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TroiaVR: A Virtual Reality Model of Troy and the Troad

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Abstract. TroiaVR is part of a project called "Virtual Archaeology". IT-components for archaeological virtual reality (VR) presentation systems are being developed. An installation including reconstructions of Troy II, VI, VIII, its past and present landscape setting, and context information, has been shown as part of an exhibition in Bonn (Germany). "Workbench" tools to create, manipulate, and present content in a VR system, and to run the system on personal computers instead of workstations, should make such systems more accessible to archaeologists. We look into possible ways of linking archaeological information systems closely to a VR environment in order to use the technology not only for presentation purposes, but also as a research tool. Marketing opportunities for archaeological VR presentation systems are being explored. In the long run, we hope to provide a source of income for archaeologists to at least partly sustain further research.

Keywords. Virtual reality, information management, presentation systems, reconstructions, 3d computer graphics.

1 Introduction

Ever since Heinrich Schliemann's attempt to discover the reality behind Homer's epics archaeologists have been excavating at Troy (Northwestern Turkey). Since 1987 – more than a hundred years after Schliemann – scholars and scientists join efforts in an interdisciplinary project under the direction of Manfred Korfmann (Institut für Ur- und Frühgeschichte und Archäologie des Mittelalters, Universität Tübingen, Germany) with a different goal: They study the development of Troy and the surrounding landscape during the Holocene – human history, the evolution of the natural environment, and their interaction (Korfmann ed., 1991-2001). While number, scope and size of individual contributions have become extensive, a general perspective has become increasingly difficult to grasp.

Since Heinrich Schliemann's time archaeology has developed into an academic profession, but it has also become part of a growing "culture industry". Archaeology is vastly popular. A Troy exhibition in three German cities drew almost one million visitors within nine months (Troia 2001). Archaeologists today have an obligation to present their results to the wider public – especially if they want to convince the taxpayer to support their research.

At the beginning of the new millenium we should ask how information technology, multimedia, computer visualization, and virtual reality can help archaeology to meet its twofold challenge: To make scientific results accesible for the researcher, and to communicate them to the public.

Archaeologists do not have the resources to build large-scale, state-of-the-art virtual reality (VR) systems on their own. For the Troy project an opportunity to explore the possibilities new technology has to offer came when one of the authors, Steffen Kirchner, suggested to take part in a "Competition on virtual and augmented reality" issued by the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung; see http://www.dlr.de/IT/IV/VR-AR). The result was a project called "Virtual Archaeology", or in full "Virtual reality-based knowledge management and knowledge marketing in archaeology" launched in February 2001. Project partners are ART+COM AG (Berlin; leader of project consortium), Troia Project (Tübingen University), German Archaeological Institute (Cairo), IXL-Satinfo AG (Oberpfaffenhofen). Our goals are:

- To develop IT-components for archaeological virtual reality (VR) presentation systems.
- To make this systems accessible to archaeologists by developing "workbench" tools to create, manipulate, and present content in a VR environment, and by porting the software to affordable hardware (PC instead of workstation).
- To explore possible ways of linking archaeological information systems closely to the VR system in order to use VR not only for presentation systems, but also as a research tool. This is also necessary to provide authentic, accurate, up-to-date, and well-documented content.
- To create two archaeological applications: Troy ("TroiaVR"), and Ancient Egypt ("Virtual Nile Valley").
- To research marketing opportunities for archaeological VR presentation systems. In the long run, we hope to provide a source of income for archaeologists to at least partly sustain further research.

A working installation including reconstructions of Troy II, VI, VIII, its past and present landscape setting, and context information, has already been shown as part of an exhibition at the German Federal Exhibition Center (Bundeskunsthalle) in Bonn (November 2001 – April 2002; demonstration at the CAA 2002 conference in Heraklion).

2. Why Virtual Reality?

Since most, if not all, archaeological information has a spatial component, an obvious way to make archaeological data "fall into place" – both for research and presentation purposes – is the creation of some kind of three-dimensional computer model.

However, the term "virtual reality (VR)" must not be applied to all three-dimensional computer graphics or multimedia content (as stated by Frischer, Niccolucci, Ryan and Barceló 2002, 4). "Virtual reality" means the use of computer graphics to achieve a representation of some aspect of the outside world, or a visualization of scientific thoughts, or a depiction of pure imagination. In addition, a VR system should include the following features:

- Three-dimensional geometry to represent shapes;
- Naturalistic rendering of surfaces (light, textures);
- Interactive user interface;
- Real-time movement in space;
- "Immersive" display, i.e. more than a computer screen.

In the context of the Troy project, there are several reasons why VR technology seems potentially useful:

- To arrange data at its actual position in space, and to access it by navigating this space seems like a natural, intuitive way of handling large amounts of archaeological information.
- Troy is far away. A VR presentation system can bring the site to "visitors" anywhere in the world.
- Preservation of architecture is poor. Reconstructions can provide a visual explanation and interpretation of the remains.
- Scattered results from more than 100 years of excavation must be brought together.
- Troy is very popular. Academic research should therefore be supplemented by presentations for the general public.

At present we have reached a point where the question is no longer if VR systems should be used in archaeology at all. Several examples of archaeological VR systems have been developed, many for use as presentation systems at museums or exhibitions (Barceló, Forte and Sanders eds. 2000; Rieche and Schneider eds. 2002). The discussion has moved to questions of quality. How can VR technology best be applied in archaeology, both from the point of view of content and technology? How acceptable is the technology both to creators and users of VR systems? By working on a practical example we hope to contribute to research into these important matters.

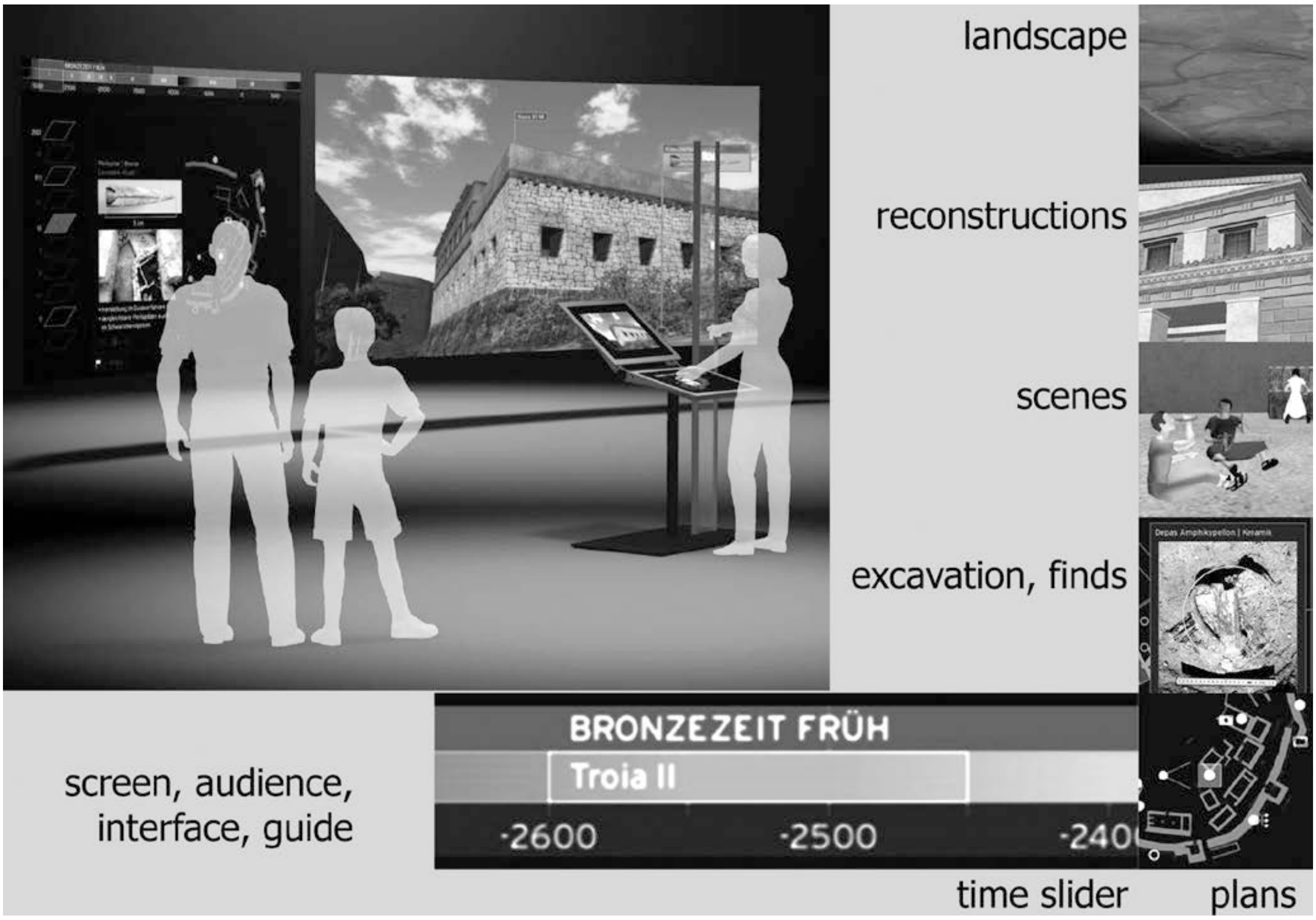

Fig. 1. *TroiaVR presentation system as shown at Troy exhibition in Bonn (Germany).*

3. TroiaVR Presentation System

During the first year of the project we concentrated on the development of the presentation system (Fig. 1), mainly because we wanted to finish a prototype for the ongoing Troy exhibition.

At present (May 2002) the system consists of two personal computers. One holds the VR system and data (Linux operating system, two Pentium III processors, tact rate 1 GHz, 2 GB RAM, GeForce 3 graphics card). The VR engine was originally developed for Silicon Graphics workstations by ART+COM and has been ported for use on personal computers. This dramatically reduces the total costs of the system and makes it more likely that archaeologists will be able to use it. The other computer, which can be a laptop, holds the graphical user interface (GUI; programmed with Macromedia Director) and context information (Windows 2000 operating system). The two computers communicate via a local area network (LAN). Since both the VR system and the GUI are fully database-driven, context information (XML-files) can be linked to any point in VR space. Thus the presentation system has built-in capabilities to be extended into an information system.

The VR system uses the following technologies:

- multitexturing;
- dynamic ROAM-algorithms for terrain generation;
- vector-based index maps for terrain texturing;
- 5 levels of detail (LODs).

The amount of data handled by the VR system is considerable. Each Troy phase consists of 200 000 – 1 000 000 polygons (18 – 74 MB). Textures are 80 MB per phase. The terrain (geometry and textures) is 1 GB per phase. The present-day landscape consists of 50 000 polygons.

For the museum installation the GUI was equipped with a touchscreen and a space mouse for navigation. At the Troy exhibition both the VR content and the interface were projected to a large screen in an auditorium seating ca. 100 visitors. The audience was given half-hour tours by trained guides.

During the exhibition we were able to gain valuable information on the acceptance of and user interaction with a VR system (studies of user behaviour are rare, for an archaeological VR example see Kadobayashi, Nishimoto and Mase 2000). As was to be expected, younger people found the VR installation more attractive than older visitors. The amount of information in the system seemed overwhelming. Large areas of the reconstructions where almost never visited, and some of the context information in the interface was rarely used. The average visitor has no knowledge of the differences between animations and full VR, or technical limitations of the latter, like the need to minimize the amount of data and reduce detail for the sake of smooth real-time movement. Therefore VR systems will only be fully accepted if the rendering approaches a quality users know from TV or film productions. We found that most users tend to have problems with interactivity. Some would have preferred pre-fabricated animations or videos that can be consumed passively. The guides where almost never asked to go to different places, or make any other changes to their tours, because most visitors did not believe this was possible. Although they had been trained on the VR system, some guides would just go to a few points, stop, and then use a laser pointer to explain a still image as if they were giving a slide lecture.

4. Contents

The VR scenery is based on landscape models (Fig. 2) produced with the help of digitized maps, satellite images, and research results. Changing coastlines and river courses are shown according to the results of a paleogeographical survey with several hundred boreholes (as summarized by Kayan 2001). Vegetation patterns derived from archaeobioglogical studies (Riehl 1999) are shown with the help of a vector-based image map on the terrain model. A high-resolution satellite image has been draped over the present-day landscape (IKONOS data provided courtesy of Compton J. Tucker, NASA, and Space Imaging Inc.).

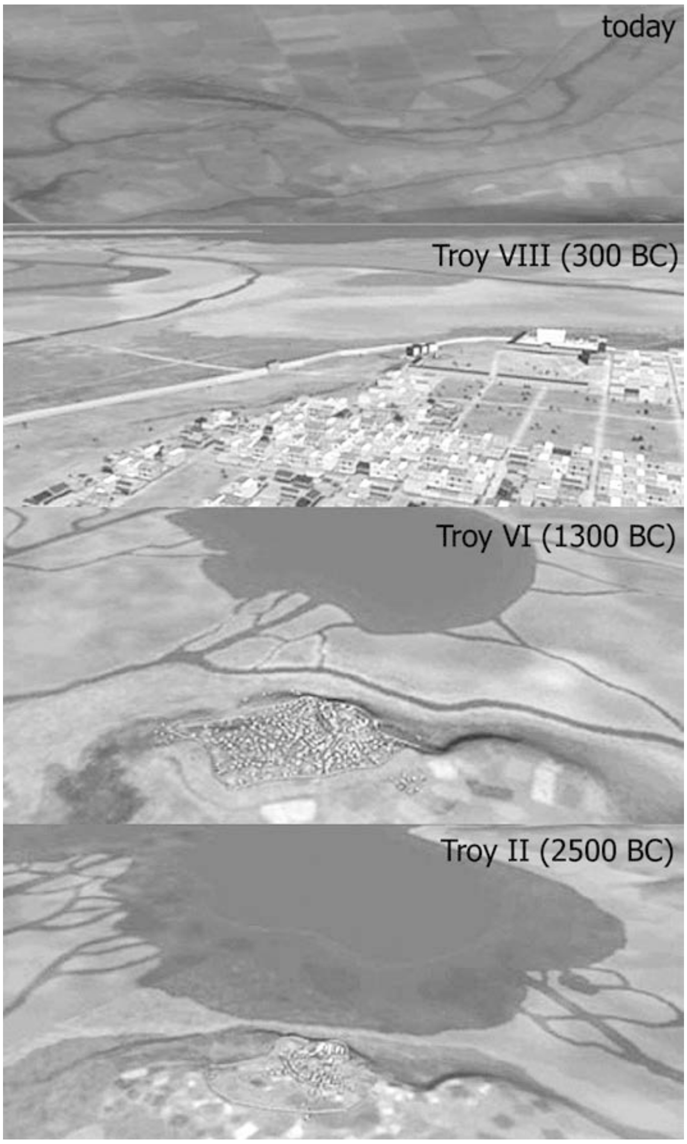

Fig. 2. *Four landscape models show changing vegetation, coastlines, and river courses.*

It usually goes without saying that archaeological VR systems include reconstructions (Fig. 3, 4). At present, TroiaVR contains reconstructions of three complete settlement phases: Troy II, VI, and VIII. A landscape model corresponds to each of these phases. Three of the most important stages in the history of Troy are shown in 1 000 year intervals.

Initially, archaeologists at the Troy project provided computer aided design (CAD) plans, descriptions, photographs, and hand-drawn reconstruction sketches. From this information, multimedia designers at ART+COM produced computer models. It soon turned out that this did not work out in practice as we had expected. Since most of the computer specialists had no previous experience with archaeology, the models had to be changed over and over again until the archaeologists were satisfied. We therefore trained archaeologists and students to do the computer models themselves. This can be done with any 3d modeling program that can export the models to standard formats (for example, VRML). Computer experts later optimize these models for use in the VR system (Optimization and simplification of polygons, naturalistic and seamless texturing, LOD creation).

We also included a few scenes with simple character figures to the presentation system: People drinking wine from *Depas*-cups inside the Troy II main *Megaron* building, a war chariot, a market stand and a domestic scene in a courtyard for Troy VI, and two persons, priests, philosophers, or Greek "tourist guides" discussing the legends of the Trojan war in front of the Troy VIII Athena temple. This gives the guides an opportunity to explain several aspects of the archaeology and history of Troy.

Criticism of archaeological computer visualizations is almost always aimed at some aspect of a reconstruction: Reconstructions show more than we actually know, they make people believe what they see, they are pure artistic phantasy, not the outcome of serious scholarly or scientific work, they are too attractive and seductive. We maintain that reconstructions are based on the same theoretical and methodological principles as an interpretation in archaeological texts (Bernbeck 1997, 85-108; Eggert 2001, 308-352; Hodder 1999, 30-65, 117-128). We assemble the actual evidence and then draw conclusions either directly from the evidence or by analogy from material collected for comparison – if we find a house with strong walls we find it likely that a second floor existed; and if we have better preserved buildings or a painting showing a house from a culture, time and region close to our site we conclude that the buildings we try to reconstruct might have looked similar. Like any other explanation or interpretation reconstructions combine our fragmentary knowledge with assumptions and believes, but will never revive what has been irreversibly lost. These inherent limits of archaeology become much more apparent in a visualization than in a text.

To emphasize the difference between actually excavated remains and free reconstructions, all reconstructions not based on almost complete ground plans can be switched on and off in our presentation system. In addition, plans and images shown on the interface screen (see below) allow for comparison between excavated remains and reconstructions. It is clear, however, that it would be wrong to show only fully excavated buildings in a reconstruction of a whole city. This would give the impression of an empty field with a few scattered buildings. Even without full excavation we have information on the size, limits, and general structure of a settlement from test excavations, surface finds, topography, and geophysical prospection. Therefore we developed several house types and distributed them over the whole area instead of leaving it empty.

In our experience, to ask the simple question: "how can it possibly have looked like?" has a value in itself. Trying to create a 3d computer reconstruction forces archaeologists to re-evaluate and discuss excavation results in previously unexpected ways. If archaeologists learn to produce 3d models themselves, they also remain in full control of all aspects of a reconstruction, can try out different variants and thus arrive at a satisfactory result by an iterative process.

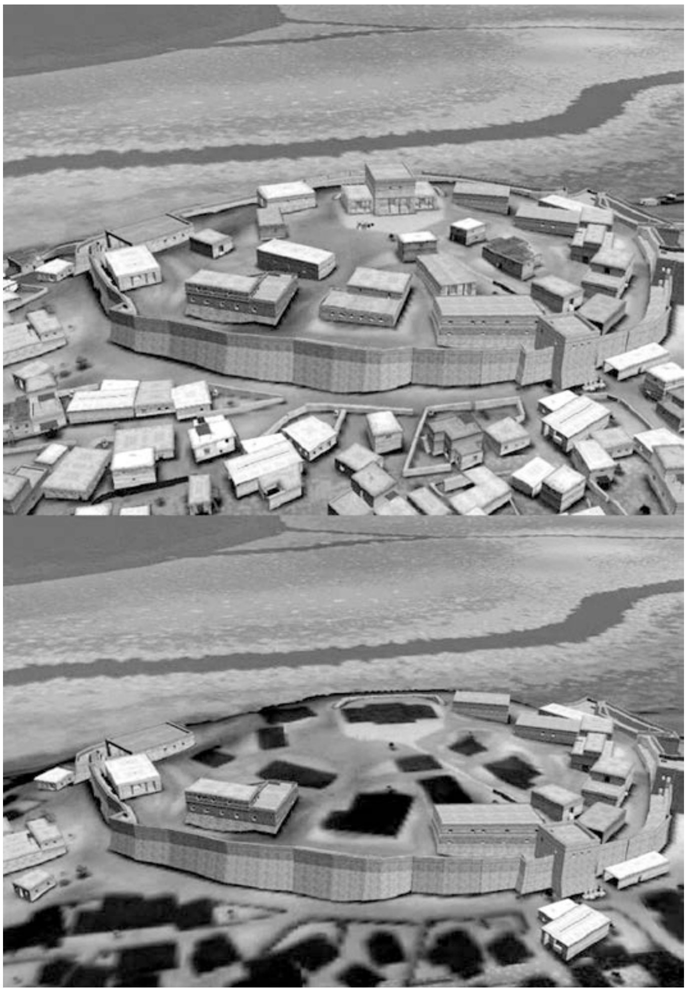

Fig. 3 *Complete reconstruction of Troy VI (top), partial reconstruction showing fully excavated buildings only.*

5. Interface

Moving through three complete phases of Troy with hundreds of reconstructed buildings in a 20 by 20 km landscape without further guidance one soon feels lost. An archaeological 3d world without additional information seems rather pointless. In addition, we want to extend our VR system into an information system useful for researchers as well as for museum visitors.

For these reasons we added context information into a graphical user interface (GUI) closely tied to the VR environment (Fig. 5). For orientation, the GUI has time sliders and a dynamic map of Troy and the surrounding landscape. A cursor on the zoomable map follows the user's movement in the VR scenery. "Hot spots" on the map can be marked with little flags in the VR scenery. Context information is linked to these points. Users can "fly" to these points of interest by clicking on them on the interface, or touching them if the interface is equipped with a touchscreen. Similarly, as users move to these points in the VR environment, the respective context information will pop up in little windows on the interface. For the presentation system we included explanatory texts, distribution maps, an image showing the results of magnetic prospection, images of finds with their actual findspots, and images of the excavations.

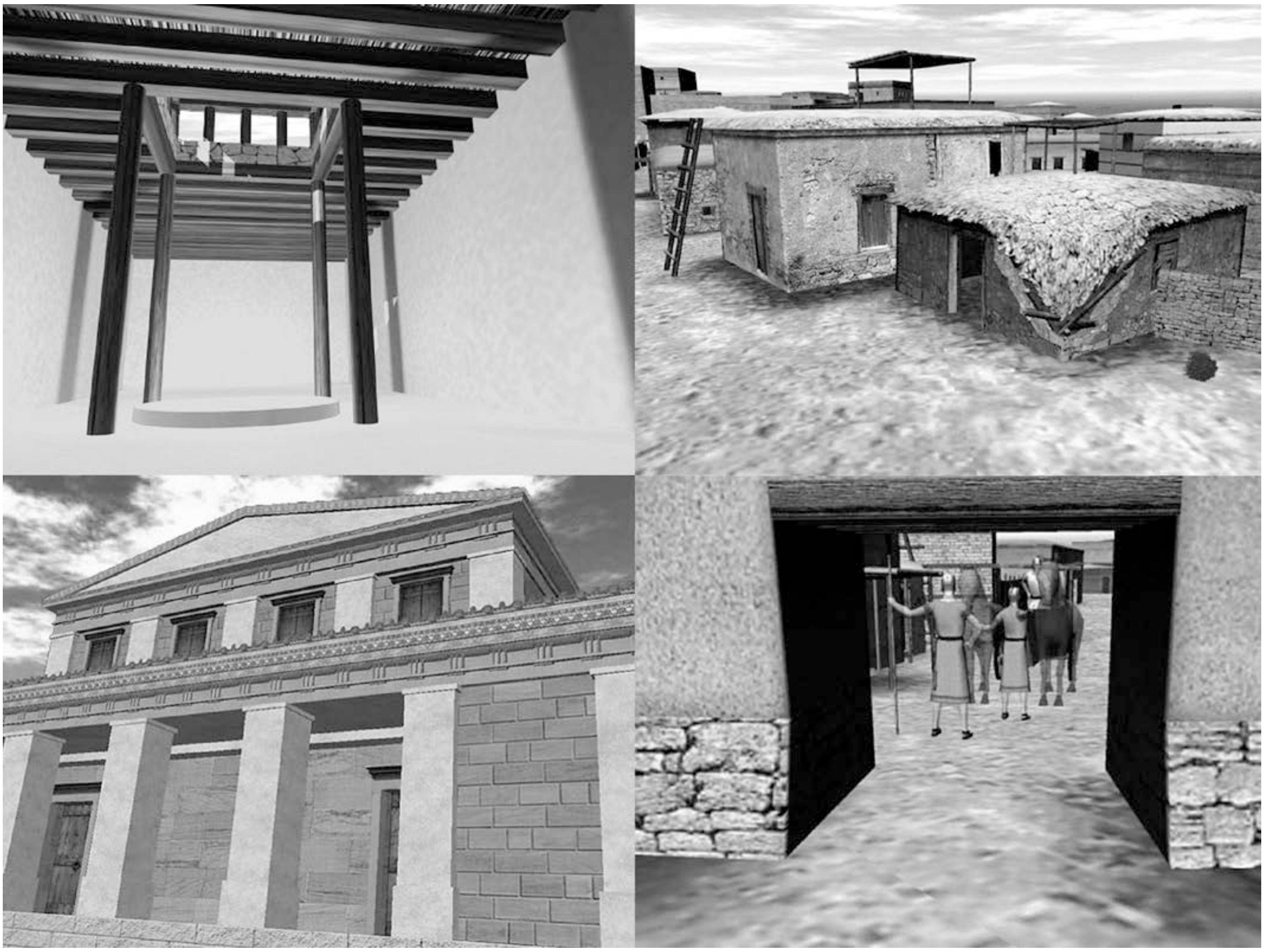

Fig. 4. *Aspects of TroiaVR reconstructions (clockwise from top left): Interior of Troy II Megaron, reconstructed destruction in Troy VI lower city, war chariot at the gate of Troy VI, Troy VIII Bouleuterion (town hall).*

6. TroiaVR: the Future

The synchronized links between the VR environment and external information we use in the GUI of our presentation system add capabilities of an information system to the VR scenery. We want to extend this into an open system where the real-time VR environment forms a high-level point of entry to underlying information. In theory, any kind of data or program output can be linked to the system, either by synchronizing databases to points in VR space and making them accessible by way of the interface, or by generating visualizations and showing them as geometry, texture, or image in the VR scenery. External information can also help to document the VR content and connect reconstructions with actual excavation results.

We are currently processing excavation documentation and other data with the help of a geographic information system (GIS) to enlarge the database of the system. The landscape models will be improved with the help of a digital elevation model (DEM) created from satellite data by our partner IXL Satinfo.

We are also working on improvements of some of the reconstructions we have done so far, and we still need to add some more buildings to Troy VIII. Apart from this, we selected some areas from other phases for detailed reconstruction case studies which will also include the interior of buildings with objects found in them.

Besides further improvements of the VR software, ART+COM is developing a toolkit that will enable archaeologists to work with the VR system without further assistance by computer specialists. We also want to develop production tools for the semi-automatic creation of output like animations or internet pages from the VR system, and for linking external information to the VR system. It should be helpful if archaeologists could agree on standards for data formats and documentation in this area (as suggested by Frischer, Niccolucci, Ryan and Barceló 2002).

Combinations of VR and databases of some kind seem like a logical next step in archaeological information management after the widespread use of GIS during the past years. While such systems have a potential to grow into useful research tools, archaeological VR applications are on the treshold of becoming standard for the presentation of archaeology in museums or exhibitions. The same content can also be used to produce illustrations, multimedia, TV or film productions. We believe that archaeological VR can offer an attractive blend of popular, high-quality content and the latest technology. We hope that eventually this can be used to create a source of income to support archaeologists and archaeological research. ART+COM is therefore exploring marketing opportunities for archaeological VR presentation systems. We would like to continue with our work beyond the end of our two-year project. To achieve this, we actively seek the cooperation of interested individuals or organizations.

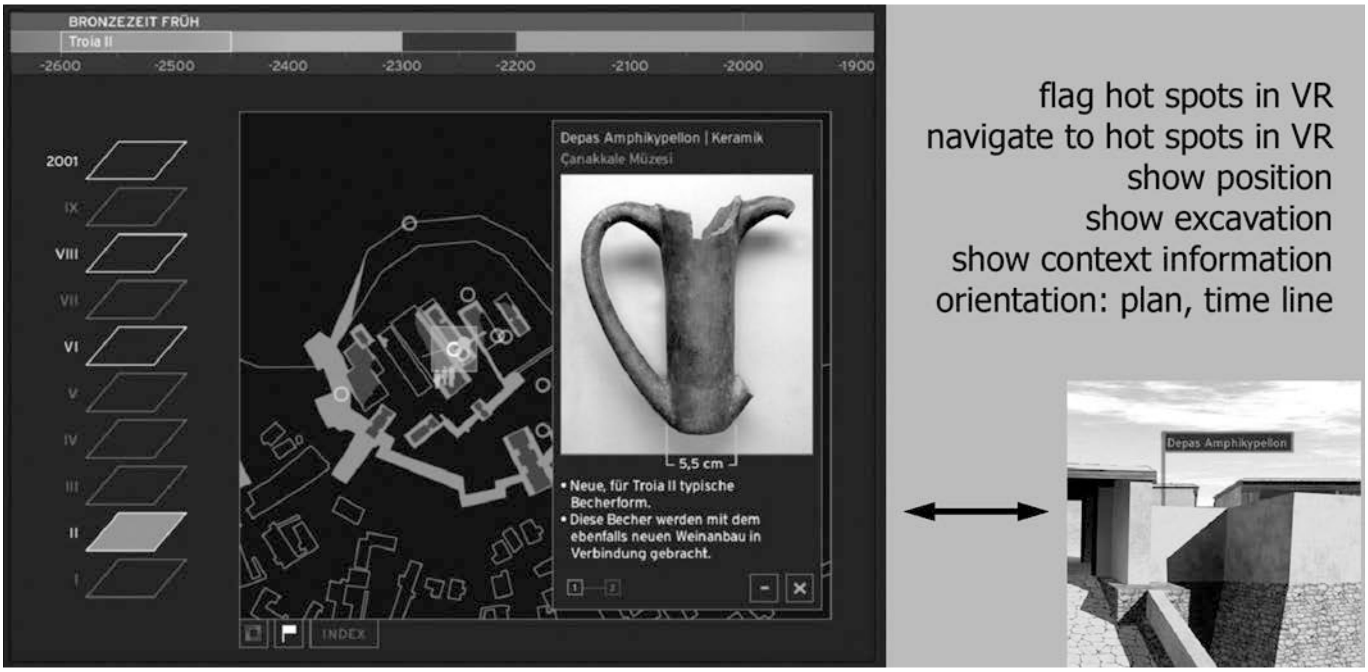

Fig.5. *The Graphical user interface (GUI) and its functions within the VR system.*

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