White Paper for the Integration of Web Resources and 3-4 D Visualization (Virtual GIS)

Nick Faust and Bill Ribarsky - Georgia Tech

I. Introduction

In preparation for the Atlanta Olympic bid of 1990 for the 1996 summer Olympics, Georgia Tech prepared a 3 Dimensional flight simulation movie that zoomed in from a rotating globe and through the North Georgia mountains to Atlanta. This was integrated with an interactive video system that allowed exploration of all proposed Olympic venues. Another detailed flight simulation into the Galapagos Islands was prepared by Georgia Tech the next year for Turner Broadcasting and the educational JASON project. These simulations required supercomputer computation from Convex and Cray systems and were decidedly NOT real time. In 1993, a presentation was made at an International Remote Sensing meeting in Cartagena, Colombia on the potential for a concept described as Virtual GIS. If: 1) computers ever became fast enough, 2) memory ever became cheap enough, and 3) computer graphics ever became a commodity product, then all operations normally performed in a GIS should be implemented in an interactive 3 D global context. Since we live in a 3 Dimensional world all GIS queries and analyses could be implemented in a virtual world in a natural way that mirrors how we interact with the real world. Such a graphic visualization framework could be used to integrate normal GIS functions with the numerical modeling techniques that were being developed for time series analysis and weather visualization.

Since the early 1990's the conditions set out for the successful development of a Virtual GIS have been satisfied by the huge improvements in the speed of personal computing, the major reduction in the cost for computer memory and disk storage, and the development of commodity 3 D OpenGL graphics chips that were developed to support the video game market. As opposed to super computers and large dedicated graphics systems, the ability exists now for normal desktop and laptop systems to support the wide adoption of a Virtual GIS system. Such a system would not need to be dependent on a particular brand of GIS software, but should support the visualization functions of a number of commercial GIS systems.

II. GIS Web Services – Data Sources

Over the same time period, the Internet has become pervasive. It provides the capability to access web pages and data throughout the world. This capability extends to the serving of potentially very large spatial data sets through map servers with a web browser interface. More and more agencies, companies, and individuals are posting GIS and imagery data on systems such as the Geography Network as implemented by ESRI using the Arc Internet Map Server (ArcIMS). The data may be viewed and in some cases directly downloaded to local disks and applications. The Open GIS Consortium has developed Open Standards for Internet map services (Web mapping Services (WMS) and Web Feature Services (WFS)). Georgia Tech is working with the National Guard Bureau (NGB) in cooperative development of the Digital Mapping Server (DMS) with the primary developer, the Navy Research Laboratory at Stennis Space Center. DMS is a Government Off The Shelf (GOTS) software system that embodies the concept of a

Geospatial One-Stop (http://ngbcdmaps.gtri.gatech.edu/). Through interaction with NRL, Georgia Tech is investigating the integration of the Georgia Tech Virtual GIS system (GTVGIS-discussed later) as a 3D front end to a wealth of data that can be accessed through the DMS Portal using both WMS and ArcIMS interfaces.

III. High Speed Internet Access

The acceptance of the Internet for Web mapping applications is greatly enhanced by the availability of greater bandwidths to agencies, businesses, universities, and individual homes. The data transfer requirements of map and image data over the Internet may be very large depending on the sources, scales, and resolutions of the data. Using DSL, Cable Modem, and satellite connections a user can access high speed connectivity to the Internet even at his business or his home.

IV. Availability of Numerical Models

With the rapid increases in the speed and capabilities of personal computer environments, the ability to dynamically run numerical models locally has increased. For example, the MM5 weather prediction code, traditionally run on main frames and large Silicon Graphics servers, may now be run on PC multiprocessor systems. The Community Multiscale Air Quality (CMAQ) Modeling System has been available on Windows NT and now is available on Linux PC systems. Other detailed models that must be run on supercomputers have the ability to transfer data via the web for local analysis. The ability to run or at least extract data from numerical models on PC systems opens the way for the dynamic local visualization of numerical model results and for some models the ability to use 3 and 4 dimensional visualization tools to assist the operator in the determination of parameters for accurate results for a particular area.

V. Digital Earth vision

Ideas for the use of a dynamic global interface to geospatial data evolved in the late 1990's with the Federal government multi-agency Digital Earth program. The idea, vocalized by Vice President Al Gore was that every child in America should be able to use a Web-based 3D Global interface to drill down through huge volumes of geospatial data in an information discovery mode and finally be able to fly through and query in a 3 D terrain overlaid with map and image data sets. The vision also include the ability to show and analyze time series measured and modeled data in a global context (such as the growth and expansion of the Ozone Hole over Antartica). While this vision has faltered in the United States with a change in administration, other countries have taken up the quest for an easy to use, web based, 3D Digital Earth interface to information about global sustainability. China has developed Digital Cities, Digital Olympics, Digital Provinces, and Digital Regions programs as a way to organize and access geospatial data at a variety of scales and resolutions. Japan also has a strong program in Digital Earth development. The 3rd Symposium on Digital Earth was recently held in Brno of the Cech Republic on September 21-25, 2003 and shows the international support for the concepts of Digital Earth.

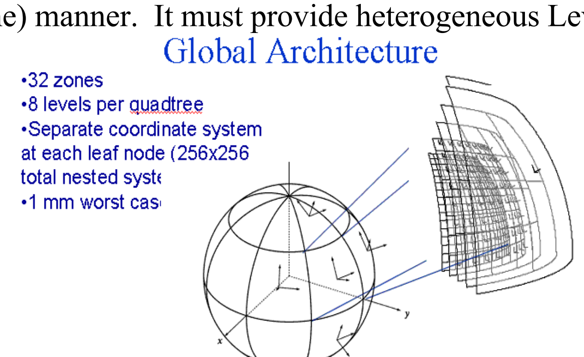
VI. Applications

The concept of using a consistent Digital Earth as an interface to myriads of geospatial data sets has applications in many disciplines. These applications span the use of the interface as a mode of data discovery to the use of the dynamic interface in the research and development of large scale environmental models. Users would be students from grade school through university, university professors, engineers, planners, and administrators from all levels of government and private industry. Where spatial context will convey more information, a virtual immersion in a 3 D world will convey the information in a more physically meaningful manner. Almost all applications that utilize remote sensing and GIS information would be able to take advantage of an expanded visualization capability to enhance their use.

VII. GTVGIS Architecture

Georgia Tech has developed a system called the Georgia Tech Virtual Geographic Information System (GTVGIS) over the past 8 years under the funding of a number of sponsors. Initial work for the Army Research Lab resulted in an optimized, continuous Level of Detail (LOD) management system for the effective 3 D rendering of large data sets (Lindstrom et al, 1996). The implementation of a global architecture for the efficient visualization of very large data sets throughout the world was implemented in 1997 (Lindstrom et al, 1997).

GTVGIS is the initial implementation of the Virtual GIS concept at Georgia Tech. Virtual GIS is the integration of Remote Sensing, GIS, and Visualization. GTVGIS is a general framework for global geospatial data and its visualization. Since geospatial data sets are very large and may be distributed spatially, the system must be scalable to assure a capability for efficient visualization of a local area while ignoring the fact that extremely large data could/will exist for other locations around the world. By its very nature GTVGIS is intended to support dynamic data discovery through extensive data holdings in an interactive (real time) manner. It must provide heterogeneous Level of



Detail management so that only the data that is appropriate for a particular viewpoint is shown to the user. Screen based rendering metrics are used to assure that spatial data that is close to the viewer is seen at its optimum highest resolution while areas far away are seen at a lesser resolution. Other factors such as terrain complexity are also addressed by the screen metrics. The data architecture for GTVGIS has been optimized around a quadtree for terrain and earth surface image data while 3 D volumetric data is organized as a connected octree. The architecture involves nested coordinate systems and assumes all data sets are transformed to the WGS 84 earth model. The GTVGIS system also supports the rendering and draping of vector GIS data (shape files) in conjunction with the terrain and image data sets.

The current implementation of GTVGIS exists in 3 modes. The same software is used as the architecture for each mode. The 3 modes include: 1) stand alone mode, 2) client-server mode, and 3) web-3D server mode. For the stand alone mode, both data and the rendering software exist on a single computer or on a local network. The requirements are for a fast CPU, large memory (disk and RAM), and a state of the art 3 D graphics card. This local capability, because of efficient data access, is usually the fastest of the 3 modes. Mode 2 assumes that the rendering software (thick client) exists on a local system, however the data may be distributed anywhere across the Internet through an IP address. This mode and mode 1 utilize a client-server architecture with a terrain and GIS/image server that dynamically receives requests for spatial data from the client navigation thread. The bandwidth limitations are eased somewhat by dynamic decompression on the fly. The 3rd mode involves a farm of 3 D rendering engines at one or many locations, with a very lightweight java enabled web browser front end. A user interface in the browser allows the user to navigate throughout the same large 3 D database that support the other 2 GTVGIS modes. As the user changes his viewpoint and center of view, the new coordinates are passed over the Internet, and sent to one of the 3 D server machines. The 3 D server generates the perspective scene, accessing a large global data set and dynamically renders a 3 D scene. The scene is JPEG compressed and sent to the client browser as an image to be displayed in the browser. The user may move within the scene, with a 1-2 second delay, or he may perform a GIS query into a GIS server supporting GIS shape files and attributes.

VIII. Volumetric rendering of model and measured data

Work has been ongoing in the past several years under NSF funding in the dynamic visualization of 3 D (volumetric) weather data in conjunction with the GTVGIS high resolution terrain rendering. A partnership of Georgia Tech, University of Oklahoma, and the National Severe Storms laboratory (NSSL) are involved in the interactive visualization of volumetric data from the NEXRAD weather radars operated by the national Weather Service (NWS). NSSL is a principal developer of new algorithms for the detection of severe weather phenomena by applying algorithms to the multiple angular scans of the NEXRAD radar systems. The visualization of the true 3 D nature of a severe storm is important in the ability to design algorithms that are able to quickly and accurately detect areas in which severe thunderstorms and tornadoes occur. As a part of this project, the ability of displaying, navigating, and querying of dynamic time series data is being implemented. The same techniques being used for the NEXRAD radar severe storm visualization also may be used with the results of the environmental models such as MM5 and CMAQ.

IX. Proposed development of a Unified Framework for Dynamic Visualization

A basic framework exists in GTVGIS that could be used as a data discovery front end for the large spatial data holdings of multiple government agencies. The architecture is scalable and allows the dynamic building of new data sets as new imagery (for example) becomes available. The system has been developed under a variety of funding sources (federal, local, private) but is available for use by Georgia Tech collaborators. Georgia Tech is not interested in licensing GTVGIS, it is interested in ongoing development to extend the existing capabilities for new applications. The system is being extended to access spatial data through the DMS web interface (Geospatial One-Stop) discussed above and dynamically create the efficient rendering architecture for real time navigation. The system is developed continuously under Concurrent Version Control (CVS) and potential collaborators have access to object code and several Application Programmers Interfaces (API's). The increased use of the system by collaborators in the environmental modeling domain will increase the preliminary capability for the visualization of model time series data within the detailed global geospatial visualization framework. The integrated multiresolution data model for visualization and data analysis brings new capabilities. These include high-resolution countrywide weather modeling based on near real-time high resolution weather inputs from NEXRAD radars across the US.

It is anticipated that all 3 modes of GTVGIS could be used to further geospatial applications in a variety of disciplines. The system runs on Windows and Linux and exists on a desktop, laptop, and (currently under development) PDA. The use of the 3 D server mode might be more appropriate for educational applications where limited resources might exist, while the laptop and desktop versions could be used for project analysis and presentations. The 3 D server PDA mode could be used directly in the field with wireless and cell phone capability.

Potential Tasks that could be accomplished include:

1) Continued development of data access through the Geospatial One-Stop
2) Investigation of more robust compression/decompression technologies
3) Implementation of GTVGIS and Web GTVGIS at appropriate agencies
4) Test of scalability and potential bottlenecks through coordination with a number of UCGIS sites with Geospatial Data Clearinghouses.
5) Collaboration with environmental modelers
6) Continued development of time series capability
7) Continued development of volumetric rendering and data access techniques

X. References

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