

Visualizing Maya Cities on Site

A Wearable Augmented Reality Tool for
Archeological Field Study

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Introduction

Public architecture in ancient Maya cities was often designed and laid out to represent significant places and events in Maya cosmology [1]. Pyramids and palaces were often aligned with the cardinal directions [1,2]. Public spaces were typically designed for visual impact in ceremonial performances [3]. Current research uses off site ‘viewshed analysis’ [2] to note what could be seen from various vantage points. Knowing how Maya public architecture would have looked in the eyes of the ancient inhabitants is particularly significant to understanding ancient Maya history, culture, and theology [2].

While visual layout is important, the tropical forest that covers many un-restored Maya sites makes direct observation of even nearby ruins difficult. Traditionally considerable effort has gone toward clearing a site of trees before excavation begins [4]. In addition to cost this is not environmentally acceptable at some current archaeological sites. Excavation of forested sites commonly involves clearing only of architecture being excavated or restored with surrounding trees left intact. This gives much less visibility than the cleared city centers prevalent in ancient times [1].

This project aims to build and test a useful research tool for visualizing ancient architecture, city layout, and artifact distribution from key vantage points on site such as pyramid summits and ceremonial plazas. The wearable augmented reality system can provide on site visualization with a reasonable 3D approximation of what architecture and artifacts an ancient inhabitant would have seen from the vantage point where the archaeologist stands. This is viewed through a head mounted display (HMD) with orientation tracking connected to a wearable computer with GPS position tracking.

Background

Augmented Reality (AR) is a current area of research in which virtual objects or sounds are superimposed on a person’s perception of the real world [5]. Wearable or mobile augmented reality computer systems have been tested for architectural visualization [6] and real object location [7] in outdoor urban environments.

Wearable computers designed specifically for use in field archaeology as picture and data gathering tools have been tested [8], but these lack the capability for 3D visualization in augmented reality. Hand held computers connected to ‘navigational quality’ GPS receivers for use in placing and retrieving location tagged field notes while working at archaeological sites have also been described [9]. A mobile system for 2D site map, 2D artifact distribution, and user location visualization combined with location based image capture and retrieval and wireless networked collaboration between archaeologists has been described for test in Alexandria Egypt [10]. This is a sophisticated system, but does not provide visualization of ancient architecture in 3D.

A project technically similar to ours called Archeoguide is underway in Greece [11]. This project aims to provide 3D visualization of ancient Greek architecture to tourists and researchers from a database of detailed 3D structures stored at a site.

The Project

This “Visualizing Maya Cities” project is unique in providing 3D visualization to archaeologists while working in the field with integrated tools to create and modify 3D maps and models as data about architecture structure and artifact location is gathered. While not limited to ancient Maya archaeology, the system is intended to meet the particular need for archaeologists working at un-restored Maya sites to ‘see’ the site as the original inhabitants might have seen it in order to create working hypotheses about architectural design and test those while in the field. This can aid the archaeologist in choosing where best to do site mapping or exploratory excavation. The system also enables observation of artifact distributions and the sharing of insights gained from visualization with other archeologists working on the site through sharing or networking multiple AR systems.

Information Display

The system displays data entirely within the HMD since LCD displays are difficult to read in bright sunlight [12]. The HMD used is semi-transparent, like sunglasses with computer displays overlaid. 2D overlays are used for special circumstances. Otherwise the display is always a full 3D representation of data objects and/or virtual architecture positioned, scaled, and oriented as if it were present in the real physical world of the archaeological site.

A flat ground grid in metric units can optionally be displayed as a wireframe or a digital elevation model data can be imported and displayed as a wireframe 3D elevation grid. The level of detail of either grid can be increased or decreased as needed by linear interpolation.

Positions of artifacts set by using the system or imported from GIS databases are displayed as 3D icon objects in the position they were found. On request, digital camera images of the objects, can be displayed as 2D overlays in the HMD and text notes can be displayed or read back using text to speech software.

Architecture is represented alternately as a wireframe for layout and modification or as flat or smooth shaded polygons in bright user selected colors for visualization. This is seen in the HMD as buildings superimposed on the landscape of the site viewed in the same scale and position they would have appeared to an ancient person standing at that position.

The alignment is imperfect due to uncertainty in GPS position and head tracker orientation. The small, moderate cost GPS units tested in this system have a position uncertainty of one to ten meters depending on hardware configuration and satellite visibility. The lightweight head trackers tested have an angular error of 0.5 to 1 degree and a fraction of a second latency. Given the large scale of ancient Maya public architecture these errors can be acceptable for observation purposes and corrections can be applied as described later.

Image rendering is handled by the OpenGL API. The current system updates the display at a rate from 10 to 40 frames per second depending on the complexity of the virtual objects in view. Faster CPU and graphics display hardware will increase this rate without a change in software.

User Interface

The system user interface operates primarily through voice commands and an extensive set of system voice responses recorded as sound files on a local hard drive. The voice recognition engine is off the shelf software (currently IBM Via Voice). Command vocabularies and recognition events are communicated by a standard API. Voice recognition is imperfect, but normally quiet remote archaeological sites provide an ideal environment and this leaves the archaeologist's hands free for other tasks. Each user will spend about ½ hour training the system to recognize his or her pronunciation of the list of voice commands. This gives the user a familiarity with the available commands. As a backup, all commands are available as pop-up menus in large print (for HMD visibility) which can be accessed by a small touch pad attached to one wrist.

Building on the voice interaction model, the system uses software agents that communicate by voice to carry out tasks commanded by the user. The software agents will prompt the user with the relevant command set in each operating context on request. Software agents which can carry out actions are represented as moving 3D objects in the display in order to help confirm that the action carried out was done as requested. For example, if the archaeologist user asks to modify the position of a virtually represented artifact, the software agent responsible will appear to move to the virtual object the archaeologist is looking at to confirm the selection, then move with the virtual object to a new position or grid point the archaeologist is looking at and confirm the move. Relating this to a standard 3D modeling software interface, one can imagine a context aware 3D drag and drop cursor in 3D space which is able to respond to voice commands, look at points, object location, and user position and orientation.

In building a virtual representation of an ancient site, the archaeologist can choose to import existing 3D objects stored in the well established 3D Studio format. 3D Studio can in turn import and export CAD produced DXF files. These can be positioned and scaled on a site grid using a combination of voice commands and user position and look at points. Existing paper site maps can be scanned, converted to vector format, and similarly imported as point and line data to the system.

If existing 3D model and 2D map data is not available, the archaeologist can create 3D models of architecture and large artifacts in the field. In the simplest case, the archaeologist can walk to corner points of a ruined building and command a software 'construction agent' to set a numbered corner point. The software agent will join successive points with line segments to create a virtual floor plan. The archaeologist can then command the agent to modify point positions in 3 dimensions and add or delete points and line segments between points. GPS satellite views are frequently obstructed at the base of monumental architecture and by areas of dense tree cover. Also the base elevation of ruined architecture is often variable due to rubble. To overcome this the archeologist can stand at a point where a GPS fix is possible and create and modify corner points at some distance by snapping to a site grid at an appropriate level of detail. Once the floor plan is complete, the archaeologist can ask the 'construction agent' to elevate the plan vertically to create walls or in a tapered pyramid shape. The base and top elevation can be modified by voice command to match the observation or best conjecture from the existing ruin.

The structure can be ornamented by loading and modifying typical Maya architectural elements from a database (ie. stairways, lintel doorways, corbelled arches, roof combs, etc). Unique elements can be created in 3D Studio or a CAD program and imported. The minority of round buildings in Maya architecture can be represented by establishing a center and inner and outer wall diameters. Intact interior rooms and corridors can be modeled by elevating grid coordinates, but dimensions will have to be independently verified since GPS positioning will not work.

Artifact locations can be recorded by telling an 'artifact agent' to set a 3D marker icon at a particular GPS location or grid coordinate. A micro video camera attached to the HMD can capture an image of the artifact from various positions. These can be reviewed when returning to those positions even if the artifact has been removed. Different types of artifacts are represented by different icons (ie. stelae, grinding stones, pottery sherds, etc.) Artifact data (images, notes, classification, location, etc.) are saved to a database for sorting and recall when the user requests. The 3D icons representing artifacts can be viewed from any position including a special birds eye view option to evaluate artifact distribution.

We are also looking into importing GIS data from the Archaeology Data Service [13] to the database.

The field archaeologist can correct for GPS errors or mismatch in map projections using a variation on a technique described by Thomas, Piekarski, and Gunther [6]. If there is a previously mapped architectural feature or artifact with good GPS visibility, the user can stand on or adjacent to that feature and give a voice command to 'correct position' The system will display a 2D overhead 'map' view. The user can drag the current user position icon with the touch pad to the artifact icon or architectural feature he or she is standing on. The user can then 'correct elevation' in a similar fashion on a 2D side view display. Position offsets are applied to the GPS readings until the user chooses to 'cancel offsets'. Back in full 3D display, the user can 'correct alignment' from the set position by selecting a virtual object or architecture point that matches a visible real world point, then looking at the real object and commanding the 'alignment agent' to 'set alignment'. The second virtual/real world point match can correct azimuth and pitch errors, a third can correct roll.

Hardware

Two test systems are in use for this project. The older system [Fig. 1] is a backpack mounted 400MHz Pentium II CPU with 512MB RAM an Elsa 3D graphics card and a 10GB hard drive. A CMC Superstar GPS card and CSX differential beacon receiver are built into the CPU box with antennae mounted on poles on the backpack. The newer system [Fig. 2] has a 750MHz Pentium III CPU with 256MB RAM and a 16MB ATI 3D graphics card in a notebook PC carried in the back of a vest. A Garmin GPS unit sits in the shoulder of the vest. For both systems, the head mounted display is a Sony Glasstron with stereo earphones. A noise canceling microphone and a 3 axis digital compass (PNI TCM 2) are added to both head units. The systems can be linked by 802.11 wireless LAN where applicable.

Results

Two test hardware systems are largely complete. Most generic AR software components are complete and being tested locally. Application specific software is in development. Two complete systems will be ready for field testing at working archaeological sites in Fall 2002.

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Figure 1. Author with older system



Figure 2. Author with newer system