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# LOCATION- AND CONTEXT-AWARE AUGMENTED REALITY NOMADIC DEVICES FOR CULTURAL HERITAGE APPLICATIONS

Augmented reality applications present visually enhanced information in situ. As such they are the adequate means for delivering personalized, location- and context-aware information to visitors of cultural heritage organizations. Nevertheless, many technological and human-computer interaction limitations prevent their use at outdoor sites. In this paper we describe the ARCHEOGUIDE system, an augmented reality guide for visitors of archaeological sites. We focus on the system evolution, the usability aspects, and the perceived quality of the content offered to visitors of different ages and cultural background. We present the mechanisms used, and the lessons learned from the system's application at Ancient Olympia. Our approach is based on three versions of the prototype device each one featuring a different interaction mechanism and offering various types of information and presentation methods. We conclude with the setting of the framework for its future installation at major archaeological sites and the improvement of its usability.

*Keywords:* mobile, e-guide, personalization, automatic, smart book.

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## 1. Introduction

The introduction of nomadic devices for visitors of cultural heritage institutions and sites seems to be a natural application of mobile systems in information provisioning. People explore unknown spaces with a great amount of information hidden behind exhibits and monuments, trying to revive the presented objects by means of travel guides etc. Many prototypes were developed in the past years in order to address this need of nomadic users in museums and archaeological sites. An integrated development, addressing various topics related to advanced nomadic guides for cultural heritage institutions, took place in the framework of the research project ARCHEOGUIDE.

ARCHEOGUIDE offers an integrated end-to-end solution, addressing the needs of both curators of cultural heritage sites as well as visitors. Various subsystems were developed to provide curators with powerful, yet easy to use, software tools for the creation of visually enhanced content, to be provided to the visitors by means of portable, Augmented-Reality (AR) guides. ARCHEOGUIDE provides a virtual time travel in situ, by displaying reconstructions of monuments and important events onto the see-through glasses or binoculars of the devices handed to the site visitors.

In this paper the concepts behind navigation and locomotion in visually enhanced reality, as well as, the tools and concepts for their effective deployment are presented. The application of these concepts in three different types of devices following different usage concepts is discussed together with a comprehensive on-site evaluation by visitors and scientists at ancient Olympia, in Greece. An important issue raised and dealt with is the satisfaction of visitors, as well as, the feeling of being correctly informed through an integrated and synchronised audiovisual presentation; especially as far as the accuracy of 3-dimensional reconstructions is concerned. Finally the concept of personalization of augmented-reality mobile guides is addressed and the solution within the context of ARCHEOGUIDE is presented. The latter is crucial for the success and acceptance of such a system, since it needs to be introduced in an environment with a vast variability of visitors, having different literacy in technology and diverse cultural backgrounds.

## 2. Requirements Analysis

The design of the ARCHEOGUIDE system follows a repetitive requirements collection and analysis process. This twofold approach took into account the needs of both archaeologists and ordinary visitors and started with a questionnaire followed by trials and observation of common work and tourist guiding routines under real conditions.

The requirements collection process was performed in Greece, Italy, Germany and Portugal by the project partners and included semi-structured interviews with ordinary site visitors of several nationalities (all continents were represented, even though not equally), site staff, cultural authorities, and Ministries of Culture. Their opinions helped identify crucial features and must-have functionalities of the prototype system. However, due to the limited use of digital technologies and Augmented Reality (AR) in the cultural sector worldwide, we decided to expand our approach to experience logging and evaluation of other similar approaches. This evaluation was continued during the project's development. Prime candidates for providing such information were a number of research projects like MARS (Hollerer et al. 1999), GEIST (Holweg and Schneider 2004), MUSE (Scagliarini et al. 2001), and 3D MURALE (Cosmas et al. 2001) with which we had exchange of experiences and technological know-how. Further on, we tested several systems installed in cultural institutions like IBM's e-guide at the Cairo Museum in Egypt (IBM 2002), Antenna Audio's PDA guide at London's Tate Modern Gallery in England (Proctor and Burton 2003), and the Minisat e-guide at the Cité des Sciences et de l'Industrie in Paris, France (Cité des Sciences). A number of other systems have been reviewed including the University of Tokyo's Personalised Digital Museum Assistant (Koshizuka 2003) and the Yohohama Museum of Art's PDA guide, both in Japan, Fraunhofer IGD's (Stricker 2004) Dunhuang Caves Exhibition in Germany, Ename's Timescope in Belgium (Pletinckx et al. 2003), IMPA's Visorama in Brazil (Matos et al. 1998), the Ambient Wood project in the UK (Weal et al. 2003), and the ARCO prototype for interactive publishing of cultural content (White et al. 2003). Significant information was also collected from other systems in various domains like the LOVEUS and POLOS projects (Karagiozidis et al. 2002, and Ioannidis et al. 2003), respectively, for Location-Based Service (LBS) and tourist guiding, the ARIS system for AR in interior decoration and furniture retailing (Gibson et al. 2003), the mEXPRESS prototype for visitor guiding at exhibition halls (Mathes et al. 2002), and the PEACH, HIPS, ARREAL and IRREAL projects (Baus et al. 2002) for personalisation, planning and delivery of guided tours. Advice was also sought after tourism experts.

In order to simplify the data analysis we group users into two broad categories; scientific users and site visitors. The first category includes all scientists and professionals involved in the running of cultural sites, and the development, installation, and supervision of Information and Communication Technologies (ICTs) in these sites. Among them are archaeologists, curators, historians, site staff, cultural authorities, and graphic designers, information engineers, web designers, and software and hardware developers of systems used in CH sites. The category of site visitors includes the general public (individuals and group tourists, schools, and students). Within this category, scientific users may also be included when they visit cultural sites other than the ones they are professionally affiliated to.

Following the analysis of the collected data, we rephrased user's reactions and needs and mapped them onto system requirements. Scientific users, needed a graphical tool to provide accurate virtual restoration of monuments and artefacts in their context, a documentation and archiving tool and a visual versioning tool where various hypotheses on virtual restorations could be modelled and examined.

Site visitors were in need of an easy-to-use navigation tool that could create a brief journey into time without loosing contact with the real environment and the members of their group (Vlahakis 2002).

The requirements collection and analysis process lasted six months and was iterated during the development cycle of the system prototypes. Multiple-choice questionnaires were used mainly at on-site data collection sessions due to the language barrier existing for a number of visitors who felt uneasy with spoken English. Informal interviews were conducted on- and off-site with potential users of both categories who were willing to devote more time (especially scientific users). A total of over 100 users with approximately uniform distribution of ages, sex, levels of computer literacy, nationalities and professions contributed to the definition of the following requirements prior to the system design and development:

- Integrated Multimedia Authoring, Documentation, and Presentation system
- Multimedia Content Scalability for presentation over a range of mobile devices
- Metadata descriptions for cultural content documentation and LBS guided tours
- Mobile computing platforms suitable for Augmented Reality (AR) applications

- Automatic and Interactive operation
- Intuitive Human Computer Interaction mechanisms suitable for users with minimal or no computer skills
- Realism and Scientific Accuracy in the AR presentations
- Personalized AR tours and support for children and visitors with special needs.

## 3. Building a Common Communication Channel between Archaeologists and Engineers

Our experience of developing and using ARCHEOGUIDE faced the task of building a common communication channel with archaeologists, historians, architects, graphics designers, engineers and computer specialists. The difficulty in this communication stems from the fact that each team has different views and expectations due to different backgrounds and working cultures.

Nevertheless, all partners had the common goal of being pioneers and promote the synergy between culture and new technologies. However, no partner, irrespective of his field of work and size, concentrated all the necessary skills to achieve the above goals. A structured project management approach was followed and formal and informal communication channels were set so that various expertises could be put together and produce the desired outcome.

To see how this is put into practice, let's consider the presentation of the 3D reconstruction models of the ancient temples. Archaeologists, architects, and designers opted for the highest accuracy in the digital representations and the highest fidelity as it is dictated by historical sources and excavation findings. On the other hand side, engineers and computer experts approached the same task with a technically oriented approach centred on the capabilities, strengths and weaknesses, and cost of available technologies. In other words, both sides had to understand each other's views and compromise on certain points. Obviously, the scientific accuracy of the common effort could not have been sacrificed. Instead, an acceptable solution was the adaptation of the 3D content to the specific characteristics of the available technologies. This was the outcome of numerous meetings and evaluation sessions. This and other similar issues directed us into the development of the initial AR prototype. Furthermore, the whole process was revisited every time new functionalities and features were added to the system and appropriate corrective measures were taken when necessary. Based on user's evaluations, features were modified and sub-systems were completely remodelled. In its initial development stages, the AR device was too bulky and heavy to be easily carried around the archaeological site. This was also reflected in the user's comments (Vlahakis 2002), consequently triggering a change in our approach. Research then led to the development of the pioneering living book and PDA guides with high success and acceptance by the visitors. These devices can be seen in figure 1.

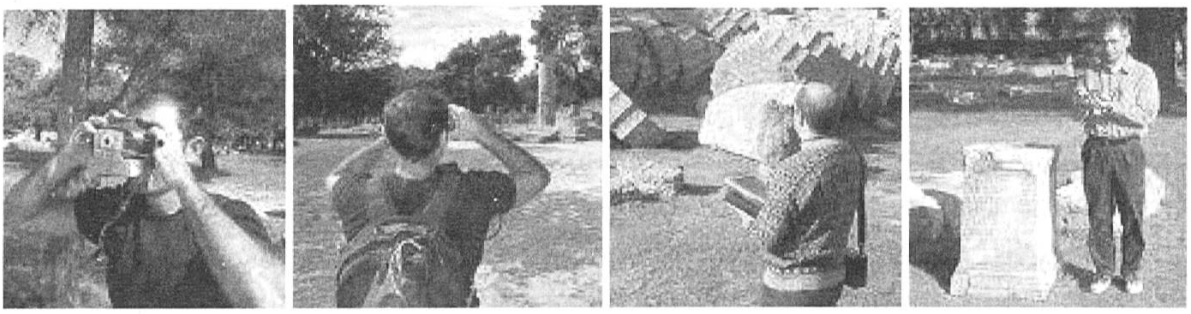

*Fig. 1: The AR device (front and back), the Living Book, and the Pocket Guide in use at Ancient Olympia, Greece*

## 4. Modelling the past

One of the most spectacular ARCHEOGUIDE features is the accurate representation of ancient temples and their seamless integration with the physical environment during the augmented visit, as illustrated in figure 2.

The fundamental problem for modelling the past may be formulated as follows: the 3D models of the ancient temples must combine the archaeologist's requirements for scientifically accurate representations with spectacular images destined to visitors, while respecting technological constraints. Relating this to the system requirements, the 3D models should be implemented and documented so as to facilitate existing multimedia content reuse in the ARCHEOGUIDE authoring and documentation suite. The outcome of this process should be in a format suitable for presentation with any type of mobile devices (e.g. Augmented Reality - AR, Mixed Reality - MR, Virtual Reality - VR) and be integrated with audio and other multimedia data into interactive and automatic Location-Based Services - LBS guided tours. Their digital representation should allow for easy adaptation to the presentation device characteristics (e.g. screen resolution) and parameters (like wireless interface bandwidth for real-time transmission from a central repository to the mobile users.

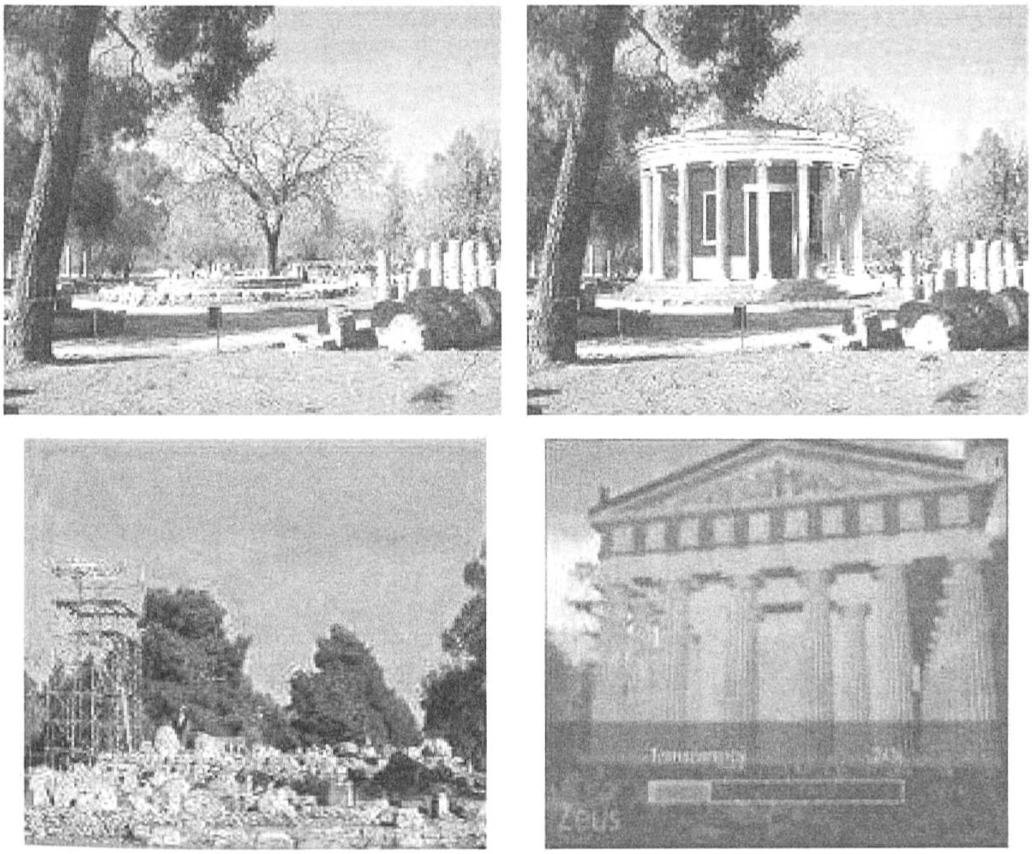

*Fig. 2: Original and AR reconstructed Philippion Temple (top). Original and reconstructed Temple of Zeus and the graphical interaction menu (bottom)*

As far as archaeologists and historians are concerned the modelled and documented data should follow common archaeological standards like the Dublin Core (Dublin Core 2005) for easy verification, scientific analysis, and comparison with other similar data. This comparison ensures scientific accuracy by using several sources, archaeological hypotheses, architectural drawings, photographs, etc. Finally, the correct metadata descriptions of the 3D data also enable the adaptation of the AR presentations to the language, interests, available time, etc. (i.e. the profile) of each individual user and visitor. Consequently, this feature helps meet scientific requirements with visitor's expectations while being feasible for implementation with today's technologies. These operations together with preview and playback functionalities are offered through an integrated graphical authoring, documentation and GIS suite, illustrated in figure 3. This content can then be downloaded to the mobile devices either prior to the tour or on demand according to the user's position and interaction.

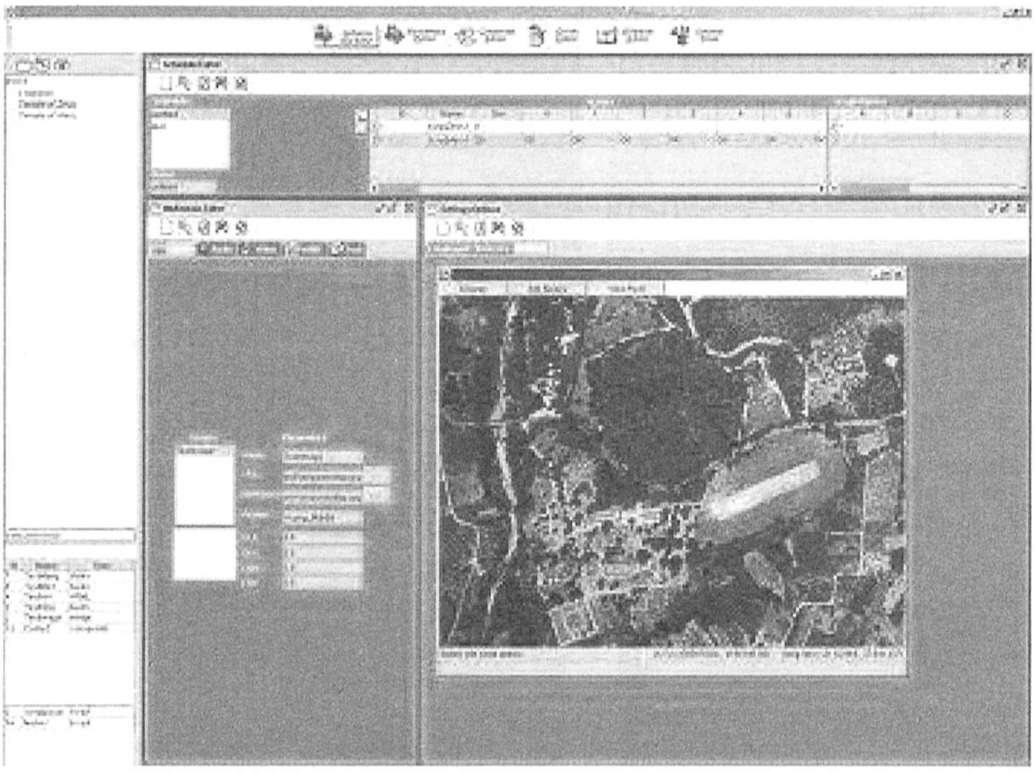

*Fig. 3: The Authoring Tools Suite*

As an archaeological tool, the 3D model must integrate the site history and the scientific knowledge to the representation. This requirement results in different versions of the same temple depending on temporal and divergent scientific opinion data and may trigger debates. The Direction for the Restoration of Ancient Monuments (DRAM) of the Greek Ministry of Culture accepted only partial physical on-site monument restoration and prefers the concept of virtual restoration.

The history of Ancient Olympia militates for the virtual restoration concept. The ancient landscape does not exist anymore, due to the river Alfios' change of course, and the temples that are in ruins, due mainly to physical phenomena (earthquakes) and religious wars (the early Byzantine Christians demolished ancient Greek gods' temples). For the ARCHEOGUIDE project the temples are simulated in the 5th century B.C., time of glory of the Olympic Games. The irregularities of the soil are integrated in the representation so that the 3D models are placed in the exact actual topographic position. Aerial photos provided the possibility to map the entire Olympic site. The 3D models represent the temples in their original state discarding any deformations and inclinations due to the temporal alteration of the vestiges. In line with this assumption, the colouring and texturing of the temples follow the excavation's findings, because the original colours are gone. With a standard commercial tool, as for example 3DS Max, the average Olympic temple is represented with 120000 polygons. In the ARCHEOGUIDE database, 15 temples were simulated in various interpretations, and a number of copies of the 3D models were provided for cross-platform use (video, Internet, CD-ROM, augmented reality, virtual reality, mixed reality, etc). As it is time-consuming to render an image resulting from the calculation of 120,000 polygons for ensuring high-quality visual characteristics in a portable PC, we had to provide an acceptable solution for "spectacular" real-time rendering. Again, the solution to accommodate visitor's satisfaction and scientific accuracy came from a careful survey of the actual archaeological site of Ancient Olympia.

The visitor of the ancient Olympic site is guided via a pre-determined path where he or she may circulate while other areas are not allowed (mainly the interior of the ruined ancient temples). It is therefore possible to determine a fixed number of observation points inside the actual visitor's path and pre-render a sufficient number of images for each point in order to cover the entire site. The use of 9 observation points with 6 pre-rendered images per point is sufficient to create an image bank covering the entire Ancient Olympia site when the visitor uses the ARCHEOGUIDE system.

## 5. Location and Context Awareness

ARCHEOGUIDE adopted a very innovative approach for bringing archaeology and cultural heritage closer to the public. It adopted mobile computing technologies and stretched them to their limits with the use of Augmented Reality (AR) to achieve realism. The key implementation aspects are mobility, intuitive operation, and scalability for use in a variety of mobile devices and applications.

Being a mobile system, ARCHEOGUIDE had to redefine the classical User Interface (UI) methodologies and eliminate cumbersome AR/VR UI hardware devices and installations.

The ARCHEOGUIDE system is based on multiple, complementary techniques in order to achieve increased accuracy in location and context awareness. Hence the system exploits a Differential-GPS (D-GPS) sensor and a digital compass for the initial location and orientation estimation (within 1-1.5m and 0,2° respectively), and a web-camera alongside visual-tracking software for accurate perspective calculation (2-3 pixels for VGA video).

The visual tracking software that was developed compares video frames captured by the camera with reference pictures taken prior to the deployment of the system. The deviations of the images of the camera from the reference ones, deliver the geometrical information that is used to estimate the transformations necessary to make a geometrically correct projection of the enhanced visual information onto the display of the visitor. This process delivers 15-25 frames/second depending in the laptop used.

## 6. Support for Users with Special Needs

Special categories of users are the elderly and those with sight problems. Both may have difficulties reading text or even interacting with their device. This physical (accessibility) problem is due to either short sight or problems with controlling their hands (e.g. Parkinson's disease). Our approach towards them is twofold.

First, we avoid the use of text or small textual tags and graphics. Instead, we use large graphics spanning their field-of-view and replace written descriptions with narration in their language.

Second, we offer the graphical menu and its features as an optional functionality for those who feel at ease with it (refer to figure 2), while the rest use the system in fully automatic mode. In this case they only need to consult their position that is clearly marked on a graphical map and invoked by the press of a single button.

This inherent limitation in the interaction with the system is further minimized by a suitable personalization scheme whose function is the adaptation of the guided tour to the user's profile, so as to minimise or even eliminate the need for user intervention to control the flow of information. Consequently, he may simply walk and stare at an object of interest to start viewing its reconstruction, listen to its history and description and view related artefacts and photographs. On top of that he feels comfortable wearing his spectacles while using the AR visualisation device.

The automation and personalization features also address the cultural (usability) problem experienced by these and other users. That is the lack of basic computer skills. ARCHEOGUIDE allows people with no previous experience to make use of its functionalities with minimum effort.

## 7. AR Tour Personalization

The proposed Human Computer Interaction (HCI) mechanisms are supported by a personalization scheme, which collects his profile comprising language of preference (Greek, English...), age (Child, Adult, Elderly), and interests (History, Sports, Arts). This profiling information is processed on the user's device and multimedia objects from a local database are matched to it and put together to form the integrated tour proposed to the site visitor. For such a scheme to function accurately we use a multilayer metadata schema where each individual multimedia object (text, image, 3D model, sound, video, animation) is described by three sets of descriptive terms (metadata elements):

- *Profiling.* They correspond to the elements logged during the user's profile capture.
- *Geographical.* They are used in accordance with a Geographic Information System (GIS) where each multimedia object is assigned to a geographic location (e.g. the 3D model of the Temple of Hera is assigned to Viewpoint 1 with coordinates x,y) to define the location, orientation and precedence conditions for the playback of the content (e.g. an introductory narration on the monument is played before a detailed historical description, while an AR reconstruction of the ruins is shown).
- *Cultural.* We use part of the Dublin Core Metadata Element Set (an archaeological descriptive set of elements comprising the name of the physical item, its dating, etc.).

These metadata elements allow the retrieval and grouping of the appropriate multimedia objects in hierarchically ordered tours.

Other versions of the ARCHEOGUIDE system (the living book and the pocket guide) incorporate touch screens for the user to manually select other types of information. A living book metaphor is based on a GUI structured similarly to a Filofax agenda. Graphical bookmark tabs appear at the bottom of the touch-screen. Their size and position make them easy for the user to choose with a stylus or with his finger and imitate the thematic browsing of the content on the printed medium. This feature makes them suitable for use by all users as they can interact in a way similar to browsing a book. The same interface allows the consultation of a site plan in 2 or 3 dimensions, with the added advantage of position, orientation and path indication. The user can also benefit of tour planning simply by touching hotspots on the site plan and previewing available content.

## 8. Device evolution based on usability evaluations

The initial ARCHEOGUIDE system was evaluated with the expert guidelines-based evaluation (Nielsen 1994) and the older summative evaluation technique (Williges 1984) methodologies. The guidelines-based evaluation started with guidelines related to virtual environments, such as the ones produced by Virginia Tech (Gabbard et al. 1999). In a second step various experts, participants of the ARCHEOGUIDE project from different European countries, were asked to create guidelines and comments, based on the initial design of the system. These guidelines were taken into account to create a prototype as well as a questionnaire for the users that would test and evaluate it on site. In particular, all three mobile device prototypes were evaluated for the quality of the audiovisual and augmented reality presentations. The process included ease-of-use, accuracy, and realism of the reconstruction and guiding functionality. Finally, it included the evaluation of the infrastructure (e.g. authoring tools and WiFi network) and captured the user's preference on any of the used devices and their intention to use ARCHEOGUIDE when it will be made available in the near future. A total of 200 users participated in the evaluation of the prototypes at Ancient Olympia and in the laboratory. Half of this sample were ordinary tourists while the other half were computer experts, 3D graphics artist, archaeologists, and architects who responded to short interviews or filled-in questionnaires. We will present qualitative results and avoid quantitative data. This is dictated by the fact that many users did not fill-in the entire questionnaire and others only responded to interviews. Our handling of these cases is to avoid producing estimated ratings so as not to bias the statistical results.

In addition, cost requirements of the various stakeholders related to the cultural heritage institutions were taken into account. The evaluation of the visitors' questionnaires combined with the experts' recommendations and semi-structured on-site interviews at exhibitions and other events where the prototype was demonstrated led to the creation and reengineering of three different system versions: the mobile AR guide, the living book, and the pocket guide.

## 9. User Evaluation, Perception and Tolerance of Faults

The overall satisfaction of the ARCHEOGUIDE users was high for the majority of visitors with elderly people and first-time computer users being the most critical. The major complaints were for the physical dimensions and weight of the system (Vlahakis et al. 2002). Regarding the interaction mechanisms, the automatic operation was welcomed with the graphical menu and AR glasses receiving some critique as to their suitability for outdoor use. The binocular version was more widely accepted as it allowed the users more freedom and enabled them to carry the device while walking and simply place it in front of their eyes when prompted for an AR presentation.

Our choice of AR presentations only at predefined viewpoints as a compromise between complexity, quality and implementation limitations was not a serious drawback as it offered the touring users the time in-between viewpoints to look at the site in its current state and interact with each other as a group. A positive outcome one could say as they are not distracted and cut off the real world. The estimation of position and orientation as described above is replacing a significant amount of interaction steps and the user benefits are obvious, since there is no cognitive stress involved in the operation of a user interface. This is achieved since he is briefed on the behaviour of the system prior to the beginning of his tour, so that he knows what to expect.

The quality of the AR renderings was high and high realism was reported by the majority of the visitors. However, their tolerance to misalignments in the mixing of the real with the virtual worlds, jerkiness or lagging of the rendering of the virtual models as a result of fast motion or rotation of their heads was rather limited especially for first time computer users and beginners. Particularly high scores were given to virtual re-enactment of the ancient Olympic Games disciplines in the stadium where they originally took place. The visitor's experience is significantly supported by the playback of audio linked to the visual information. Hence locomotion problems, known in virtual environments (Regian 1997), are avoided.

Finally, ARCHEOGUIDE was praised for the absence of invasion to the protected area of Olympia and the absence of any aesthetical cacophony or disruption to the normal operation of the site. This was achieved by the absence of any hardware installation in the site. Only the optional communications infrastructure of the wireless network was installed and camouflaged behind the vegetation surrounding the site and outside the protected area, so rendering it undistinguishable.

An important point to note is the strong objection of professional tourist guides who felt under threat. They could not accept

ARCHEOGUIDE as their assistant but as a rival. This is a point we have to clarify, as ARCHEOGUIDE is not intended as a substitute but as a tool to supplement their work and guided tours.

Guidebooks are scaled-down versions of the AR device. Users praised the living book for the high quality of its graphics, and the perfect presentation of the audiovisual part without the flickering or lag experienced with the AR system. The interaction mechanism scored high in the evaluation as it resembled browsing a paper book while providing easy touch interaction and perfect contrast in outdoor conditions, including direct sunlight (Figure 4). High scores were also logged for the augmented panoramic views and the 3D VR presentation that automatically aligned with the user's position and field-of-view.

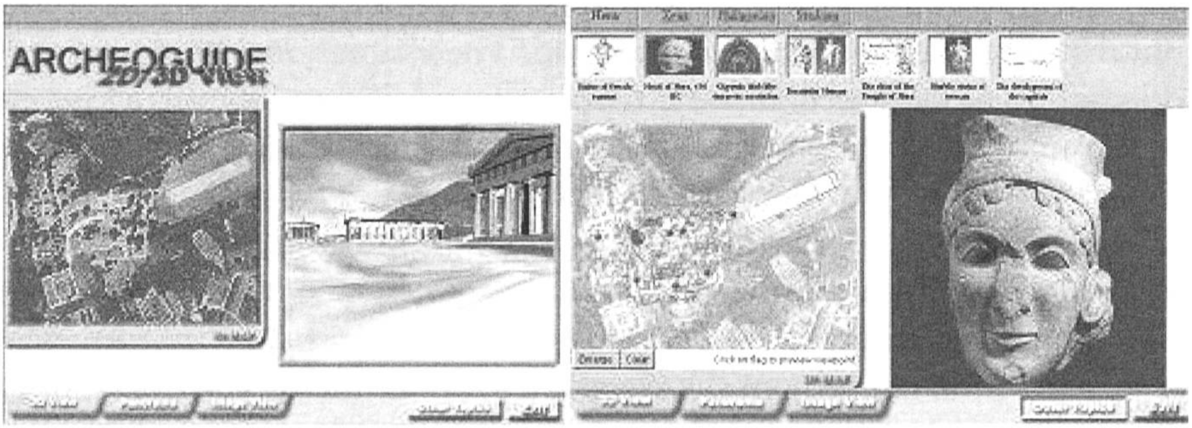


*Fig. 4: The presentation on the living book*

The PDA, in particular, was very popular due to its small size and weight but some users felt uncomfortable with the small size of its graphics. Even more important are the personalization and interaction options, which draw their users' attention and provoke their interest.

Regarding people with special needs, the intuitive operation proved very helpful. Negative comments were received only for the PDA's small screen. We note, however, that no users with kinetic disorders participated in the trials, neither mentally retarded visitors, as they were not present in the test sites during the evaluation dates and times.

On the other hand, the authoring and documentation tools offered by ARCHEOGUIDE were evaluated by the archaeologists and scientific staff of the Euphorate of Olympia, in Greece, as well as, the Department of Restoration of Ancient Monuments of the Hellenic Ministry of Culture. All the users had previous experience on computers and graphical Windows-based applications even though they had never used similar authoring tools before. Their satisfaction for the demonstrated applications was explicitly expressed during the trials, as well as, after their completion through specific questionnaires.

Negative comments were received for the modelling of the 3D objects (temples, etc.), which was performed with commercial 3D graphical software packages and adapted to the AR presentation scenario with custom-made graphical tools.

An important point to note is the high quality of all types of visual presentation. The colours and textures used in the modelled monuments satisfied both the ordinary and the scientific users. Shading is a problematic aspect of the presentations, as it stays fixed while in reality it varies during the day and the season. This is a point to be further investigated.

The development of ARCHEOGUIDE and its use in the archaeological site taught us interesting lessons, which could be applied to a variety of cultural heritage systems. The most important aspect of such a system is simple and intuitive operation even at the penalty of sacrificing additional features and functionalities. This is necessary in order to attract visitors into using and adopting it. Perceived quality of the audiovisual content plays a key role. Without high quality content the best available system will score low in its users' rating and consequently will fail to be successful. Considering now the devices themselves, size and weight significantly affect their adoption potential. The smaller, lighter and more compact a mobile device is, the more popular it becomes. Finally, having satisfied all these parameters, customization of the system and its functionalities to the individual user's preferences will differentiate it from competition and offer higher satisfaction.

## 10. The Future of ARCHEOGUIDE

Having successfully passed its evaluation phase at Olympia, the ARCHEOGUIDE prototype is currently under major reengineering. The feedback we received is now used for improving it and building a commercial product that could be installed at any outdoor site or museum simply by creating and modelling the appropriate content and performing a survey of the site. This ambitious effort is already beginning to blossom and a permanent installation is expected in the near future to offer visitors a travel into time.

Our efforts are based on evaluations received from 200 visitors and scientific users during the prototype system trials. The mobile AR devices are being replaced with lightweight wearable PCs and miniature AR glasses, and the new real-time 3D tracking technique is being introduced to allow continuous AR augmentations at any point along the tour path. The Living Book is being reengineered to feature guiding with miniature AR glasses and integrated sensors. Finally, a light AR guide is being implemented on the PDA, and Authoring and Documentation Tools are evolving so as to accommodate better support for AR authoring and content personalization.

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The living book and PDA notebook, and the location-tracking and management infrastructure for outdoor and indoor sites are commercialized by INTRACOM S.A. under the names intGuide and intCulture. These are custom-made solutions for virtually any cultural or tourist site, and offer integrated content authoring, device tracking and remote management, and statistical analysis tools.

The multimedia content and 3D monument reconstructions are used by Post Reality in commercially available DVD and other interactive presentations.

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