CAA 2009 Williamsburg

Developing an Intuitive GIS Interface for Archaeological Data at the Pyrgos Museum, Greece

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Abstract

The Pyrgos museum project was undertaken to develop an interactive computer installation for the Archaeological Museum at Pyrgos, Greece. The installation's GIS interface allows museum visitors to virtually explore Byzantine, Frankish and pre-Modern sites located within the prefecture of Eleia. While GIS provided options for preserving the spatial context of the project data, usability issues associated with the design of most GIS software necessitated an examination of user needs and interface design. The project focused on the needs and expectations of museum visitors and implemented a series of observations of users to improve the usability of the application. Usability assessments and informal discussions with users provided input for the redesign of the application. OpenSource software and "slippy maps" developed using OpenSource libraries for Adobe's Flash CS3 platform were used to provide an intuitive interface for museum visitors. The installation is both a learning tool for users and a catalogue of sites, structures and settlements for the region that can be served to the public through the exhibit or the internet.

Key words: *GIS, Web mapping, Usability, Museum*

1 Introduction

Geographic Information Systems (GIS) provide a robust foundation for developing interactive museum installations and web based educational tools. Unfortunately, the advantages of GIS applications are frequently offset by usability issues.[1] The tools and terminology used in off the shelf software are tied to the fields of Geography, Cartography and Computer Science and often are not intuitive to individuals without a background in these disciplines or Geographic Information Science. Museum installations and web based educational tools that implement GIS software must keep this in mind and take usability into consideration throughout the process of design and implementation. These concerns have become integral to the development of an interactive

[1] Carol Traynor and Marian G. Williams. "Why Are Geographic Information Systems Hard to Use?," In Mosaic of Creativity. Proceedings of ACM CHI'95 Conference on Human Factors in Computing Systems, Denver, Colorado. Denver: ACM, 1995. http://www.sigchi.org/chi95/proceedings/shortppr/ct_bdy.htm (accessed 4/21/2009).

David J. Medyckj-Scott "Designing Geographical Information Systems for Use," In Human Factors in Geographical Information Systems, edited by David Medyckyj-Scott and Hilary M. Hearnshaw, (London: Belhaven Press, 1993), 87-89.

Hilary M. Hearnshaw and David J. Medyckyj-Scott. "The Way Forward for Human Factors in GIS," In Human Factors in Geographical Information Systems, edited by David Medyckyj-Scott and Hilary M. Hearnshaw, (London: Belhaven Press, 1993), 235-240.

installation for archaeological data at the Pyrgos archaeological museum, Greece. This paper discusses the development of this installation and the methods that were employed to enhance the usability of the application.

2 PROJECT OVERVIEW

The Pyrgos Museum project is a collaborative effort involving researchers from the University of Minnesota, Maryville University in Saint Louis, Clemson University and the Greek ministry of Culture, Directorate of Museums, Education, and Exhibition Programs of the Sixth Ephorate of Byzantine Antiquities. The goal of this collaboration is to provide public access to settlement and architectural data for Byzantine, Frankish and pre-modern sites in the prefecture of Eleia. These sites are distributed across a large and topographically diverse region that contains a wealth of archaeological remains. Some archaeological sites remain hidden on hilltops and mountainsides, while others are embedded within the fabric of modern cityscapes. The geographic nature of the data calls for a spatial solution, which has taken the form of a geospatial kiosk located within the museum.

The museum installation provides visitors with digital access to information at a range of scales and levels of detail. Users may browse settlements by type and period. Detailed information including typical floor plans, architectural decoration, and section and perspective drawings are available to users. Aerial photographs, satellite imagery, and rectified maps provide base layers for examination of regional patterns. 2-D and 3-D visualizations of settlements provide additional information about site layouts and organization on a local level.

The museum's geospatial kiosk functions as a learning tool and a living catalogue of the archaeological materials of the region. The location and details of sites and their contents are maintained on a central database and the information associated with each site is made available to the public through the installation's interface.

3 MOREA INVESTIGATIONS

The Pyrgos Museum project developed from earlier investigations conducted by the Minnesota Archaeological Researches in the Western Peloponnese (MARWP) and the following introduction to this work provides a context for the development of the current museum interface. In 1990, MARWP began an architectural survey called the Morea project to document previously unrecorded vernacular architecture in the northwest Peloponnese of Greece. From 1990-1997 researchers involved in the Morea project inventoried Frankish and pre-modern sites, collecting detailed information about pre-modern architecture and settlement distributions throughout this part of Greece. Building coordinates, architectural details (see fig. 1) and descriptive data were catalogued by MARWP field crews and entered into a project database.[2]

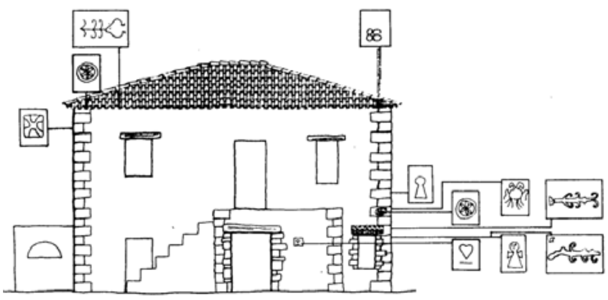

Figure 1. Inked drawing illustrating architectural details catalogued by the Morea Project.

Additional information drawn from Venetian records, modern census data, oral histories and textual sources provided a historical context for the surveyed features. The data recovered during these investigations was published in 2002[3] and forms

[2] Todd Brenningmeyer et al. "Satellites, Silicon, and Stone: Spatial Information and Greek Archaeology." Geo-Info Systems Magazine. January (1998): 20-28.

[3] Frederick A. Cooper. Houses of the Morea. (Athens: Melissa Publishing House, 2002).

the foundation dataset for the Pyrgos museum project**.**

In 2005, MARWP researchers made this data publicly available through a web GIS application served from the University of Minnesota (http://marwp.cla.umn.edu/gis; hereafter MoreaGIS).[4] The interface used PHP and JavaScript to display and interact with maps that were generated using the University of Minnesota's MapServer software.

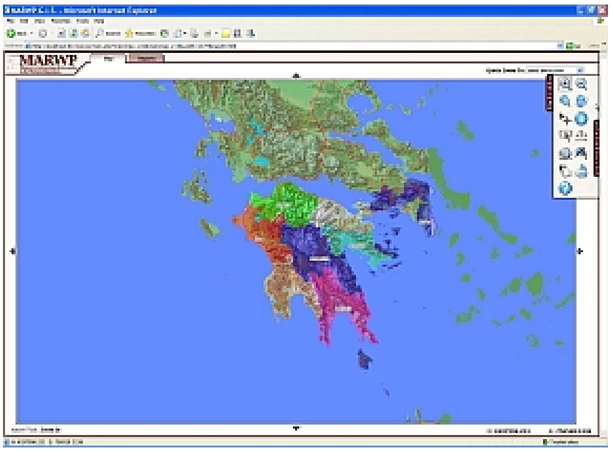

Figure 2. MoreaGIS website with tabbed toolbars.

As with the current museum project, attributes were stored in PostgreSQL with PostGIS providing access to the geographic objects in the database. The application emphasized the mapping window and moved attribute displays to expandable tabs (see fig. 2). Options for digitizing new features were built into the application to enable users to add to the existing database. The result was an application that was innovative but not unlike other web GIS of its time.[5] The MoreaGIS modeled its interface on traditional GIS software. The tools and user interface departed only slightly from off the shelf GIS products such as ESRI's ArcView and ArcIMS platforms. Standard GIS tools enabled the user to zoom, pan, identify and select geographic features. WMS requests to the server generated map images that were symbolized according to specifications provided in a mapfile. The design of the user interface was intuitive to those familiar with GIS software.

When we began work on the Pyrgos project, we used the MoreaGIS as our starting point. Initially, we were optimistic that we could port this application to the museum with relatively minor code adjustments. As we began to investigate the needs and expectations of museum users it became apparent that we needed to revise our approach. While the MoreaGIS made project data accessible to anyone with internet access, the interface was designed for users with an understanding of typical GIS tools and functionality. The application was not designed for or tested against groups with little or no GIS experience. As we began to take the needs of these users into consideration, issues of design and usability became central to the development of the museum application.

4 Usability Assessment

The process of development began with an assessment of user expectations and an evaluation of our original system, the MoreaGIS. The design of the new user interface was based in part on information derived from this evaluation. Our assessment methodology drew from usability and human-computer interaction (HCI) practices**.**[6] Usability is a broad term that encompasses the relationship between user, task, system and environment.[7] Evaluations of usability involve an

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[4] Todd Brenningmeyer and Frederick A. Cooper. "A Remote Inventory of Greek Vernacular Architecture: Online Capture of Spatial Information," In Layers of Perception. Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA), Berlin, Germany, April 2–6, 2007, edited by Axel Posluschny, Karsten Lambers and Irmela Herzog,. (Bonn: Dr. Rudolf Habelt GmbH, 2008): 243.

[5] For a similar approach see: M. A. Brovelli, D. Magni. "An archaeological webGIS application based on Mapserver and PostGIS." The International Archives of the Photogrammetry, Remote Sensing, and Spatial Information Sciences 34, Part5/W12 (2002): 89-94.

[6] Jakob Nielsen. Usability Engineering. (London: Academic Press Limited, 1993).

[7] David J. Medyckj-Scott. "Designing Geographical Information Systems for Use," In Human Factors in

examination of multiple attributes, which together provide a view into the effectiveness of the interaction between the user and the interface.[8] Nielsen[9] identified five components of usability that provide information about this interaction. These components include learnability, efficiency, memorability, errors and satisfaction. Following Neilsen's usability model, learnability can be defined as the ease with which individuals learn to use a system.[10] This may also be measured as the time required to reach a level of proficiency.[11] Efficiency is an attribute that describes the efficiency or productivity of the user when using the system. Memorability is an attribute describing the ability of a user to remember how to use the system. An error is an action taken by the user that does not produce the intended or desired result.[12] Satisfaction is a subjective attribute that describes how pleasant or enjoyable the system is to use.[13] The attributes proposed by Nielsen provided baseline criteria for assessing the original MoreaGIS application.

The museum application is developed for a unique environment and user group. These realities were also taken into consideration when examining usability through Neilsen's attributes. Unlike software developed for production environments, museum visitors are not compelled to use our application. The system's success is dependent on its ability to encourage interaction and use. User satisfaction is therefore among the most important attributes to evaluate. Likewise, visitors will not be trained in the use of this system. Unlike software developed for a workplace setting, our users must learn to interact with the application on their own. The interface should therefore be intuitive and build on basic computer skills that most visitors will have when they arrive. The efficiency of the museum application is closely tied to learnability and user satisfaction. Museum visitors are unlikely to spend inordinate amounts of time with the application. The design should enable users to extract information with a minimum number of steps. In terms of creating a positive experience for the user, the window of opportunity is limited by the attention span of the museum visitor and the applications ability to maintain and cultivate their interest. Since our users will not receive training prior to use the intent was to simplify the interface and focus on a basic but intuitive interface that will be understood by individuals with no prior experience with the system. This would enhance the user's ability to remember how to use the interface and also limit errors associated with this use.

5 USABILITY TESTING:MOREAGIS

In the fall of 2008, we installed the MoreaGIS in the Morton J. May Foundation Gallery at Maryville University and observed the experiences of visitors as they navigated the interface. The location offered an opportunity to test the application in an environment that is similar to the Pyrgos museum. The user group included a mix of faculty, students and numerous alumni and guests who visited the gallery during the annual alumni weekend. The users included individuals with varying levels of computer expertise. Observations and informal discussions were used to evaluate their experiences with the application.

The initial usability assessment provided feedback that was helpful as we began to design the museum application. We discovered that most users were unfamiliar with GIS tools used in the MoreaGIS. While the magnifying glass icon is frequently used in GIS software, this symbol did not clearly indicate the button's function or method of use (see

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Geographical Information Systems, edited by David Medyckyj-Scott and Hilary M. Hearnshaw. (London: Belhaven Press, 1993), 87.

[8] Mordechai Haklay and Carolina Tobón. "Usability Evaluation and PPGIS: Towards a User-Centered Design Approach." International Journal of Geographical Information Science 17, no. 6 (2003): 580.

[9] Jakob Nielsen. Usability Engineering. (London: Academic Press Limited, 1993), 26-37.

[10] ibid

[11] Mordechai Haklay and Carolina Tobón. "Usability Evaluation and PPGIS: Towards a User-Centered Design Approach." International Journal of Geographical Information Science 17, no. 6 (2003): 580.

[12] Jakob Nielsen. Usability Engineering. (London: Academic Press Limited, 1993), 32-33.

[13] Ibid, 33.

fig. 3). Users occasionally clicked the icon and waited for the map to change without realizing that the tool must be applied to the map canvas by clicking on an area of the map.

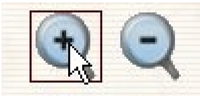

Figure 3. Example of typical GIS tools used in the MoreaGIS (zoom icons shown).

Likewise, many individuals did not understand terminology used in the popup labels that were supposed to clarify the function of these tools. For example, the term "identify" provided little help to users who were unaware that additional information could be accessed by clicking on this tool and then selecting specific objects on the map. Our observations were similar to those described in other GIS usability studies[14] but the impact of the toolset on usability was somewhat unexpected. In almost all cases, users were reluctant to change tools or to interact with the interface beyond the default zoom tool that loaded at startup. Informal discussions with visitors at the gallery reinforced our own observations: users were unaware of the function of the application's tools and did not know how to select or navigate the interface to retrieve additional information about houses or villages. Minimal delays (typically two seconds) associated with requesting and loading new maps during navigation also reduced user interest in the application. Gallery visitors expected images to load immediately, navigation and selection of features to function without changing tools, and of course an interactive experience throughout to lead them through the application. Users noted that the appearance of the maps as well as their speed of delivery also factored into their decision to use or abandon the application. We took these observations into consideration as we designed the new interface.

[14] Mordechai Haklay and Carolina Tobón. "Usability Evaluation and PPGIS: Towards a User-Centered Design Approach." International Journal of Geographical Information Science 17, no. 6 (2003).

6 PYRGOS MUSEUM APPLICATION

Our evaluation of the MoreaGIS provided some insight into the needs of our users. We used the results of this evaluation to drive the redesign of the map interface. The observations indicated a disconnect between the users' knowledge of GIS tools and terminology and the intended functionality of the application. Users were unsure how to use the selection, pan, and zoom tools and unwilling to click icons to switch between tools. This uncertainty frustrated many of the users who quickly left the application and moved on to other exhibits in the gallery. In the museum environment, where competing exhibits vie for the time and attention of the visitor, "…a low threshold for interaction is essential…".[15] The new interface needed to be comprehensible to most users and easy to navigate. It was particularly important to design the interface so that selection, pan and zoom operations were available without switching tools. The mapping window would drive the rest of the application and provide access to data, images and other content associated with each site.

The issue of integrating the zoom, pan and selection tools has been addressed during the past 4 years in the mapping applications of commercial internet providers. So-called "slippy-maps" have become the standard for distributing and exploring geographic data through the internet. These mapping applications, first popularized by GoogleMaps, provide integrated zoom, pan and select capabilities. Users simply click on the map and drag the image to pan to a new location. Zoom and select likewise function without switching between tools and rapid data loading is made possible through the delivery of multiple map tiles that provide a sense of continuously streaming data. Several OpenSource "slippy-map" libraries

[15] Eva Hornecker and Matthias Stifter. "Learning from Interactive Museum Installations About Interaction Design for Public Settings," preprint, Proceedings of OZCHI: 18th Australia Conference on Computer-Human Interaction: Design: Activities, Artefacts and Environments, Sydney, Australia, November 22-24, 2006. (Sydney: CHISIG, 2006), 4-5.

exist and we explored two of these during the development of the museum application. We first explored a popular JavaScript API known as OpenLayers (http://openlayers.org/). OpenLayers displays map tiles from commercial sources like Google, Yahoo and Microsoft as well as WMS servers like MapServer and GeoServer. OpenLayers also supports rendering of vector data in WFS, GML and other common formats, but it is not yet capable of effectively handling large or complex vector features. Performance degrades when handling more than 100 vector objects. The second platform we examined was ModestMaps (http://modestmaps.com/). Like OpenLayers, ModestMaps is an OpenSource library that can pull data from commercial map providers or WMS servers but it has much better support for handling vector data. ModestMaps also builds on the multimedia capabilities of Adobe's Flash platform, which provides tools and components for creating a rich user experience. Ultimately, the multimedia components in Flash and the possibility of developing an interface that served vector data to the user encouraged us to develop our application on the ModestMaps library.

We next turned our attention to the application's design. Our goal was to develop a "user friendly or intuitive" mapping application. The initial usability assessment provided guidelines for the design process. As noted above, users were not required to use the museum application. Successful implementation involved creating an experience that was compelling and enjoyable. The application, therefore, should be interactive as well as visually clear and inviting. This involved removing or redesigning components that were distracting and incorporating new features that would enhance user interest and satisfaction. Navigation and selection options were reduced to basic click and drag actions that are common to "slippy map" applications. Unlike the MoreaGIS, users interacted with the map canvas without switching between tools.

To encourage interaction with the application, we made all parts of the interface from the symbols to the legend responsive to user actions. Our intent was to give users multiple avenues to explore data served through the application. We leveraged the multi-media components in Flash to accomplish this task. The new interface replaced the static symbols used in the MoreaGIS website with movie clip objects with embedded behaviors and attributes that can be manipulated through the application's code. These symbols are not bound to layer specific rules that govern most web GIS systems but instead are individual objects that can respond to user input individually.

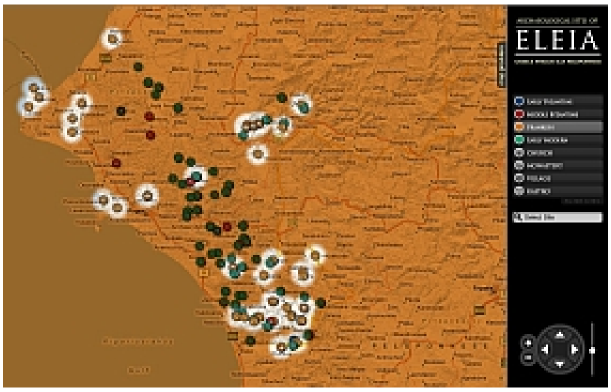

Figure 4. Pyrgos museum application with Frankish period sites highlighted.

The application builds and positions movie clips dynamically using the attributes held in the museum database. Interactive features attach to these icons and pull the user through the application. For example, animations linked to movie clips in the legend highlight sites by period and type (see fig. 4). Sites can be turned on or off by clicking the appropriate legend symbol, enabling users to filter displayed sites if desired. These animations respond directly to user actions encouraging the user to interact with ("click") all parts of the application. Additional animations, which outline the village extent and open a new navigation and report window, are initiated when the user selects a site symbol from the map (see fig. 5). The user can then explore the site using the interactive site map and report elements.

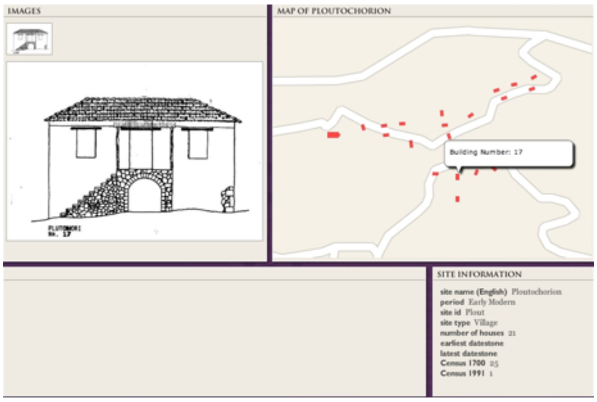

Figure 5. Pyrgos museum application, secondary map and report windows.

These components present site and building information as well as architectural reconstructions of building elements. The doorway reconstructed in fig. 6 provides an example of a template feature that was constructed from individual movie clips and assembled using database descriptions. In the future we hope to make such components more interactive so that users can select a specific lintel and retrieve additional information about it.

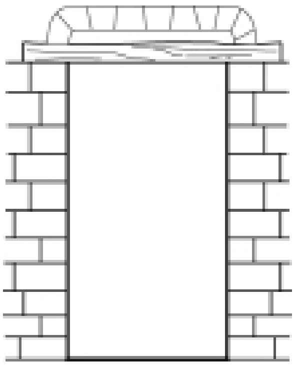

Figure 6. Example template feature constructed from movie clips

Porting the application to Flash provided new options for developing an interactive interface but the data distributed using the ModestMaps framework still needed a context. As noted previously, our users stated that the quality of the map as well as the speed of delivery were important for creating a positive user experience. While application speed is often discussed during development, cartographic quality is often overlooked. This criticism is not restricted to our own system or to archaeological GIS in general but is a reality that can be identified in many of the web GIS applications created during the past decade. We believed that there must be a happy medium between delivery and content and re-evaluated our approach to presenting background data to the application.

The earlier Morea application distributed data via WMS requests to the server. This request generated a new image file through MapServer and styled the map according to specifications in the mapfile. This is one of the most widely used methods to access and manipulate geographic data via the web. While WMS gives users the ability to control the visibility of layers served from the server, our observations indicated that few users were interested in manipulating the map in this way. Instead, users wanted a simple, cartographically pleasing context for the data points. They also wanted this data to load rapidly (seamlessly). As we redesigned the interface we moved away from WMS requests to the use of pre-built image tiles for our areas of interest. These prebuilt tiles provide a unified cartographic context and remove the processing overhead associated with complex WMS requests.

Google, Yahoo, Microsoft and other commercial (and some OpenSource) providers use pre-built image tiles in their applications. While each implement a slightly different approach there are commonalities that enable data from these providers to work seamlessly. Data generated by each application is presented in a common Spherical Mercator Projection which has become the standard for “slippy map” applications. The spherical Mercator projection simplifies calculations and given its wide use presents a view of the earth that despite its distortions is commonly understood. The pre-built tiles are stored on a server as 256 x 256 pixel images that are named according to rules developed by the provider. For example, Microsoft’s Virtual Earth dataset implements a system that identifies each tile based on its position and zoom level.[16] In fig. 7, a series of 256 X 256 pixel images are divided into tiles defined by their X,Y coordinate pairs.

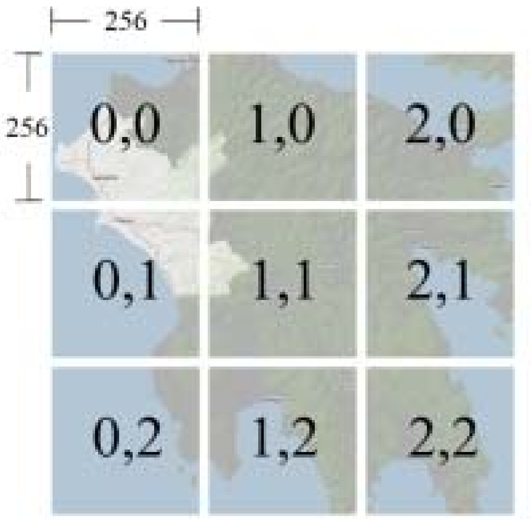

Figure 7. Illustration of tiled images used in Pyrgos application with cartesian coordinates.

In Microsoft's Virtual Earth these coordinate pairs are replaced by Quadkeys that uniquely name every tile based on the zoom and coordinate position of the tile itself (see fig. 8).[17] The client retrieves a specific tile simply by translating the geographic coordinate and current zoom level to the Quadkeys that occupy that space. The tiles are pre-rendered and can be pulled into the client rapidly without the overhead that is associated with on the fly generation of images in a typical WMS. A variation of this technique was used in the Pyrgos project to generate and provide multiple datasets to the users.

Our application provides access to several commercial and project datasets that are served using a common Spherical Mercator projection. Satellite and road networks from Yahoo, Microsoft and OpenStreetMap are accessible from a map provider list at the right.

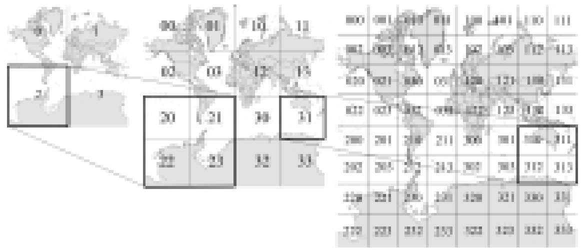

Figure 8. Representation of quadkeys used to identify images in tile server.

A high resolution mosaic of 1:50,000 maps from the Greek Military is also provided using the same coordinate system. A final background dataset was compiled from open source and project data sources. We developed this dataset using an OpenSource cartographic product called Mapnik (http://mapnik.org/). Mapnik was designed to assist with the production of high quality maps. Its use by the OpenStreetMap project also provided a starting point for developing an accurate map of Eleia as we could pull from work initiated by other developers within the OpenSource community. The maps generated by Mapnik were also cut into 256x256 pixel tiles and can be accessed rapidly through our application.

7 Testing and Future Directions

We evaluated the new but still incomplete application at the end of February, 2009. This second informal assessment took place during faculty development activities at Maryville University with Maryville faculty providing the sample population for the evaluation. The application was installed with other exhibits connected with the day long event. Very few of those involved in the evaluation had previous experience with GIS software. The observations and informal discussions with users were promising. Unlike the earlier gallery observation, users appeared to understand how to navigate the

[16] Joe Schwartz. "Virtual Earth Tile System," Virtual Earth Developer Center. http://msdn.microsoft.com/en-us/library/bb259689.aspx (accessed March 24, 2009).

[17] Joe Schwartz. "Virtual Earth Tile System," Virtual Earth Developer Center. http://msdn.microsoft.com/en-us/library/bb259689.aspx (accessed March 24, 2009).

interface and were more willing to explore sites and their associated information. While the mechanism for navigating the map appeared to be intuitive, our observation indicated that we will need to constrain users to a predefined geographic extent in future versions of the application. The underlying geographic information included data outside of our project area and users frequently explored other regions, sometimes navigating to other countries when they used the application. The map remained in the final location when the user left the exhibit, which sometimes confused subsequent users. Users also noted some uncertainty in determining which features could be selected. For example, the symbol used for houses in the secondary map blended in with the background map. While the houses can be selected the current symbol does not make this clear. Similar issues associated with symbology will be examined as we continue our development of the system. The report tools were incomplete when we evaluated the system and some users noted difficulties in interpreting the information presented by our application. In the future we hope to enhance the report features in the application and increase the number of interactive features in the installation. In addition, we will include more 3D features, reconstructions and multimedia elements to enhance the user experience.

We hope to test the application in the Pyrgos museum during the summer of 2009. Our previous observations involved a small population of users associated with Maryville University. It is important to test the application against museum visitors in Pyrgos as usability expectations will most likely vary by location and culture. The results of these tests will help us adjust our approach in later versions of the application.

The goals of the Pyrgos museum project were not unlike those of other cultural heritage projects.[18] We approached our system with the goal of making historical information available to the public. This information served two purposes: it provided a learning tool for museum visitors and it presented a digital document of the archaeological materials of Eleia. The importance of developing this digital record was underscored in 2007 when many sites documented in our database were threatened by fires that swept through parts of this region. While our project shares many of the same concerns as other archaeological GIS, our approach differs in its emphasis on the end user. GIS applications, including those developed for archaeological data, tend to minimize the importance of usability. In truth, the ability of a user to successfully interact with an application is perhaps the most important factor in determining the success of the system. The preceding discussion presents our approach to understanding usability in an archaeological GIS. This approach drew from usability engineering practices and analyzed user interaction both prior to and during the process of design. The initial results suggest that this process leads to a more "user friendly" system. The Pyrgos project is ongoing and future tests will determine the extent to which the initial assessments presented in this paper were successful.

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[18] Eros Agosto et al. "WebGIS Open Source Solutions for the Documentation of Archaeological Sites," In AntiCIPAting the Future of the Cultural Past. Proceedings of XXI International CIPA Symposium, October 01-06, 2007, Athens, Greece. (Athens: CIPA, 2007).

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Acknowledgements

This project is the result of collaborations with the Greek ministry of Culture, Directorate of Museums, Education, and Exhibition Programs of the Sixth Ephorate of Byzantine Antiquities, the University of Minnesota, Maryville University and Clemson University. We would like to thank several individuals who contributed their time, data and expertise throughout this project. Professor Frederick A. Cooper of the University of Minnesota contributed his database of Frankish and vernacular architecture, served as the project director and organized the digitization of much of the data used in this project. Kostis Kourelis of Clemson University provided a gazetteer of Medieval sites compiled during his dissertation research. Demetris Athanasoulis contributed a collection of forty four Byzantine church locations from Early Christian, Middle Byzantine and Frankish/Late Byzantine sites. Jonathan Fahnestock of Maryville University provided his expertise as a graphic designer, Flash programmer and usability expert.

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