS [Chu 2002], spatialised audio for greatly improved comprehension [Shilling 2002] and exploring foreign language training with Vcom3D.

Other projects to note

Other 3D projects not described above are:

Our 3map project: http://www.ping.com.au/3map.html which incorporates the Rez terrain modeling project [1] and is described below.

The "Great VRML Model - the 3D Earth" by Peter Graf (http://mission.base.com/theearth/bot.htm) which uses 1km topological data and false colouring with informational objects and media at key locations such as cities.

Some interesting "3D" views – generated as snapshot images can be found on the site http://www.fourmilab.ch/cgi-bin/ungci/Earth. However this is not an interactive, immersive system.

Meadowlands Environmental Research Institute (MERI) has an environmental project portal [14] run in collaboration with the Center for Information Management, Integration and Connectivity (CIMIC) at Rutgers University and the New Jersey Medowlands Commission [13]. MERI conducts and sponsors research into ecology, environmental science and information technology that are significant to the Heckensack Medowlands District, an esturine system in northern NJ. This site has nice 2D false colour views but no 3D and, of course is restricted to a small region.

Summary - where goeth the DE Vision?

The DE vision as described by Al Gore was of a true 3D virtual online experience where vast quantities of a vast range of information would be accessible to the people of the world. There is, however at this time NO substantial 3D online, free to use, simalucrum of Earth. Further, there is only one system: Terravision II that even approaches that vision. Of the commercial systems which come close Keyhole's EarthViewer is notable as a low cost system compared to the expensive simulation systems like EDGE.

Summary of relevant geographic and geo-VR specifications and technologies

GeoVRML

GeoVRML addressed the need for geographic coordinate specification in VRML and also helped to overcome the precision limitations of the VRML specification. The limited precision in VRML prevented its use on serious DE representation (to a level of detail finer than about 10m). GeoVRML is now part of the VRML Specification (Ammendment 1) and a version is included with the geographic component of X3D.

SRI's GeoWeb

SRI developed the GeoWeb – a geographically enhanced protocol and indexing system that used a location based Domain Name System (DNS) which paralleled the current internet DNS. SRI also proposed a ".geo" top level domain be added by ICANN. If successful, ".geo" would have used the GeoWeb system. This proposal was initially received well but knocked back in the 11th hour in favor of other commercial TLDs. Some time between 2000 and 2002, as part of the slow down or "transition" of DE to GAI, funding discontinued for SRI's work on TerraVision and GeoWeb. As already described, SRI made their latest product, TerraVision II, available as open source, minus the GeoWeb component. The two together would be perhaps one of the most significant VE technology contributions to date in the spirit of the original DE vision.

The Geospatial Interoperability Reference Model (GIRM)

The latest Draft is version 0.8, December 2002. The GIRM [17] is the successor to the Digital Earth Reference model (DERM) - a guide to the standards and specifications that enable DE interoperability [16]. The GIRM was prepared by the Federal Geographic Data Committee (FGDC) for the Geospatial Applications and Interoperability Working Group. It still seems to be current. The working group seeks to facilitate communication of geographic information from multiple sources over the internet. The document recommends standards, specifications and agreements for geospatial interoperability.

OGC Specifications

The approved OGC OpenGIS specifications to date are:

1. **Catalog Service interface Specification**. Defines a common interface that enables diverse conformant applications to interact with catalog servers.
2. **OpenGIS Coordinate Transformation Services Specification**. Provides interfaces for general positioning, coordinate systems and coordinate transformations. Coordinates can have any number of dimensions.
3. **OpenGIS Geography Markup Language (GML).** This is an encoding in XML for the transport and storage of geographic information, including both geometry and properties of geographic features. More detail provided below.
4. **OpenGIS Grid Coverages (Grid, image, DEM) Specification.** Designed to promote interoperability between software implementations by data and software vendors providing grid analysis and processing capabilities.
5. **OpenGIS Simple Feature Specification**. Describes the interface for OpenGIS Simple Features. A Simple Feature is defined by the OpenGIS Abstract Specification to have both spatial and non-spatial attributes.
6. **OpenGIS Web Map Server Interface Specification (WMS).** This is a set of interface specifications that provide uniform access by Web Clients to maps rendered by map servers on the internet. . More detail provided below.

There are also a large number of candidate specifications:

1. OpenGIS Basic Services Model Specification (BSM),
2. OpenGIS Gzetteer Service Interface Specification (GAZ),
3. OpenGIS Geocoder Service Specification (Geocoder or GeoC),
4. OpenGIS GeoParser Service Specification (Geoparser or GeoP)
5. OpenGIS Location organizer Folder Specification (LOF)
6. OpenGIS Image Coordinate Transformation Specification (ICT)
7. OpenGIS Stateless Catalog Specification (Cat S)
8. OpenGIS Styled Layer Description Specification (SLD)
9. OpenGIS Web Coverage Server Specification (WFS)
10. OpenGIS Web Registry Service Specification
11. OpenGIS XML Imagery Markup Language Specification (XIMA)

GML

The Geography Markup Language (GML) is an OGC specification for expressing OGC Simple Features Specification compliant data in XML syntax. GML is gaining wide industry acceptance and was being supported by several GIS vendors in 2002 [Lehto 2002]. GML offers a strong basis for geographic data storage that supports multipurpose publishing, particularly using XSLT.

WMS

The Web Mapping Server (WMS) specification started as a specification for implementing the Web Mapping Testbed (Web Map Service Implementation Specification) as defined by the OGC. This was then extended to cover all of the OGC Simple Features to become the current WMS specification (as of this writing it is version 1.1.1). WMS initially focused on 2D representation but was later extended to include elevation information and multidimensional coordinates. However it is not a fully 3D specification (e.g. it still uses bounding boxes of 2 dimensions).

X3D
X3D is an evolutionary successor to VRML as it extends and improves upon the capabilities found in VRML. X3D is a Web3D technology, which, it is hoped, will become more widely adopted than VRML. Its architecture is highly flexible and accommodating of wide ranging industry needs. There is an XML encoding of X3D – the only available implementation to date. This encoding plus the architecture should put X3D in a good position for exceeding the level of support and adoption of VRML. As X3D incorporates the gains made from GeoVRML into the specification it is also very appropriate for geographic web3d visualization. There is currently an implementation of an X3D browser in Java3D [19] and other Web3D browser developers, such as Media Machines with their Flux[21] product, are building support into their browsers.

Synthesis

From the foregoing survey, it can be seen there are a number of notable open source geographic end even geo-VR systems such as OpenMap, GeoServer and Terravision II. One of these could form a good basis for constructing many of the interoperable geographic information handling components of WAVE. There are, also a significant set of open standards such as GML, the OpenGIS specifications, GeoVRML, X3D and XMSF upon which we could base our platform. A suite of web services components is also needed and the main contenders would be .NET and Sun One or a similar web services platform built on smaller components such as Jakarta Struts, Apache Tomcat, J2EE, etc. A number of other open source packages such as XJ3D and Rez have the potential to form part of the overall structure. Lastly, to finish the macro-level componentisation, XML components are central to the interoperability requirement.

The architecture of WAVE may use the architectures of similar systems, in particular like Terravision II+GeoWeb as a starting point but incorporate aspects of other (more GIS-like) systems such as OpenMap or GeoServer. Of the web services architectures, java based ones are of particular interest because of their open and cross platform basis and compatibility to other potential components (such as XJ3D, Struts, etc). In fact, Java features large in non .NET web services implementations, GeoVRML and X3D implementations, in OpenMap and GeoServer. In addition XML based technologies also feature large in Web services, X3D, GML, WMS, OpenMap and GeoServer. Supporting the OGC specifications, in particular WMS and GML, will provide for the greatest interoperability with the growing list of OGC OpenGIS compliant applications.

OpenMap, although based on Java is also built upon a .NET + IIS platform, making it not meet our portability requirements. GeoServer is currently reliant on Postgresql for the RDBMS but that is a limitation that is not hard to change (it is not hard to interface other databases with Java).
Self-publishing is an important aspect our system that is absent from the other systems reviewed. It is not just important from the perspective that it provides significant added capability the user but also because it is the multitude of self-publishers that will in the end be the most significant force in creating the VE.

The 3MAP project

Conclusion

The DE vision as described by Al Gore was of a true 3D virtual online experience where vast quantities of a vast range of information would be freely accessible to the people of the world. There is at this time NO substantial full 3D online, free to use, simalucrum of Earth.

Virtual reality has captured the minds of many and we intend to bring a virtual experience that extends our work in the physical world. Despite this emphasis it does not prevent entertainment-style applications, which we hope will also be of commercial interest to businesses considering using the platform. WAVE will provide an avenue for expanding our imaginative power leading to direct benefits in our everyday activities.

Allowing people to publish their own information into the online Earth will be a significant aspect of the project and may turn out to be the most exciting part of all. The importance of a strong, easy to use VR interface is not to be downplayed. Much of the success of WAVE could depend on this aspect.

It is clear that Java and XML based technologies and systems will be important building blocks on which to construct an open, cross platform system. Exemplary open non Java systems, such as VTP, Terravision II and Terralib are also worth consideration. However for greater cross platform operation and web based deliverability Java based technology looks to be the better contender.

For the purpose of developing WAVE, we conclude the best technologies/systems to look more closely into are: GeoServer, Java based web services, J2EE, XJ3D and XML applications; the best standards to use would be: X3D, GML, WMS and as many of the other OGC specifications as possible should be supported.

What began as a small ripple in the minds of science fiction fans spread and formed up into a strong virtual Earth vision. Though it subsided a little this WAVE will rise up again before sweeping the world into a new era where everyday activity is enhanced with virtual experience.

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