Designing Process of a GIS-based System for Historical Documentation of Two Ottoman Fortresses on Dardanelles

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Key words: GIS, database, data modeling, visualization, multimedia, internet, temporal GIS, object-oriented, project management

SUMMARY

The historical documentation project of the Ottoman fortresses at "*Seddülbahir*" and "*Kumkale*", carried out between 1997 and 2002 by the Division of Geodesy at Istanbul Technical University and the Department of History at Koc University provides an ideal case study for the integration of historical research methods and new GIS technology. This paper demonstrates how to explore a design of a multimedia supported four dimensional (4D) information system to aid geographically-oriented the documentation of the two Ottoman fortresses of "*Seddülbahir*" and "*Kumkale*" through internet. This paper demonstrates how a GIS project can be designed and managed for historical researches. This paper examines a variety of ways in which GIS application for a historical documentation project can be integrated with technological developments within the fields of database, visualization and internet.

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1. INTRODUCTION

The cultural heritage is the most important evidences regarding the past society and each object of these has valuable information about the past. Unfortunately each valuable element of the historical structures has been vanishing day by day through time, nature, and human effects. Hence, some precautions are needed for protecting these historical structures from the corrosion and human effects. There are also two Ottoman Fortresses, called "*Seddülbahir*" and "*Kumkale*" on Dardanelles, Turkey in the same situation, however, the project team working with these monuments believes that the fortresses can be restored and protected only when it has been fully measured, documented and stored in proper historical information and management systems. (Guney et al., 2002)

This paper describes a project undertaken at the Division of Geodesy, Istanbul Technical University (ITU) and the Department of History, Koç University; to explore a preparation of a multimedia supported four dimensional (4D) information system through internet to aid geographically-oriented the documentation of the two Ottoman fortresses of "*Seddülbahir*" and "*Kumkale*". It is with this larger, long-term goal that the team of surveyors, architects, historians and archaeologists began in 1997 to working together on the Survey and Documentation Project of "*Seddülbahir*" and "*Kumkale*".

The location of the fortresses is approximately 26°.199 E_{ITRF} and 41°.006 N_{ITRF} and the distance between the two fortresses is approximately 4150 meters. As "*Seddülbahir*" is located on the European side of the straits, at the southern end of the Gallipoli Peninsula. The fortress of "*Kumkale*" is on the opposite Asian shore, approximately five kilometers from Troy.

Fast developing technology in the area of geo-informatics makes the use of "Geographical Information Systems (GIS)" exciting to utilize and an opportunity to challenge much better decision making for many fields like history, archaeology etc. GIS can be used to analyze any issue with a spatial component in these fields.

This paper demonstrates how a GIS project can be designed and managed for historical researches. This paper examines a variety of ways in which GIS application for a historical documentation project can be integrated with technological developments within the fields of database, visualization and internet.

2. GIS PROJECT

GIS-based applications must be considered as a multi-purpose and multi-participants information technology (IT) project. In that case, the design and management of such a GIS project requires more responsibilities and hard tasks. (Guney and Celik, 2004) "Documentation Project of two Ottoman Fortresses on Dardanelles" is considered as a multi-participant project since each discipline in the project contributes to the study with its science domain and expects different outputs rather than other science domains. The project is also regarded as a multi-purpose project because the project has various purposes for the different level users such as decision makers, users, end-users.

After project team understood the context of the project, formulated the questions concerning the project with rich pictures and root definition and determined the expectations from the project the vision and mission of the project was created.

The vision of the project is to model accurately the "*life history of the fortresses*" within a GIS project to determine more accurately and efficiently the architectural changes from 17th century to the present day and to explore the natural, economical, social and political events, which have caused structural changes to the fortresses and surrounding buildings and environs.

The mission of the project includes:

- modeling "*GeoHistory*" as a comprehensive 4D geo-processing model for historical documentation research with the help of historians in the project team defining the problems and expectations,
- developing "Temporal (4D) GIS (TGIS)" of the fortresses since "life-history of the fortresses" changed continuously over time,
- developing "Object-oriented GIS (OO-GIS)" of the fortresses to abstract the reality on a business model more effectively,
- developing "Virtual (3D) GIS (VGIS)" of the fortresses to allow the viewer to be immersed in the model, therefore increasing perception and realism,
- developing "Internet GIS (Web GIS) or distributed GIS" of the fortresses to publish GIS application through world wide web (www) due to cost-effectiveness and wide accessibility,
- developing "Integrated GIS" of the fortresses to utilize spatiotemporal object data model (ST-Object model).

The system based on the vision and mission of the project was designed and the strategic plan of the project was produced due to the requirements and the phase of analyzing. Flow chart of the stages and timings were constituted upon the strategic plan or GIS development process. Management of the project is being realized on internet via web site of the project as an e_management.

The strategic plan of the project includes following stages:

- Making a project web site,
- Breaking the GIS project into its components,
- Data Modeling (database modeling and design),
- Nature of database, type of data, how stored etc. (database construction),
- Geo-Visualization,
- Publishing through Internet,
- Spatial Queries and Analyses,
- Integrating all components,
- GIS use and system maintenance.

Project web site that has been developing website for managing the multi-participant GIS project over internet transforms a data source into communication hub and an analysis tool effectively for project members and users to share information about the project and discover the fortresses and historical background of them.

3. GIS MODEL: *GeoHistory*

"*GeoHistory*" is temporal 4D (3D+Time) interactive GIS model with object-oriented approach based on multimedia application through Internet environment to model accurately and efficiently the life history of the fortresses. This model which is an application with interactive interface on internet to manipulate the historical information, recreate and visualize the fortresses and the cemetery consists of three modules:

- *GeoHistoryRepository* which is a data modeling and database component of the GIS project.
- *GeoHistoryVirtualInterface* which is a visualization component of the GIS project and the user accesses with web browser and walks around the fortresses in virtual environment.
- *GeoHistoryQueryInterface* which is an internet component of the GIS project and the user manipulates and displays the system.

Building 3D models, storing them and providing a user interface to visualize and manipulate them require new database and graphic technologies and robust programming languages. What is really needed is a model such that all data and functions can be accessed and manipulated in one seamless programming environment. "*GeoHistory*" is being implemented in order to build an open, seamless development environment. This paper will describe the design of "*GeoHistory*" and integration with its sub-components, such as "*GeoHistoryRepository*", "*GeoHistoryVirtualInterface*", and "*GeoHistoryQueryInterface*" and provide an efficient method of documenting historical structures.

3.1 Database Component: *GeoHistoryRepository*

Most information applications are built on an underlying business model that includes a semantic description of the information content for a system. Using expressive and powerful

modeling techniques is imperative to accurately capture this business model. A data model is a plan for building a database. To be effective, the data model must be simple enough to communicate to the end user the data structure required by the database yet detailed enough for the database design to use to create the physical structure. (Guney et al., 2003c).

Database and database management have become the key components of the GIS projects. As the need for large and complex databases continues to grow, more effective access to the data is needed than ever. Developing of a GIS data model is an important step in order to integrate large volumes of different data. However, searching and analyzing the data can become very time consuming and complicated. Data modeling is probably the most labor intensive and time consuming part of the development process. Data models are critically important to GIS because they control the way that data are stored and have a major impact on the type of analytical operations that can be performed. (Guney et al., 2003c).

Additionally the step from 2D to 3D causes several problems; building three-dimensional models, storing them and providing a user interface to visualize and manipulate them. As 3D GIS applications become increasingly important, new database technologies such as object-oriented database management systems (OODBMS) are essential. Object oriented programming systems (OOPS) are now recognized as a key component in building powerful applications which are robust and maintainable and which are also to be seamlessly extendible. (URL1, 2003).

Spatio-temporal data model has been widely studied by researchers from different perspectives to model dynamic phenomena in GIS. Furthermore, an object-relational data model gradually becomes an industry trend because it borrows rich data types and operations from relational models and concepts from object-oriented models. On the other hand, many GIS data models have been proposed to incorporate temporal information into spatial databases like a spatio-temporal object model (ST-Object model) that represents the world as a set of discrete objects hold in both space and time. GIS needs a complete and rigorous framework for geographical data modeling to overcome the difficulty in handling geographic complexity, scale differences, generalization, and accuracy.

A data model named "*GeoHistoryRepository*", which is an open ending object-oriented approach to GIS, is being designed for "GeoHistory", 3D interactive GIS model, as a means to integrate all the themes and provide the user with the ability to organize, update and display spatial, and attribute data according to the scientific and thematic domains. The scientific domains are history, art history, Ottoman history, archaeology, architecture, land surveying and geodesy over 3D base map provided by the Geodesy Division of Istanbul Technical University. (Guney et al., 2003c)

The data model is one part of the conceptual design process. The other, typically is the functional model. The data model focuses on what data should be stored and how data should be designed in the database while the functional model deals with how the data is processed and how the queries and analyses are designed. (sofia2).

The concepts and technologies used to develop the module of "GeoHistoryRepository":

- Spatial Theory: Spatial Thinking (cognition) and Spatial Reasoning
- Spatial Data Structures and Spatial Relations
- Spatiotemporal object model
- Entity-Relationship (ER) Modeling and ER diagrams which represent the data structures in a pictorial form, Object modeling,
- Conceptual Data Model which is a conceptual description of the main types of objects and relationships between them,
- Logical Data Model which is an implementation-oriented representation of reality that is often expressed in the form of diagrams and lists describing the names of objects, their behavior, and the type of interaction between objects,
- Unified Modeling Language (UML) which is a modeling language,
- Physical Data Model describes describe the exact files or database tables used to store data, the relationships between object types and the precise operations that can be performed,
- Databases: Oracle, MySQL, Access etc.
- Query languages, such as Structured Query Language (SQL), SQL3.0, Object-oriented query processing.

The goal is to develop a GIS data model for a 3D historical documentation with spatial and non-spatial data under the same architecture and to implement a complete database system based on this data model. The next component explains a graphical user interface which allows interaction with the data in "GeoHistoryRepository".

3.2 Visualization Component: *GeoHistoryVirtualInterface*

GIS is generally related to 2D maps combined with thematic maps in the market, on the other hand "Virtual 3D GIS" applications let the ability to immerse in three-dimensional virtual worlds and interact with geographical information in real-time. The purpose of the visualization component of the GIS project is to represent graphically spatial reality of the fortresses, their surroundings and spatial relationships between the artifacts, the architecture, and the topography as realistic as in 3D display and full color that allows the viewer to more quickly recognize the issues within the life history of the fortresses. Moreover, 3D modeling of geographic scenes presents opportunities of scientific exploration and visualization that are not possible in 2D. In this spirit, "*GeoHistoryVirtualInterface*" is being developed as an immersive virtual reality environment to explore the productivity of the documentation of two Ottoman fortresses on the Dardanelles. The project team hypothesizes that the use of an immersive virtual reality interface to the GIS will allow investigators to easily perform complete and accurate spatial analysis of the data collected. Interactive navigation through the virtual historical site, by means of walkthroughs and flights over the model will be provided, therefore increasing perception and realism. The 3D overlays will enable the user to perform complex queries of the information and see the results displayed together within the virtual environment. (Guney et al., 2002)

The historical scenario being created in this research is derived from investigating of life history of the fortresses. Historical documents, archaeological evidence, as well as imaginations are indispensable in the completion of the work. The object oriented approach and GIS are tools for helping historians to investigate the best model and virtual reality is a visualization technique to present the model in 3D with navigator called "*GeoHistoryTutor*". (Guney et al. ,2003d) With being developed system the users are not required to have a previous knowledge of computers or GIS and they are unaware that they using GIS. While designing the system, it was kept in mind that the total system must be highly interactive so that the users can proceed in one of the scenarios offered to the user. The concepts and features of fortresses are explained through graphic illustrations, supported by brief textual descriptions. For example, "GeoHistoryTutor" can be used to explore the identities and experiences of different persons who could have lived or been involved in the construction of the fortress. One could choose the figure of the patron of the fortress, the commander of the navy that was stationed there, the mason who built the Turkish bath etc. The common point for all scenarios is to give an abundant amount of historical information concerning monuments. (Guney and Celik, 2003a)

In order to generate a realistic representation of the fortresses the system developers in the project team have focused on developing a flexible "Graphical User Interface (GUI)" on Internet that builds to facilitate data access and interaction for navigating the site and accessing to standard GIS capabilities such as query, selection, spatial analysis, etc. and their distribution through web. (Guney et al., 2002) As the development of the geospatial interface for GeoHistory demonstrates, the GUI plays a key role in facilitating effective communication between the tool developer and user about data and model scales.

JAVA\VRML approach was chosen as a means of visualizing in 3D because it offers a platform and software independent interface. Its flexibility, ease of transfer and for the viewing options it allows users are the other specifications to select in 3D applications. Developed Java or JavaScript codes provide that the user can easily interact with the 3D VRML model, predefined walking or flying around and through it. VRML is also the chosen 3D format for the Web. There are many VRML browsers that can be used to view and interact with the model; although there is considerable variation in how well they render the models. This approach, however, 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 a virtual interface to 3D GIS. (URL2, 2003; URL3, 2003)

GIS is acquiring ever more multimedia functions. These multimedia abilities are potentially very useful in a historical documentation context to describe and visualize built environments. It is now possible to display pictures within a GIS, to run animations based on abstract maps as well as video clips and photorealistic VR panoramas, and to link such media to many of the data and functions of the GIS. Much graphics software is moving to web. It is now possible to develop extremely elegant and powerful animations, 3D design, and virtual reality systems in a networked environment using such technologies like VRML and QuicktimeVR (QTVR) variants. "QuickTime VR" and "streaming digital video" multimedia

techniques have been mixed for optimal viewing in order to construct the realistic model of the fortresses, or to visualize the existing environments and interiors of the historical structures. (Guney et al., 2002).

3.3 Internet Component: *GeoHistoryQueryInterface*

Access to spatial data and interactive database applications with querying capabilities over the internet is growing rapidly. Internet has already been one of the important developing platforms of GIS, the function of GIS has been extended by Internet, and furthermore it becomes a kind of new GIS architecture. The current paradigm shift involves the migration of application software from individual desktop computers into an internet-based client/server architecture. (Guney and Celik, 2003b) As a result, it is seen large-scale development of GIS applications that can be accessed by a great number of users through a web browser interface. Internet GIS is a network-centric GIS technology that uses the Internet and the World Wide Web as a primary means of providing access to the functionality (i.e., analysis tools, mapping capability) of GIS and to the spatial data and other data needed for various GIS applications.

Major advantages of web-based GIS system: (URL4, 2003)

- GIS client software is not required since GIS software is installed only on the server. Therefore, GIS access is free of charge (unless a charge is imposed on the server connection). However, some map servers may require installation of a plug-in to run the software.
- The client interface is the web browser. All the user needs for access a web browser such as Netscape or Internet Explorer with a connection to the Internet.
- The end user does not need special GIS training or skills.

The internet has brought GIS, high quality maps and virtual 3D applications to any internet user's web browser, which has changed the science of GIS in recent years. Web distribution of GIS is related to the forms of 2D or 3D web mapping. Current forms of output for 2D maps from GISs are many and include bitmap, gif and pdf. An attractive format is VRML for distributing 3D GIS output. VRML browsers work as plug-ins for common Web browsers and are currently available for most platforms. (Guney et al. ,2003d).

"*GeoHistoryQueryInterface*" module based on three tier client/server web GIS architecture is an interactive geo-query tool designed to promote the usage consisting of a large geo-database, "GeoHistoryRepository", with querying capabilities that includes the ability to output results in a map-based format using a GIS. This web-interface developed contains an application that enables query and extraction of the information belonging to fortresses and interactive mapping. (Guney and Celik, 2003b).

The technologies are applied to design and implementation of virtual 3D GIS on www environment:

- Virtual Interface: Application Programming Interface (API), External Authoring Interface (EAI), Graphical User Interface (GUI)
- 3D Internet modeling languages: VRML, GeoVRML, X3D, X3jD
- Internet programming languages: JAVA, JavaScript, PHP, ASP, Common Gateway Interface (CGI)
- Multimedia: Open Graphics Library (OpenGL), QuickTime Virtual Reality (QTVR)
- Three-tier architecture: first tier (web browser at the client side), second tier (web server and map server), third tier (database server)
- Markup languages: Extensible Markup Language (XML), Geographic Markup Language (GML), LandXML
- HTML authoring: internet web browser, web-authoring tools (MS Office FrontPage)
- Internet Map Server (IMS): AutoDesk Map Guide, Esri ArcIMS
- Flash, Studio Max
- Software Packages: 3D Studio Max, Adobe Photoshop 2D, Flash

4. CONCLUSION

The modules of "GeoHistory", "GeoHistoryRepository–GeoHistoryVirtualInterface-GeoHistoryQueryInterface", is being linked each other with hyperlinks and internet programming like scripts of Java, PHP and worked together on web. Whilst the project has been successful in that it hides the size and complexity of the system behind an easy to use interface, the real success of "GeoHistory" has been the development of a GIS optimized for use over the Internet that integrates various technologies in a model. Once completed the integrated GIS of the fortresses can be used to discover the fascinating past of these historic structures, and to discover the present problems that face these cultural heritage sites.

This study is focused in the reconstruction of the fortresses of "*Seddülbahir*" and "*Kumkale*" and the cemetery of "Kumkale" in the virtual environment. This application helps the project members, architects, archeologist and art historian to centralize database, predicts the cultural heritage after recreation and provides history information for people who are interested in. Therefore, this study is very interesting for tourists and people who are trying to discover the past.

In developing the system, GeoHistory, the system providers are utilizing various visualization and interaction techniques, web and database technologies adequate for this specific GIS application of historical documentation. In addition, by evaluating its usefulness in its final field of application the providers hope to define techniques that could also be used in other GIS projects.

Both the production of maps and the development of the GIS of the fortresses have been realizing in the laboratory of "IGS-ISTA Satellite Observation and Processing Laboratory" in Istanbul Technical University. Any one who is interested in the project can follow the

progress on the integrated GIS project with the project web address “http://www.seddulbahir-kumkale.com”.

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BIOGRAPHICAL NOTES

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