ARCHAVE: A virtual reality interface for archaeological 3D GIS

Master’s Thesis Proposal

Daniel Acevedo Feliz
Computer Science Department. Brown University

December 19, 1999

Abstract

Archaeological researchers often use Geographical Information Systems (GIS) for the analysis of their findings because of the capabilities of these systems to generate spatial correlations and visualize large amounts of data. These very features become a problem when the information is not confined to a 2D plane but has a strong 3D character. In that case, the use of an adequate user interface marks the difference, either by allowing the investigator to really visualize all the information as data, or creating such cluttering that important features are not seen.

I hypothesize 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 archaeological site, by means of walkthroughs and flights over the model will be provided.

The system will be tested on the database created for the ongoing excavations Brown University has been performing at the Great Temple of Petra (Jordan) since 1993 [JOUKOWSKY98]. The cave in the Technology Center for Advanced Scientific Computing and Visualization, as the main facility, and the workbench in the Graphics Lab at the Department of Computer Science, as a development and testing environment, will be the two VR working environments used for this project. I will begin by developing the connection between the GIS package, ESRI’s ArcView, and the VR API, JOT. The next step will be implementing both the navigation interface, to effectively move through the virtual site, and the GIS interface, to perform basic operations like data overlaying and intra-theme operations. Finally, a virtual flight application will be integrated, using level of detail (LOD) techniques for terrain visualization, and more advanced GIS operations, like individual artifact identification, will be also implemented.

To test my hypothesis, several archaeologists will be asked to compare, based on their experience, typical analysis methods vs. three different versions of the system: Using direct desktop access to the GIS package, a semi-immersive version in the workbench and a fully immersive virtual environment using the cave. Post test comparison of the different approaches they took in each situation, and analysis of the results and conclusions obtained for the Petra site will be performed.

1 Introduction

In archaeological practices, there are a few recurring research methods applied to each site regardless of its specialized conditions. As excavation begins, archaeologists must find a dig system that will allow them to precisely record each object they unearth [SHARER80]. This can be problematic because, while they want to excavate and record as much of the site as possible, it is very time consuming to record each object and its traits. On site, archaeologists must make important judgments about the object to record, characteristics of those objects and their relationship to the site and the culture they came from. Because of the large quantity of artifacts and site information to record, they must do all of this under severely limited time and cost constraints [SHARER80].

At the Great Temple site in Petra, the "archaeological record" has been limited to bulk and special find artifacts [JOUKOWSKY86]. The find locations are limited to trench/locus definitions (see apendix for archaeological terminology). Defining an exact, globally referenced, in situ location for each object and attributing specific qualities (object type, use, condition, weight, texture, etc.) of a find would be the ideal. However, in the majority of cases, gaining all this information is far too time consuming and costly to achieve. Therefore, storing this information and producing a 3D model is a difficult task for most researchers. As a result, they rely on statistical analysis of bulk finds and other similar methods.

In the past, archaeologists could query a database and retrieve statistics about artifact concentrations throughout a site. This allows them to do statistical analyses with data that exists in tabular format, but when the data to be analyzed has an important three-dimensional component, this format is clearly not enough. The use of GIS has improved these studies but still limits them to 2D overlays as graphic representations of data. More recent software has introduced 3D visualization capabilities to these systems. With this additional dimension, there is a strong possibility for advanced queries of data. I believe the system which I am proposing will also provide the adequate interface for investigation of large three-dimensional data sets and representation of query results in an immersive 3D environment.

2 Background

A definition of GIS is a set of tools for collecting, storing, retrieving and displaying spatial data for a particular set of purposes [BURR98]. This definition describes concisely the four major components of every GIS, each of them implemented by different pieces of software and hardware that vary depending upon the use of the system. Many GIS users have difficulties accessing their spatial data with current user interfaces, and Virtual Reality offers a more natural interaction with it. Since VR is about the production of a simulated physical world, and some GIS databases contain three-dimensional data about this world, the combination of both technologies is obvious [KRAAK99].

The origins of GIS can be placed in the early 60's when the Canadian government ordered the creation of a Canada-wide land use inventory. The necessity of a system to efficiently do this job led to the creation of the Canada Geographic Information System, the first GIS in the world [TOM90]. Since then, multiple applications of GIS in a variety of disciplines had been developed: Land use and territorial management, urban planning and cadastral information systems, civil engineering applications (road and channel planning and design, for example), epidemiological studies for geographical distribution of different diseases, market analysis and commercial decision-making systems, phone and electrical companies database systems, archaeology applications and military simulations are some of them.

The introduction of virtual reality techniques in the process of managing spatial data has generated a whole new separate group of systems called, as expected, VRGIS. Giving freedom of movement, interactivity and immersion to the 3DGIS user is the main advantage introduced by VR interfaces [NEVES95]. The same way we analyze a map with total freedom (either a physical or a computer generated representation of it), these new systems provide the investigators with the same interactivity but, in this case, being immersed in the virtual 3D representation of the data.

Research efforts to study the links between GIS and VR can be found in [MCGRE93], [RAPER93], [SCHEE95] and [RHYNE97], where the authors try to demonstrate the utility of this new interface to efficiently interact with three-dimensional data, stating the main characteristics of such systems [FAUST95]:

- Realistic representation of the three-dimensional nature of real geographic areas.
- Freedom of movement for the user within the selected terrain.
- Access to standard GIS capabilities such as query, selection, spatial analysis, etc.

Multiple practical applications using virtual reality in combination with GIS have been developed since then. One of first projects was the VGIS project at the Georgia Institute of Technology [KOLLER95]. This system uses a head mounted display (HMD) for the immersive virtual reality interface version. For the interaction with the GIS, pop-up menus are displayed in front of the user and any information is displayed in a similar manner. The ARCHAVE system will explore new ways of interaction developed towards their use in VR, like speech recognition or a virtual belt of options, rather than adapting classical WIMP interfaces.

Another interesting project is the Virtual GIS Room project [NEVES95] developed at the New University of Lisbon (Portugal), in which, using also a HMD, the user was able to select different terrain sections to visualize and decide among several layers of information to be draped over it, simulating the actual job in a real GIS room. My system will use the cave and the workbench, which are projective environments in which the rendering process for real time interaction is less computationaly intensive than HMD systems. Since these first projects, the number of applications and research projects that involve VR and GIS have increased constantly [HAKLAY99].

Cave-like systems are not being used as much as the ones mentioned. One recently presented project is the Karma VI system [GERMS99] in which different virtual reality interfaces are used, including desktop VRML, the workbench and the cave, although the latter is only used for presentation purposes and the interaction with the GIS is very limited.

Regarding archaeological applications of GIS and VR, projects with data representation and analysis using GIS are being conducted by archaeologists almost exclusively in the area of mapping and remote sensing. This is probably because GIS applications were developed to accept topographical and other 2D feature plans as overlays in order to understand how each set of attributes could be related.

There has been some experimentation with VR by archaeologists and architectural historians who are interested in the reconstruction of lost civilizations such as Pompeii, Rome, Athens and at a variety of smaller scale sites. In most cases, when funding allows, VR is being used mainly to reconstruct buildings and sites that no longer exist or those that have been so damaged that reconstruction is needed to understand what they originally looked like. There has been a few attempts to visualize data in 3D but for a very small area with a minimum number of object types [HERMON99]. In a larger site like ours, this would not be very useful. To my knowledge, there are no projects trying to link GIS and VR in archaeological research.

3 The system

The application created for this project will have three main parts:

- The VR end, created using the JOT libraries for the cave. Implemented interaction techniques will be based on the use of PinchGloves, a Wand-type navigation device and speech recognition using BBN Hark Speech Recognizer. This code will be adapted to run both in the cave or in the Barco Baron Table.

- The GIS package, that will be ESRI's ArcView.
- An intermediate web client will be implemented to create the connection between JOT and ArcView's Internet Map Server (IMS) application. Thanks to this last application, ARCHAVE will be able to run on remote GIS databases via the web. Allowing also several researchers to interact with the same project at the same time. For this project, the GIS will run locally.

The ARCHAVE project will be done in collaboration with Eileen Vote, PhD candidate in the Department of Old World Archaeology and Art at Brown University, who developed the GIS database for the Great Temple site. She will also create the main 3D model of the temple which will be adapted to JOT. The GIS package that we will use, ArcView, will be provided by the EarthLab of the Department of Geology at Brown University.

The Great Temple Site, in real life scale, is approximately the size of a football field. Therefore, when we model it and visualize it in a cave environment, the user will have a large area to explore. The user will have full mobility inside the environment. Upon entering the Great Temple virtual site, there will be the option to view different layers of information. For example, if a user is not familiar with the site, he/she will probably want to view the terrain with the architecture only, to gain a frame of reference. As the user becomes familiar with the setting, additional layers can be added for a more complex investigation.

To begin to understand data derived from the archaeological excavation, the user can add, for example, the trench layer as needed. With the trench layer added, the user will see a visual representation of the dig matrix that was imposed on the site by the archaeologists. The next layer that can be added is the locus formation within each trench. This information will help the user to understand how each trench was excavated and, when artifact data is also added, artifact concentration and special find information.

The layers that will be added at this point will have specific delineations that will allow for multiple types of data to be viewed together. The user will be able to visually differentiate between the layers and data types by recognizing the different physical traits used. For example, the higher the level of pottery fragments found in a locus the less transparent the locus representation is. The user will be able to visually differentiate between the layers throughout the site with the most dense pottery concentrations by floating layers with a variation of color. That will be one level of cognition for the user.

A next possible layer can be added to indicate special find spots such as where important sculptural finds were originally found or architectural fragments. A sculpture of the Goddess Tyche was found in an area of the lower temenos between the east exedra and the triple colonnade. Additional important special finds were found in a cistern nearby [JOUKOWSKY98]. This type of information, obtained while visiting the site at real scale, can be very important for architectural reconstruction purposes and to figure out where those pieces fall from (parts from a wall, from the roof, etc.). If the user would like to take a closer look at these finds, he/she can pick up a specific find and move it to a different location for a close comparison with other special finds.

Additional representations of find values can be added as layers with different attributes. For example, after viewing high pottery concentrations and special find, the user can add bone concentrations as a textural component. Textural values can be represented as bump mapping.

Summarizing, in a first implementation, the kind of queries that will be implemented will involve requests for layers of information, that is, trench situation, locus situation per trench, pottery distribution across the trenches, special findings (coins, lamps, etc.) distribution, etc. Each query result will have individual physical traits (linear delineation, color, solid or transparent and texture) that can allow the user to distinguish between the various layers and ranges within each layer. More complex queries will require displaying text with specific information. This will be done by using a portable CLIO tablet in the cave/workbench.

4 Timeline

The proposed schedule is for an estimated time of 8 months, specifying tasks and goals in a monthly basis:

- *Month 1 (February 2000):* Implementation of the web client. Adaptation of the Great Temple model to JOT and getting the topographical data of the site ready. Simple navigation (using already implemented techniques) through the model will be possible. The connection VR-GIS will be in place.
- *Month 2 (March 2000):* Implementation of the walking interface using the Wand. The terrain data should be in place and the first walk-through the site at real terrain level will be possible.
- *Month 3 (April 2000):* Customization of Avenue scripts and creation of GIS interface in the cave/workbench. Requests made to the GIS from the VR end will be possible and the first UI's will be tested to decide the best solution.
- *Month 4 (May 2000):* Creation of the data visualization models. How the results are displayed in the 3D environment. Different possibilities will be tested.
- *Month 5 (June 2000):* Intra-theme visualization models. Different transparencies, texture maps, shapes, color, etc. will be tested.
- *Month 6 (July 2000):* LOD implementation and flight interface. Different techniques will be tested and implemented to accomplish optimal performance.
- *Month 7 (August 2000):* CLIO tablet integration and final GIS querying methods. Specific data about individual artifacts will be available and the tablet will be used to display it.
- *Month 8 (September 2000):* Final review and testing of the system. Design and perform a user study to qualitatively define, as much as possible, the success of the system as a helpful tool for archaeological research.

5 Contribution and conclusion

The main contribution of this project will be the creation of the first VRGIS application for archaeology research. We are setting up a system to model architecture and excavation data in 3D so that the user can interact with it at real-life scale in the cave. We will design a way to do 3D overlays of architecture, trench and artifact information so the user understands how the artifact layers relate to the architecture and vice versa. The 3D overlays will enable the user to perform complex queries of the information and see the results displayed together within the virtual environment.

New interaction techniques will be developed to allow interaction with the GIS database in the form of queries, overlaying of data and displaying of results. Navigation techniques will be implemented both for walking through the virtual site and flying over it, in combination with optimized LOD terrain visualization strategies.

A final test of the system and comparison with other interfaces, like desktop access to the GIS database, will help me probe the initial hypothesis that this system is usefull in archaeological research and allows a deeper and easier understanding of the spatial relations in large databases with three-dimensional information. The goal will be to try to visualize as much of the excavation data as possible to do analysis and comparison. Qualitative success with each interface will be measured and pros and cons of each interface will be addressed.

6 References

[BURR98] Burrough, P.A. and McDonnell, R.A. , 1998. *‘‘Principles of Geographical Information Systems’’. Oxford University Press.*

[KRAAK99] Kraak, M. , Smets, G. and Sidjanin, P. , 1999. *"Virtual reality, the new 3-D interface for geographical information systems". Spatial Multimedia and Virtual Reality, pages 131-136. Camara, A. and Raper, J. (Ed.).*

[TOM90] Tomlinson, R.F. , 1990. *‘‘Geographic Information Systems – a new frontier’’. Introductory readings in Geographic Information Systems, pages 18-29. Ed. Taylor & Francis.*

[MCGRE93] McGreevy, M.W. , 1993. *"Virtual reality and planetary exploration". Virtual Reality- Applications and Explorations. Wexelvlat, A. (Ed.).*

[RAPER93] Raper, J. , McCarty, T. and Livingstone, D. , 1993. *"Interfacing GIS with virtual reality technology". Proceedings of the AGI Conference, Birmingham: AGI.*

[SCHEE95] Schee, L.H. van der and Jense, G.J. , 1995. *"Interacting with geographical information in a virtual environment". Proceedings of JEC-GIS, The Haghe, Vol. 1, pages 151-157.*

[RHYNE97] Rhyne, T.M., 1997. *"Going Virtual with Geographic Information and Scientific Visualization". Computers&Geosciences, Vol. 23, no. 4, pages 489-491.*

[FAUST95] Faust, N.L. , 1995. *‘‘The virtual reality of GIS’’. Environment and Planning B: Planning and Design 1995, volume 22, pages 257-268.*

[KOLLER95] Koller, D. , Lindstrom, P. , Ribarrsky, W. , Hodges, L.F. , Faust, N. and Turner G. , 1995. *"Virtual GIS: A Real-Time 3D Geographic Information System". Proceedings of Visualization’95.*

[NEVES95] Neves, N. , Goncalves, P. , Muchaxo, J. , Jordao, L. , Silva, J.P. and Videira N. , 1995. *"Virtual GIS Room: Interfacing Information in Virtual Environments". Proceedings of the 1st Conference on Spatial Multimedia and Virtual Reality, Lisbon, pages 45-53.*

[HAKLAY99] Haklay, M. , 1999. *"Vi.R:G.In Catalogue". University College London. http://www.casa.ucl.ac.uk/virgin/cat/*

[GERMS99] Germs, R. , Maren, G. van , Verbree, E. and Jansen, F. , 1999. *"A multi-view VR interface for 3D GIS". Computers&Graphics, Vol. 23, no. 4, pages 497-506.*

Archaeological References:

[JOUKOWSKY86] Joukowsky, M. S., 1986. *"A Complete Manual of Field Archaeology: Tools Techniques of Field Work for Archaeologist". Prentic Hall Press, p.236*

[JOUKOWSKY98] Joukowsky, M.S., 1998. *"Petra Great Temple. Volume I: Brown University Excavations, 1993-1997". Providence, Rhode Island: Martha Sharp Joukowsky, 1998.*

[SHARER80] Sharer, R. J. and Ashmore, W., 1980. *"Fundamentals of Archaeology". The Benjamin/Cummings Publishing Company, Inc. pages 211-263.*

[HERMON99] Hermon, S., 1999. *Paper for the Computer Applications in Archaeology Conference, April, 1999. (not yet referenced.)*

7 Appendix

*Archaeological Terms***:** (from: Joukowsky, Martha Sharp, "A Complete Manual of Field Archaeology: Tools Techniques of Field Work for Archaeologist", 1980, Prentic Hall Press).

Locus:** a unique designation for a volume of earth that is recorded separately along with its level. (Once features of soil differences are encountered, or if each side of a wall or part of a room is excavated separately, these areas are assigned separate locus numbers; thus if the excavation is in level 5, and the locus was number 2, it would be recorded 5-2.) Locus numbers are assigned either by the field director or the supervisor.

***Special Finds*: Certain types of finds are processed in a distinct manner; they receive special cataloging treatment because of their specific nature and the unique evidence they provide. Coins, intaglios, inscriptions, scarabs, cylinder seals, and seals may present a detailed or schematic study of a personage, a monument, a mythological theme, and/or an inscription commemorating an event. As such, they manifest the artistic development of the populo who fashioned them. As artifacts, they are portable and durable and are of great importance to the scholar. Each of these respective finds and their details must be examined thoroughly for their proper interpretation, and the cataloger must pay particular attention to their conservation and style.

***Bulk Finds (explanation):* Because so much depends on having a complete , accurate record, the catalog card has been deliberately kept free of too much detail so that all, or nearly all, objects can be recorded, rather than recording a few finds in great detail and others not at all. Briefly, an overview of special find processing is as follows: when a find is unearthed, excavation stops while the square supervisor cleans around it, measures its position, and records it in the field notebook. The find is allocated a serial number, described measured, sketched and photographed and mapped on the site plan. The same day, the tagged object with its Special Finds Form is placed in a plastic bag and is deposited with the cataloger. Naturally, coordination between the square supervisor and the cataloger is essential to assure the accuracy of information and the proper care of the find.