

Augmented Reality Based User Interfaces to Assist Fieldwork on Excavation-sites

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Abstract

This paper presents the models of both the hardware and software of a digital fieldwork assistant tool for archaeologists at excavation sites. The hardware prototype consists of an ultra-mobile PC, embedded with a camera, mounted with positioning and orientation sensors. We implemented GIS (Geographic Information System) interfaces to navigate the archaeologist on the excavation site in real-time and Augmented Reality (AR) based user interfaces to create and visualize rough 3D models of found artefacts. Since AR is the study of augmenting the real world with computer generated 3D graphics in real-time, our approach allows the archaeologist work on real artefacts with virtual annotations and save work directly on-site. Currently, we are testing our prototype at the Istanbul Yenikapi Marmaray Rescue Excavation site, where the ancient port of Constantinople (*Portus Theodosiacus*) was revealed during the excavations.

Keywords

Mobile augmented reality, archaeological excavation, user interface design

1. Introduction

Archaeological site excavation is a destructive and irreversible process. Archaeologists try to follow the phases of the excavation using traditional methods, i.e. querying access databases, examining spread sheets, analyzing CAD files, etc. According to archaeologists, there is a certain need to visualize and analyze the previously collected data and completed work. Over the past years, researchers have developed virtual and augmented reality applications for cultural heritage sites. The current applications are mainly focused on AR context, where 3D virtual objects are integrated into the real environment in real-time. They can be classified into two main categories: mobile tour guides (Vlahakis 2002; 2004) and reconstructive tools of remains (Benko 2004; Green 2001). Although there are examples of excavation analyzers in indoor augmented and 3D virtual reality contexts, there is no such application which offers real-time on-site digital assistance using outdoor augmented reality (Benko 2004; Green 2001). In this work, we present a tool to assist rescue excavation fieldwork on-site.

1.1. Test site: ‘Yenikapi Marmaray Rescue Excavation’

We are testing our tool in Yenikapi Marmaray rescue excavation site, an area on the European side of

Bosphorus, in Istanbul, Turkey. Since Turkey has a rich historical background, construction projects dig into archaeological artefacts occasionally. Therefore, rescue excavation is an active research area in Turkey.

The Marmaray Project aims to link the European and Asian parts of Istanbul with an undersea rail tunnel. During the excavations, the ancient port of Constantinople *Portus Theodosiacus* was revealed with port walls, cisterns, 24 perfectly preserved shipwrecks, ancient coins, pots, etc. (Smith 2007). The excavation project began in 2004 and the expected end date is 2010. A team of archaeologists, geologists and authorities of Istanbul Archaeology Museum are working on the remains of the fourth-century port. This area is considered as the most important and exciting archaeological discovery in the history of Istanbul.

1.2. Augmented reality

AR is an active research area in Computer Science, specifically in Computer Graphics. It is the discipline of augmenting real-time video images with computer generated 3D graphics in real-time. As defined by Azuma, an AR application should satisfy the following properties:

- combines real and virtual,
- interactive in real-time,

- registered in 3D (Azuma 1997).

The hardware components of a classical outdoor AR system consist of a laptop, positioning and inertial measurement units, battery pack, and a head mounted display.

2. Hardware and software design

In our project, we present an outdoor augmented reality tool to assist archaeologists on excavation sites, which provides a user-friendly interface. Our prototype consists of an ultra-mobile PC embedded with a camera and connected with orientation and positioning sensors (*Fig. 1*). The ultra-mobile PC serves as a navigation and annotation tool. The prototype is highly mobile in comparison to other outdoor AR hardware systems. The dimensions of the ultra-mobile PC, Sony Vaio UX 280p, are 15cm x 9.5cm and it weighs only 0.5kg. The internal camera can take 1.3 megapixel pictures and captures video up to 640x480 resolution. Image quality is an important parameter for the computer vision module of our software prototype. Higher quality decreases the error rate in camera calibration and in texture matching. Camera calibration provides the internal parameters (focal length, principal point, lens distortion coefficients, skewness coefficient) and external parameters (ro-

tation matrix and translation vector) of the camera. The internal parameters are required to project a 3D coordinate in the world coordinate system to the image plane, hence introduce augmented reality. We calibrated the camera in our laboratory with the Camera Calibration Toolbox for Matlab (Bouguet 2008).

The inertial measurement unit is XSens' MTx, which feeds our prototype with arm posture angles and heading of the user. It provides Euler angles in 3D coordinate system with an update rate of 100Hz via USB connection. The positioning unit is Fortuna GPS receiver. The earth coordinates in latitude and longitude are fed to our prototype with an update rate of 1Hz via Bluetooth connection.

The software is implemented with Microsoft Visual C++ 2005. The libraries integrated to our software and their functionalities are listed in *Table 1*.

Software Module	Library
User Interface, Windowing / Rendering	OpenGL library
	Freetype Font library
Video and Image Processing	OpenCV library
Sensor Communication	MTx software development kit
	Bluetooth communication interface
Data Handling	PostgreSQL 8.3.1 (included PostGIS)
	Libpqxx 2.6.9

Table 1. Software components and libraries.

3. User interfaces

After interviewing the archaeologists, geologists, and architects working in the Marmaray excavation site, we decided to divide the problem into two parts: completed excavation and ongoing excavation. An excavation site assistant for a completed excavation must visualize the excavation temporally and analyze the data collected. For an ongoing excavation, the previously completed work can be handled as in the completed excavation work; in addition to those properties, the user should be able to add/delete/edit data.

The interface offers the user three different viewing options of the site:

- Navigation interface (aerial map view),
- Navigation interface (vectorial map view) (Because the vectorial map data that we received from field architects is not



Fig. 1. Hardware prototype.

standardized for map drawing, this interface is not currently implemented.),

- Rough 3D modeling interface (AR view).

Each interface shows current user global positioning and heading, and categorizes each newly or previously (user-)defined area as a point of interest (POI). Currently, we consider the remains of the port walls as POIs.

Each POI has its own information sheet which contains information on positioning, time, digging, and layer, as well as user notes and the 3D model. Using the aerial view or vector based map view of the site users can navigate themselves on an actual map of the area and view/edit POI information.

The interface consists of a main menu tab where the user can

- change the view of the map between aerial view and vectorial view by selecting MAP menu item,
- add, edit or remove POIs by selecting POI menu item.

Selected menu elements are represented with white to clearly distinguish the current selection. On the right side of the main menu tab, the compass and the position information is displayed. The user is represented by a large arrowhead to designate position and user's heading.

On the map views, POIs are displayed with their label numbers, which are assigned automatically by the system. The color behind the label number of a POI indicates its area size. For example, lighter brown represents a smaller area whereas darker brown represents a larger area. The horizontal lines next to the label number represent the count and depth of revealed archaeological layers inside current POIs area. Below these lines, X and O signs represent five different stages of stratigraphic work and their completeness, X means work incomplete; and O, work complete (Fig. 2). Although these stages are currently symbolic to consistently represent UI, the actual number of stages may vary according to the archaeologists' needs.

When the user selects a POI with the stylus, its information sheet appears on a drop down window. The user can fill the appropriate sections of this sheet according to the completed work on-site (Fig. 3).

To activate the rough 3D model creation mode, the user has to lift the ultra-mobile PC to his gaze direction. The integrated inertial measurement unit tracks the arm posture of the user and allows the application to switch between different interfaces. To start modeling, a picture of the POI has to be taken from the current position of the user. The corners of the POI are the reference points for rough 3D modeling. For each reference point, the real-world measurements are assumed to be collected



Fig. 2. Navigation interface (Aerial map view).

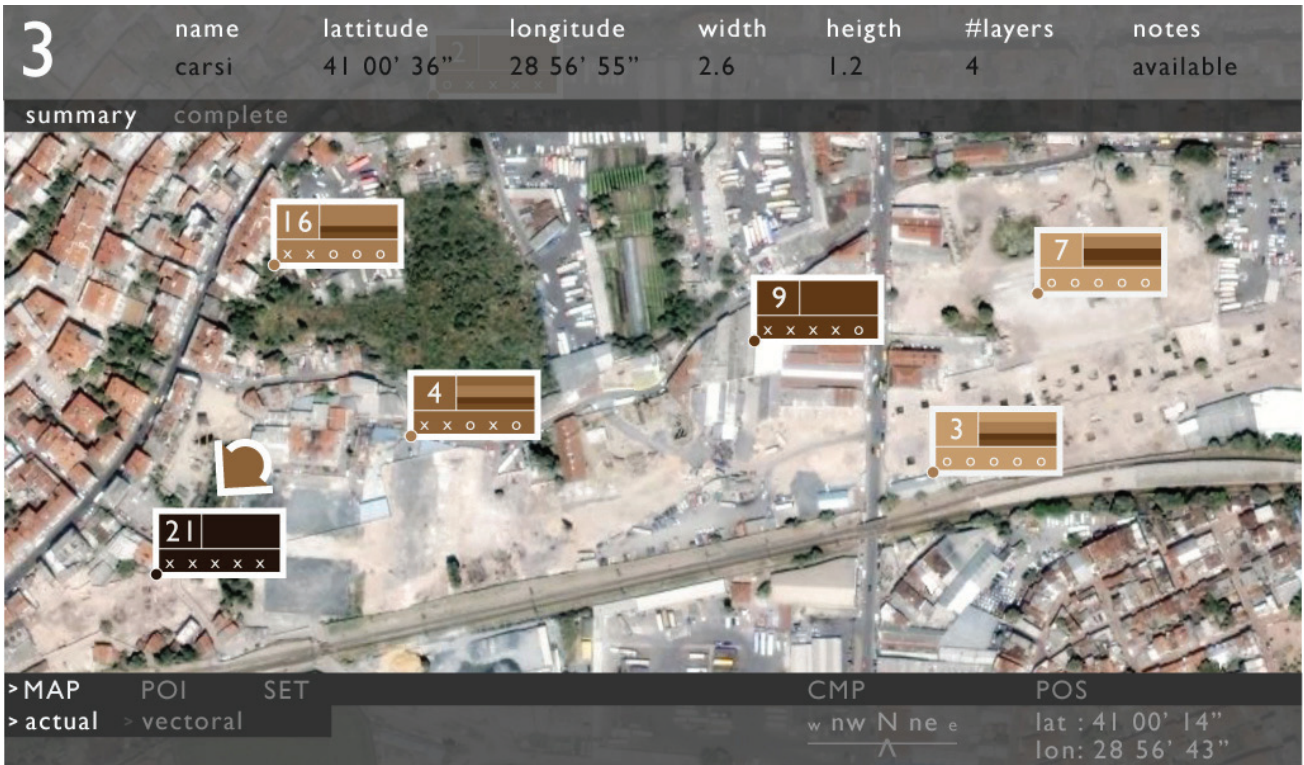


Fig. 3. Navigation interface displays the information sheet of a POI.

beforehand. Hence, they form a correspondence between the real-world coordinates and image coordinates to augment the worlds. Four corners representing the width, depth, and height of the POI are sufficient to create a 3D sketch over the real world image. To initiate the progress, the user selects reference points in the same sequence given

in the reference image on the lower right corner of the screen. Computer-vision techniques are applied to create correspondence between the real-world coordinates and image coordinates. The remaining corners are placed onto the image according to this correspondence; thus the rough 3D model is projected according to the current camera parameters. We are



Fig. 4. 3D modeling interface.

in the process of refining 3D models using known techniques from 3D modeling tools such as extrusion and slicing.

Once the 3D model is augmented to the view, the user may start to add information about the POI. One type of information that the user can enter for a wall are the strata which belong to different centuries. The user can draw lines between different layers on the image and introduce the labels for different strata to the 3D model (Fig. 4). This model can be saved for later examination. We are in progress of implementing and testing this step indoors using the pre-collected location, orientation, and image data from the archaeological field.

4. Conclusion

In this paper, we introduced a context-aware, highly mobile fieldwork assistant for excavation sites. Although many examples guide users in cultural heritage sites, no such system exists to assist the archaeologist's fieldwork directly on-site. We offer different interfaces, where the users can navigate themselves, add/delete/edit data and an augmented reality based interface which allows direct work on artefacts found with virtual annotations and objects.

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