

3D Interactive, On-site Visualization of Ancient Olympia

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ABSTRACT

This paper describes the work performed for the ARCHEOGUIDE (Augmented Reality-based Cultural Heritage On-site GUIDE) project. ARCHEOGUIDE is funded by the EU IST framework (IST-1999-11306), and pursued by a consortium of European organizations. It delivers an interactive, personalized, augmented reality (AR) guide for the visualization of ruined archaeological sites. It is based on mobile real-time computing, networking, and 3D visualization. Its users are presented with monument reconstructions, navigation aid and historical information in a user-friendly way through the use of multi-modal interaction techniques. The key features of the system are a novel hybrid position and orientation tracking technique used in determining the user's viewpoint, navigation aid, outdoor operation, and real-time 3D visualization of monuments, artifacts, and life. This paper presents examples of the system's use at the archaeological site of Ancient Olympia in Greece.

Keywords:

Augmented Reality, Position Tracking.

Project URL:

<http://Archeoguide.intranet.gr>.

1. Introduction

Recent advances in mobile computing and visualization techniques have triggered the introduction of computers in museums and cultural heritage sites. Their aim is to give more realism and additional information than the traditional paper guidebooks, as well as, navigation aid.

These systems actually become attractions themselves as they give additional information to their users and help them better visualize and understand the history and former glory of the site.

Examples include 3D modeling of artifacts and monuments like 3D-MURALE [1], pen-tablets and palmtop devices for guiding and informing visitors as

TOSCA, MUSE and SHAPE [1], and "cave" installations like CVR and IHW for immersive experiences in the exploration of ancient sites. Augmented Reality [3] kiosks have been implemented and installed at outdoor sites and museums like Ename [1].

Most of these applications offer their users pre-fabricated solutions, limited features, no personalization and fail to perform satisfactorily in outdoor and uncontrolled environments.

ARCHEOGUIDE [2] aims to fill-in the gap left by other systems already installed or still under development. In contrast to the current state-of-the-art applications, where "pre-fabricated" information is presented, it provides personalization of augmented and virtual tours and allows visitor to automatically receive audio-visual information corresponding to their natural view. It also allows interaction and serves requests for additional information by means of natural interaction suitable to mobile users.

The user can receive information and audio narration in the language of his choice and alter the flow of information automatically set by the device according to his profile and current position and orientation.

The paper starts with a description of the system's architecture, and components, and gives an overview of the modeling involved in the preparatory phase. It continues with a description of the user interaction techniques and the principle behind the construction and presentation of the personalized tour.

Finally, it presents results of the system's installation at Ancient Olympia in Greece, and concludes with some thoughts on the future plans of the development team.

2. Overview of the System's Architecture

ARCHEOGUIDE is based on a client-server architecture and consists of three basic component (illustrated in Figure 1):

- *Central server* implemented as a dual-processor high-end PC workstation with enough storage space to implement a multimedia database.

- *Mobile devices* implemented as portable computers with adequate processing power to support high-quality visualization applications and networking.
- *Communications infrastructure* implemented as a Wireless Local Area Network (WLAN) enabling full-duplex data communication between the server and the mobile devices.

The server is used as a central repository for multimedia information related to the archaeological site of

centralized point of access to the latest archaeological information, so that archaeologists can share and disseminate their latest findings with the scientific community. These goals are achieved through the use of purpose-built graphical authoring tools, which help the database administrator to categorize and group them in relevant tours according to attributes like type, detail level, etc. These are then presented to the system users via mobile units or over Internet. The choice of the

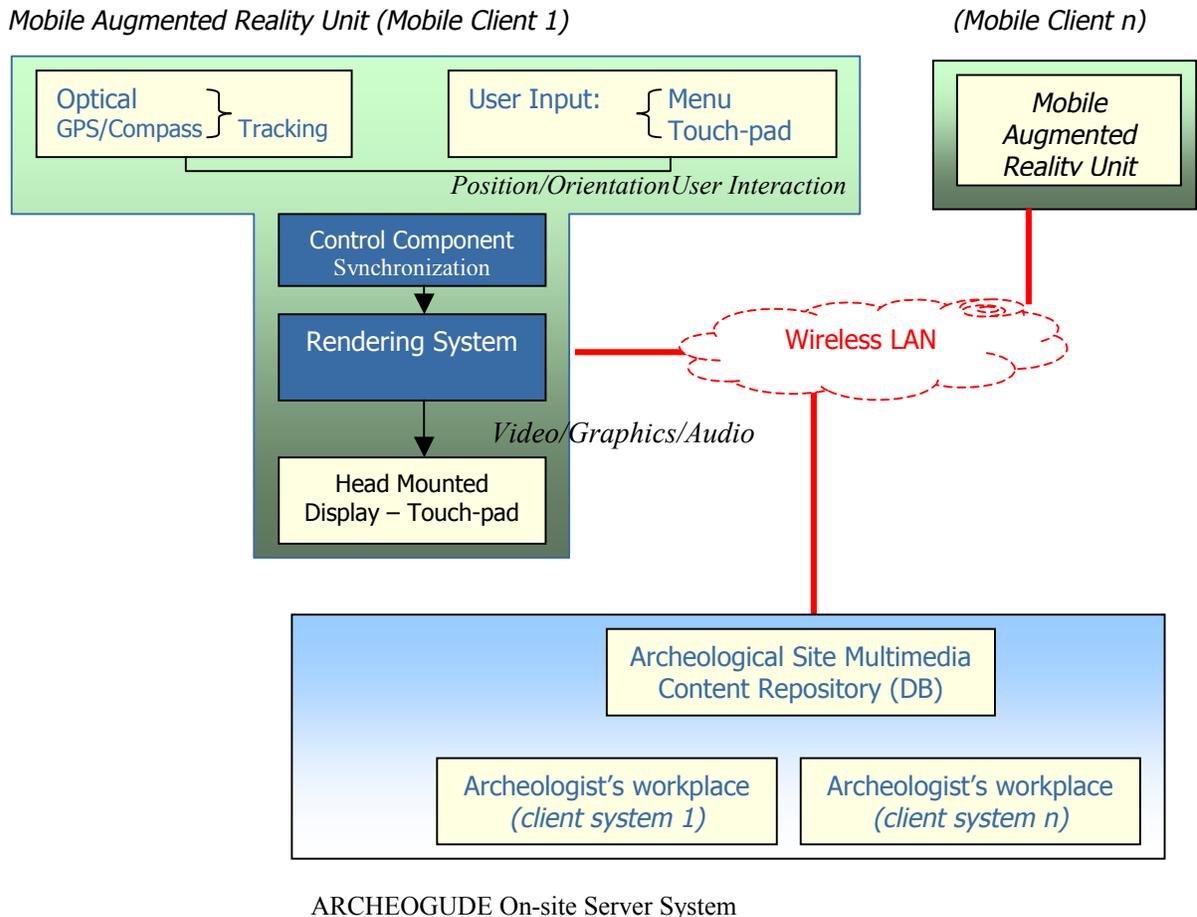


Figure 1: Simplified architecture of the ARCHEOGUIDE system.

Olympia. Its contents comprise 2D images, 3D models, videos, audio and text and are used in the creation of virtual and augmented tours of the site. The same material can be used for the creation of CD-ROM presentations and accessed over the Internet for educational, and recreational applications (e.g. museums, schools, etc.). In addition, the database is intended to promote scientific research and provide a

server was based on the high processing needs of the 3D authoring tools and the simultaneous access of the web server application.

The Mobile Units (MU) are portable computers that are carried in the archaeological site and offer augmented tours featuring 3D reconstructions of ruined monuments, revival of sports disciplines of the ancient Olympic Games, navigation information, and access to

related information stored in the database. The user can choose between four different implementations according to his preferences. They are all suitable for outdoor use, feature multi-modal user interfaces that minimize cumbersome keyboard etc. -based interaction while the user is moving, and possess enough processing power to handle complex real-time tasks such as video processing and 3D visualization.

The top-of-the-range devices are based on laptop computers and feature special AR displays in the form of video see-through binoculars and optical see-through glasses (Figure 2).



Figure 2: Visitor carrying the Mobile unit and the AR glasses. The camera on the helmet captures his natural view.

Lighter versions exist based on pen-tablets and palmtop devices with reflective, touch-sensitive screens suitable for outdoor use from direct sunlight to dark cloud. These are treated as the electronic equivalent of paper-guidebooks.

The mobile devices initiate the on-site touring experience by capturing the profile of their user. This includes age, nationality, sex, knowledge of archaeology and education, and is used to personalize the offered tour. So, based on this information, a suitable tour is automatically defined and the individual multimedia objects it comprises are requested from the server database. In response, the server transmits them over the WLAN to the mobile unit who posted the request. Upon reception, they are put in order and synchronized for presentation according to what the user is currently staring at.

The network solution was chosen for providing adequate coverage for all visitor-accessible areas of the archaeological site, and for supporting a high number of mobile devices (up to 50 devices can be supported at

any time). A radio-based solution, operating under the IEEE 802.11 WLAN standard, was chosen for better performance in the presence of obstructions from vegetation, visitors, etc., and for easy expandability and upgradeability should the need arise.

For a more detailed description of the system's architecture the user may refer to [2], [12]. A final point to note regarding the software architecture, is that the Mobile Unit software has been written in C++ for speed (as it must run in real-time) whereas the server components have been written in Java for maximum portability.

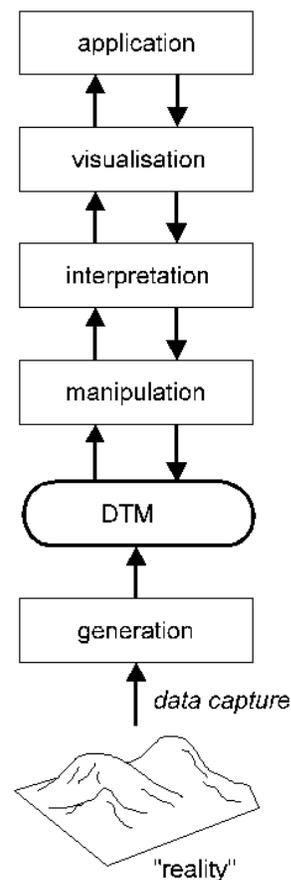


Figure 3: The main tasks of a digital terrain modeling system

3. Site Modeling

The initial phase of the ARCHEOGUIDE system deployment consists of the data collection and 3D modeling of the archaeological site. This process can be described with reference to Figure 3 and involves the integration of Geographic Information Systems (GIS), computer cartography, and scientific visualization.

Digital ground elevation data can be collected using photogrammetric techniques, such as stereo aerial photography and stereo satellite imagery, GPS, and ground surveying.

Once captured and digitized, the raw data has to be interpolated to estimate the elevation of points falling off the digitization grid.

These data can then be visualized in a number of ways, more commonly in contour maps depicting iso-curves (i.e. curves of the constant elevation) (Figure 4), relief shading (where the brightness of a surface depends on its inclination and varies as the cosine of the angle of incident parallel light), combination of the two, or perspective display (in the form of mesh of triangles of varying sizes) (Figure 5).



Figure 4: Isometric map of ancient Olympia. Main monuments appear in red.

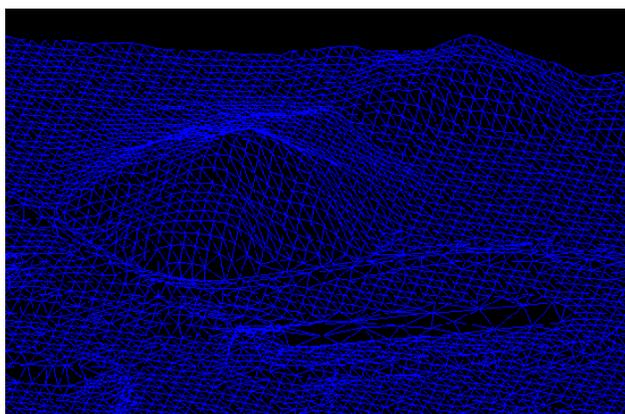


Figure 5: Perspective map of ancient Olympia.

In an effort to expand the interactive visualization capabilities of the standard 2D raster-maps and Digital Elevation Models (DEM), this geo-referenced raster-data can be translated to VRML format. This 3D representation of the site can then be enhanced by adding 3D VRML models of reconstructed temples to create a virtual world for touring (Figure 6).



Figure 6: Enhanced 3D map of ancient Olympia.

The temple reconstructions were based on archaeological findings and architectural drawings and are scientifically accurate with respect to size, coloring and decoration. The visual quality of these models has been varied according to their specific use and processing capabilities of the visualization unit. Highest quality is used for off-line visualization on desktop computers as well as in the construction of 2D augmented images, while lower quality has been used for internet-based virtual touring and on-site virtual navigation using the pen-tablet mobile unit.

3D scanning and modeling has also been employed for statues and artifacts related to the site and made available to the interested user of the system.

4. Tour definition

Based on the 3D modeling of the archaeological site, suitable viewpoints and tours can be defined. This effort has taken into account the need for unobstructed views of all the major monuments of the site, as well as, the adequate wireless network coverage of the whole site and in particular the areas accessible to the system users.

We have selected a total of 9 viewpoints in the archaeological site of Olympia for viewing the following monuments: the Stadium, the temple of Hera, the temple of Zeus, the Philipion, the Palestra, the Metroon, and the Treasuries (Figure 7).

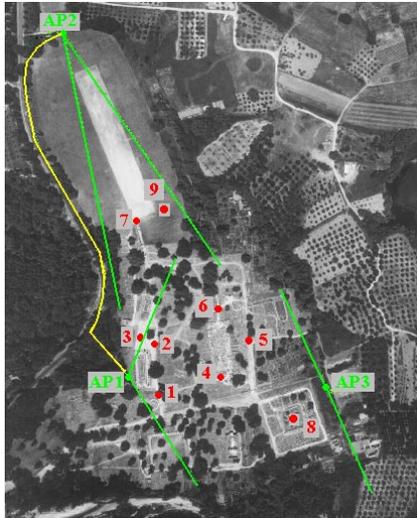


Figure 7: Predefined viewpoints and network coverage of the Ancient Olympia site.

These viewpoints are served by a wireless LAN with 3 Access Points (AP) providing reliable data communication between the central server and the mobile units carried by the users.

Suitable tours can be defined according to the user's profile and available time, so that different parts of the site can be covered. For instance, a user interested in sports may spend more time and receive detailed information at the Stadium and the Palestra as opposed to the remaining monuments in the site.

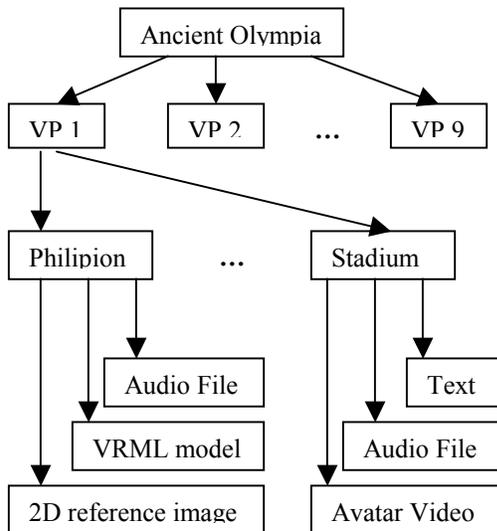


Figure 8: Tour creation with multimedia objects.

Tours can be defined on the server with special graphical tools. A path is drawn on a digital map of the site (Figure 9) and special editors can be used to populate the tour with suitable multimedia material.

This material includes images, 3D models, videos, audio narration, and text corresponding to the individual site monuments, viewpoints, and related artifacts. These are all stored in the system's database and are organized in a hierarchical tree structure; the root corresponding to the whole site, the branches to the viewpoints and monuments, and finally the leaves to individual multimedia objects (Figure 8).



Figure 9: Tour drawing with the GIS editor.

In terms of their software representation, the following structure is adopted bottom-up:

- NMObject (New Media Object)
- Composite Object
- Tour script
- Tour schedule

The user can follow the proposed virtual tour over the Internet, or if on-site, he may also wander freely. In this latter case, he can navigate the VRML model of the site and its reconstructed temples and when positioned at the pre-defined viewpoints he can see real-time AR views of reconstructed temples (on the AR glasses and binoculars), augmented panoramic views (on the pen-tablet and the palmtop devices), videos of avatar athletes competing in the stadium, textual descriptions (on the palmtop), and listen to audio narration in his language of choice. All three devices offer navigation information at any moment in the tour, both on-site and on-line.

5. User Interaction

ARCHEOGUIDE introduces new human-computer interaction techniques. Its aim is to provide a user-friendly system suitable for mobile touring in outdoor (and indoor) environments. The resulting system employs a series of techniques minimizing the traditional keyboard and mouse, normally used in computing systems. This way the learning curve is minimized for all kinds of users irrespective of their computer skills.

5.1 Position Tracking

The basic element of this interaction system lies on the automatic real-time tracking of the user's position as he tours the physical site. His position is estimated by means of a GPS device, which receives signals from a constellation of geo-stationary GPS satellites. 4 to 12 satellites are needed for the triangulation of the user's position with an accuracy of 1 meter.

Based on this information, the system can identify the most appropriate information for presentation to its user. As soon as he approaches the ruins of a monument, the system automatically starts the audio-visual presentation corresponding to it. It comprises reconstructions of the monument in its original state and narration giving historical and other information. In essence, the system treats its user as a live pointing device.

At the same time, a list of related topics is made available to the user to choose. This choice depends on the particular type of the mobile device. On the pen-tablet and the palmtop devices, a special pen can be used to write and select "bookmark-tabs" on their pressure-sensitive screens (Figure 12). This gives the user the feeling of browsing through a paper-guide or notepad while listening to a professional human guide; that is a simulation of the traditional guided tour followed by the majority of tourists. However, the ARCHEOGUIDE approach allows for personalization according to the user's profile, interests, and available time and enables viewing of additional information on demand. On the AR-display-based solution, the user can request the additional information via a special menu rendered on the user's view and controlled via a standard gamepad or via three buttons integrated on the display itself.

5.2 Orientation Tracking

Further refinement of the user's role as the pointing device can be achieved by tracking his orientation and, correspondingly, the viewing angle. This is implemented by means of a digital compass. It features a three-axis magnetometer for absolute measurements with an accuracy of 0.2° . This way, several monuments can be

differentiated from a single viewing position and the relevant information can be presented in synchronism with the user's natural view as he turns around in real time.

5.3 Hybrid Optical Tracking

As mentioned earlier, the pen-tablet and the palmtop devices are used as the enhanced, electronic equivalent of the standard paper guides. That is, the user stares at the monument ruins and then consults the screen of the device he holds. In the case of the AR-display devices, the user sees the natural world through a pair of special (optical) see-through glasses or video-see-through binoculars. This approach provides higher realism but cannot tolerate any limitations in the accuracy of the tracking system. This would result in the rendering of reconstruction models misaligned with respect to their positions in the natural view and situations like temples flying in the air would be common. Our approach to this problem consists of the addition of a third module to the tracking system.

An optical (image) tracking algorithm has been implemented [4], [5], [6], [7], [8], [9], [10], [11], [13]. It uses the GPS and compass readings as an initial estimate, which is further refined by image matching. A web camera, integrated with the AR-display unit, captures the user's natural view. This live video stream is matched on a frame-by-frame basis with calibrated reference images, corresponding to the current viewing angle and position. This matching is performed in the frequency spectrum and makes use of global image characteristics for immunity to occlusions and changes in lighting conditions. The method can handle occlusions of up to 60%, and accommodate translation, scaling, and rotation between the two images. It runs at 15 frames/sec on an 800 MHz laptop, providing almost real-time tracking. The matching is used to calculate a warping transformation, which can be used in the rendering process.

The reference images are stored in the system database together with models of the reconstructed temples. These correspond to the size, position and orientation of the ruins depicted in the reference images. Having computed the warping transformation described above, the same transform can be applied to these models and the result is used to accurately render the reconstructed temple on the ruins seen by the system user. As the user moves or turns around, the reconstruction "follows" him and always stays aligned with his natural view. During this process, seamless transition between the corresponding reference images ensures that the correct monument is rendered, at its precise location and from the appropriate viewing angle.

The user can alter the flow of audio-visual information simply by moving away from the pre-selected viewpoint or by turning at an other direction. He also has more

accurate control of his tour through a special menu displayed on the AR glasses and binoculars, controlled either by a standard gamepad, or by special buttons on the device itself. This simple interface allows him to request additional information on items, such as statues and artifacts, related to the currently visualized monument, and to control the visualization parameters (e.g. transparency) (Figure 10).



Figure 10: Menu selection on the AR displays for transparency control of a reconstruction model.

The same interface can be used to receive navigation information. A plan of the archaeological site can be displayed at a touch of a button. It displays all the monuments in the site, the pre-defined viewpoints, the user's position and orientation (updated in real time) and the itinerary the user has followed since the start of his tour. This information is also made available to users of the other two mobile devices, which can access it by using special pens on their pressure-sensitive screens.

6. Touring

After the beginning of their on-site tour, the users can navigate in the 3D (virtual) model of the site and its monuments. This application is available at any point irrespective of the user's position with reference to the pre-defined viewpoints and tours. The modeling of this 3D world has been simplified for reducing its size to a few MB. This allows for real-time operation on the pen-tablet controlled by the user's position and orientation. The same application over the web can be accessed in high resolution assuming a fast link is available or it may be installed on the local machine.

Upon his arrival at a viewpoint, the user is presented with a real-time rendered model on his natural view over

the AR display, or with pre-rendered views on the other devices, as illustrated in Figure 11.



Figure 11: Augmented Picture of the temple of Zeus in Ancient Olympia.

He can also see augmented panoramic views on the pen-tablet and the palmtop devices. These are synchronized to his natural view as he turns around the viewpoint. This allows for realism and can be regarded as the equivalent to the real-time rendering used in the top-of-the-range devices.

Examples of the application on the pen-tablet and the palmtop devices can be seen in Figure 12 and Figure 13.



Figure 12: The pen-tablet. Example of the user interface with 3D navigation.

Another important feature offered by the system is the re-enactment of the ancient Olympic Games in their original venue, the stadium in the archaeological site of

Olympia. Sports disciplines have been modelled using avatar athletes and information from archaeologists and historians. These include the stadium race, the race in armor, the long jump with hand-weights, the discus throw and the javelin throw. An example is illustrated in Figure 14.

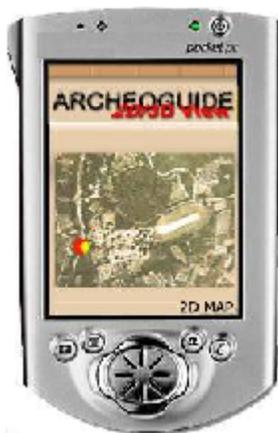


Figure 13: The palmtop device. Example of the user interface with navigation information.



Figure 14: Avatar athletes compete in the stadium of ancient Olympia. The models are rendered in real time on the user's natural view as seen through the AR glasses and binocular displays

7. Conclusions

ARCHEOGUIDE has been tested and evaluated by visitors at the ancient Olympia site. It was received with enthusiasm and lies in front of its competition due to its personalization features, navigation, and realism it offers its users. The use of multi-modal interaction techniques

allows for user-friendly operation even by computer illiterates, minimize user intervention and fill the gap left by other similar system, which can only operate in controlled indoor environments, or present pre-fabricated (off-line) solutions.

Currently ARCHEOGUIDE undergoes a final stage of minimization of its hardware components. New installations prospects have opened and it is expected to be installed soon at many major cultural heritage sites across Europe.

8. Acknowledgments

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9. ARCHEOGUIDE Consortium

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