UTILIZING 3D WEB-BASED GIS FOR INFRASTRUCTURE PROTECTION AND EMERGENCY PREPAREDNESS

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ABSTRACT:

Geographic Information Systems visual products have become a powerful resource for Infrastructure Protection and Emergency Preparedness. The utility of informed decision making processes could significantly be improved using 3D web-based GIS visual models. However, collective efforts are needed for further improvement of currently available visual models to address Infrastructure Protection and Emergency Preparedness requirements. This paper delineates an approach taken to emphasize and provide capabilities for web-based three-dimensional visualization of GIS data for Infrastructure Protection and Emergency Response. In this paper, issues related to visualization models, concepts, and requirements have been examined with emphasis on a mock emergency scenario for Santa Barbara International Airport in California. Integration of Internet capabilities with 3D GIS rendering have enabled new modes of analysis and exploration, particularly for Infrastructure Protection and Emergency Response. Despite all the ease that 3D web-based GIS brings to Emergency Preparedness community, still there is a crucial question remains unanswered: how 3D Web-based GIS can bring with it great opportunities, while it presents very significant problems in effectively communicating information, particularly to non-GIS professionals i.e. Disaster and Emergency Response Managers? GeoServNet, a web-based GIS system developed by York University GeoICT lab, aimed at solving this problem through providing variety of mechanisms for visualization that may help in eliminating in-experienced user interaction obstacles.

1. INTRODUCTION

Interdisciplinary methods have been used for long time by scientists and decision makers for visualizing spatial data. The objective of building GIS visual models is to assist in data exploration and real-world conceptualization. Building visual data models involves a set of data processing and display techniques that aid in providing reasonable interpretation and analysis of the complex relationships in large spatial data sets rapidly. This represents a crucial issue for the application of emergency preparedness and response.

GIS Data visualization refers to the presentation of data by digital images, vector data, digital elevation models, tabular information, and virtual reality, in either two or three-dimensional presentations, static or animated. The motivation for exploring 3D web-based GIS applications for Infrastructure Protection and Emergency Preparedness and Response goes far beyond providing approximated real-world model. From GIS perspective, the main objective of visualization is 1) to produce visual models that can effectively aid decision makers to identify spatial patterns and processes that relate to solving problems at hand. Having said that, GIS visualization utmost aim is not only to produce pretty looking models that exploit human visual systems and identify spatial features, another objective is 2) to provide innovative solutions that integrate heterogeneous data sources. Beyond all that 3) visual 3D models provide additional dimension that can help in determining more realistic approximation of feature space.

At present, variety of software have the capability of handling a wide range of spatial problems, beginning with approaches for describing spatial objects to quite complex analysis that provided up-to four dimensional visualization. Nevertheless, increasing number of applications should have more advanced tools for representing and analyzing the 3D real world. Among all types of systems dealing with spatial information, web-based systems has proven the accessibility and dimensionality that are required by systems that operates with the largest scope of objects either spatial or semantic relationships, and provide means of modeling them. An alternative development approach to GISystems would be a service oriented approach that is distributed across a network, via standard internet browser (Tao, and Yuan 2000). Based on GIS service concept, significant advances have been made in the development of visual 3D models of natural topography, in the recent years. 3D-GIS distinguish itself from a 'normal' GIS by two, the dimension of the spatial data in the system; and the visual dimension of the spatial data. In a 2D GIS, storage of data is still often based on 2D layers, possibly with an extension to 2D surfaces. The nature of spatial relations between objects will be two-dimensional in general. Today's technology development enabled GIS users to render very complicated and rich detailed simulations of various environments over the internet in an easy way of interaction and understanding that is not currently present in many simulation models. Exceptional than others, GeoServNet, provides this ease. GeoServNet, is a 2D/3D web-based GIS package developed by York University, GeoICT Lab. It generates 3D models that can be used as a comprehensible interface for querying features, hyper-linking web-based information, for analyzing and visualizing model results, and accessing different simulation models. Furthermore, the addition of a third dimension to our knowledge base of modeled features allowed GeoServNet to greatly enrich the simulation capacity of predictive models, which are very crucial for emergency preparedness applications.

2. 3D VISUALIZATION FOR EMERGENCY PREPARDNESS

2.1 Types of Visualization

Much of GIS contribution to Infrastructure Protection and Emergency Preparedness could be addressed at different levels and in various interconnected applications. GIS visualization mainly focuses on two domains: computer graphics and GIS data. Because of interconnections between the two domains, it is not difficult to integrate techniques exploiting the two respective domains in terms of 3D application. However, by reviewing the recent advances in GIS technology, particularly, web-based GIS, it is found that visualization and rendering techniques have the largest usage. These developments in visualization models are in the following areas: a) interpretive: where the user is basically a "reader" who is attempting to extract the meaning of the data by visualization. b) Expressive: In expressive modeling, the user is an "author" who is attempting to convey the meaning of the data through visualization, and c) Interactive: where the user integrates both interpretive and expressive models to generate and extract the meaning. Interestingly, GIS modeling combines the three; nevertheless it always depends on the perspective of the recipient.

2.2 3D Web-based GIS Visualization requirements

Van Driel (1989) recognized that the advantage of 3D lies in the way we see the information. The real contribution that 3D web-based GIS present for Emergency Preparedness comes from its special characteristics. Simply, the purpose of interactive web-based visualization is to provide smooth navigation through large 3D GIS models. There are basic requirements of the visualization process in order for it to be used as the basis of the GIS client's user interface. It is very necessary for us to have 1) Display quality 2) Stable network and system performance 3) Modeling Efficiency 4) Interoperability that allow for data and system capabilities share with others 5) Reliability to the level that permits of having continued analysis. 6) Security, that prevents from undesired intrusions.

Some of the 3D web-based GIS visual models for users Infrastructure Protection and Emergency Preparedness include, Governmental/municipal authorities require tools to perform administrative tasks (including traffic planning, disaster preparedness etc.) more efficiently. 3D models also help to improve public participation in a decision making process.

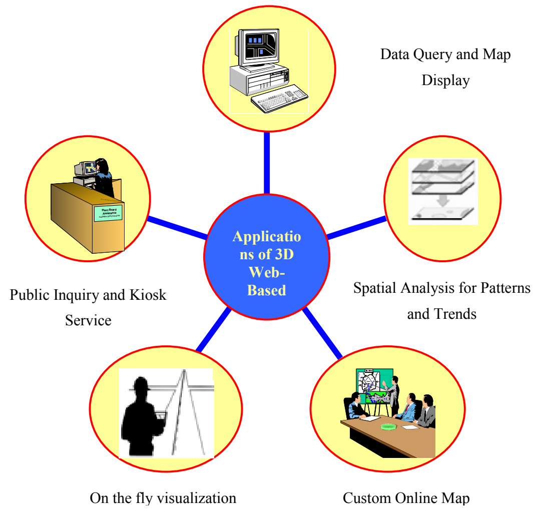

Figure 1 showing some applications of 3D Visualization Integration

3. CASE STUDY

Santa Barbara lies on the West Coast of the United States, 148 km north of Los Angeles and 534 km south of San Francisco. It is the largest city in Santa Barbara County. Santa Barbara gains special importance due to the distinguished topography of its region. It as well falls in a seismic active zone, which puts it under earthquake risks.

Figure 2 showing study area

3.1 Datasets and Scenario

Vector datasets represented by obstruction layers. Raster data sets in the form of LIDAR imagery and a Digital Elevation Model (DEM) were used for conducting this analysis.

A mock scenario to demonstrate the situation was created In order to simulate emergency response and to test emergency preparedness level. The scenario indicates that, a high jacked airplane was ordered to land in Santa Barbara Airport with warning of blowing out the plane if demands were not met. Disaster Mangers and Emergency Response community were exploring the level of danger, and which terminals and other buildings of the airport are at risk, in case of worst case scenario. Emergency response team was also exploring the way of communicating the current situation in visual format with other centers so that an effective, collective decision should be taken. Time of response, best options for reducing the damage in case of worst case scenario, which nearby infrastructure and natural resources would be affected. How they could monitor the situation using fly through simulation and how they could make their decision and action to end up this dramatic situation.

3.2 Modeling Methodology

Constructing visual model of Santa Barbara International Airport involved two processes, i.e., (1) desktop data preprocessing and setting visualization parameters and (2) building web-based visualization model using GeoServNet. The first part involved matching various data sets coordinate systems, data conversion to shapefile, since all vector layers provided were in shape 3D format (either polyline z or point z) it was crucial to convert those data sets to shapefiles as initial stage for using GeoServNet. The second stage was setting visualization parameters in terms of layers sequence and colors.

GeoServNet has provided an easy and accessible data publishing facility. There are three major steps in converting desktop model to a 3D model. This involved building the data using GSNBulider module. Administrating and registering the data to the GSNServer using GSNAdministrator Module and finally authoring and setting vitalization parameters for the model using GSNPublisher Module. After this process was complete, an HTML application file was created and linked to a webpage as shown in Figure 3. All Internet users can access GSN models through standard internet browsers.

Emergency Preparedness conceptual modeling resulted from GIS web based visualization models utilized the following techniques:

1) Three-dimensional perspective views, which was created to provide different angle looking views for particular infrastructure.

2) Animation or fly-through which provides sequence visualization for pre-determined section.

3.3 Modeling Results

Results obtained from modeling Santa Barbara Airport using GSN have clearly demonstrated that visualization of Santa Barbara Airport was efficient and effective in allowing interoperable web-based rapid response model for infrastructure protection and emergency response.

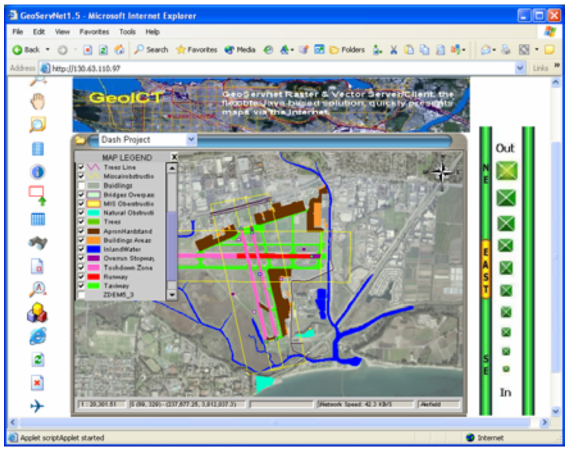

Figure 3 web-based 2D model of Santa Barbara

As it is noticeable from Figure 3 above, the utility of using web-based visualization published results over the internet makes visualization very effective in approximating the real world models, as well in determining the effectiveness and efficiency of informed decision making process over the internet based on a mocked scenario.

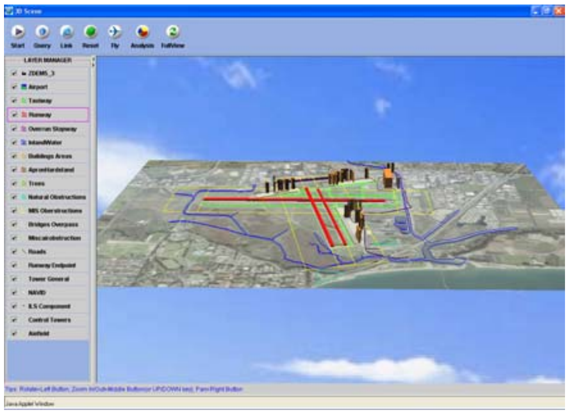

Figure 4 3D model of Santa Barbara airport runway and buildings

The 3D fly through shown on figure 4 above can be used in fulfilling the scenario requirements in terms of determining which part of the runway might be affected in case of the worse case scenario, GeoServNet also posses the capability of conducting measures and analysis surface profile based on the 3D visualization and on interactive two points on screen selection. This function is very crucial in determining the slope and aspect if any based on the scenario. The above figure (Figure 4) also demonstrates the capability of simulating fly-over the scene in case of airport shut down in order for close monitoring to the situation.

Capabilities of GeoServNet go beyond that to allow on the fly layer rendering and change, which is effective in visualizing multiple scenarios at the same time, below shown a 3D model fly through with a LIDAR image and single vector layer of the airport airfield obstructions, this reflects the capability of visualizing a single 3D layer based on the Digital Elevation Model (DEM) and as well as multiple layers. 3D fly through control panel in GeoServNet 3D model allows for controling the fly elevation, fly pitch and speed. These model controls are very effective in allowing for different controls and angles.

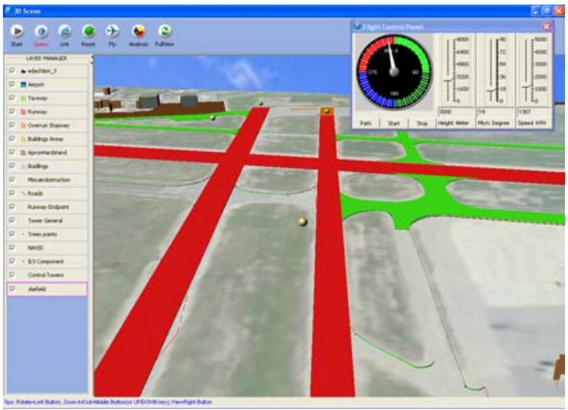

Figure 5 - 3D fly-through model showing the change in layers of the Airport model

3.4 Significance of 3D modeling for Emergency Preparedness:

The answer to the question: what is special about 3D GIS? Depends on the interpreter's point of view most of the time, if 3D GIS are compared to 2D GIS, simply, there is one major difference which is the amount of data to be processed. Since the amounts of data to be used for 3D visualization are far more than 2D including the DEM and other 3D visualization aspects.

The advantage of 3D visualization mainly based on the way we visualize the data and how we may interpret and perceive the fact of what we have modeled, whether it is symbolic conceptual or semi real world as in 3D perspective display.

The main utility for web-based visualization systems for disaster managers is based on four criteria: (1) *what* type of information is needed (2) *when* this information is used, (3) *where* this information is acquired and stored, (4) *how* information is delivered during emergencies, and at what pace it is needed. By applying these four criteria on all the information used during emergency response, particular information is classified and analysed. The results of this analysis might be considered as the base for the investigation of the possible ways to transfer information (How?), besides ordinary one to one communication. The advantage of visualization of critical infrastructure models through the internet is crucial, since it provides different decision making levels with near real-time data access, which would significantly expedite the processes of evaluating and analyzing information and taking decisions based on the model generated from Santa Barbara Airport.

Besides the ease that GIS data visualization brings, still there are some issues that are arising from data visualization, which may cause uncertainty. These issues include data quality and format, the representation and modeling the real world, interpreter's objectives in interpretation objectives as well as visualizations objectives. Another important factor is the abilities and targets of the analyst who will be using the model. Data Characteristics include, data reliability, accuracy and interpretation aims, which are defined by the viewer for identifying objects, and comparing values, distinguishing objects, categorizing objects, this include software capabilities, and whether the focus on text/data structures/performance/algorithm in addition to what type of information visualization is required and whether the focus is on detail or the over all view, or relations among other objects. User's desires and abilities which are restricted by color perception ability and color coding, and preferences in addition to the availability of the suitable software, including visualization capabilities. Real time connections in some cases (field data collection) and color coding and information communication to the public may be considered as other limitation to visualization of similar models.

4. CONCLUSIONS

Responding to unexpected disasters, whether natural or man-made, is one of the greatest technological challenges ever to face. Events fall completely outside the range of the planned capabilities of organizational tasks. Moreover, major components, entirely unplanned, need to interoperate and policies and technologies need to converge in real-time. The scope of research and development (R&D) in responding to the unexpected (RUE) requires a broad range of technologies and relationships, among those is certainly, 3D web-based GIS.

Research in responding to unexpected events engages issues ranging from risk assessment of major assets (human, structural, transactional, etc) to scenario building and organizational decision systems and architecture. A major focus of the research agenda is the application of information technology tools and systems. The scope of Disaster Management, Infrastructure Protection and Emergency Response research is beyond the capabilities of even modest-sized research teams, this mainly because the need for interdisciplinary vast research group.

Visualization Technologies are developing the same as web-based GIS, so the interaction level would be high in the near future, and the needs would be more. Therefore, critical Infrastructure protection using 3D web-based GIS is evolving. In Canada, the Office of Critical Infrastructure Protection and Emergency Preparedness (OCIPEP) was founded in 2001 with growing applications and needs for web-based GIS. This would certainly support the growing demand for Web-based GIS. GIS is gaining more grounds and is unique for such applications. Two central issues are very crucial in 3D web-based GIS applications for Infrastructure Protection and Emergency Preparedness, they are the need of strategic plans that minimize data flow and emergency planning that GIS would contribute considerably. Findings of this research have clearly demonstrated that the application of web-based GIS for disaster management is very effective, in particular 3D visualization allow for advanced analysis functions i.e. fly through. Web-based GIS also provide unique capability in terms of providing distributed interoperable services that allow for collective decision making process.

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