Resolving Archaeological Site Data With 3D Computer Modeling:
The Case of Ceren

Jennifer S. Lewin and Mark D. Gross
Sundance Laboratory for Computing in Design and Planning
College of Architecture and Planning
University of Colorado, Boulder and Denver
Boulder, CO 80309-8314

ABSTRACT

This paper reports on our experience working with a team of anthropologists to construct three-dimensional computer graphic models of Ceren, an archaeological site in western El Salvador, using inexpensive hardware and software. In constructing the model we discovered various ambiguities and inconsistencies in the raw site data and drawings we were provided. We resolved these problems by analysis and reinterpretation of the data, working closely with our archaeologist collaborator. What began as a simple exercise in rendering developed into a collaborative research effort to understand and interpret the source data. The process of computer modeling forced us to re-examine, analyze and reinterpret the information from the site.

INTRODUCTION

Three-dimensional computer modeling of archaeological sites and data extends traditional techniques for archaeological recording and analysis. Although this technology is not new to other fields such as architecture and urban planning it is still being explored in fields such as archaeology and anthropology. Computers can augment archaeological data by displaying it in three dimensions to simulate the original appearance of a site. Previously, visualizing archaeological data was limited to two dimensional orthographic drawings and costly one-off artist's renderings (Simmons 1996). Today, archaeologists and computer modelers can work together to interpret archaeological data and recreate more accurate three-dimensional views.

The use of computer graphics to visualize archaeological data has increased over the last few years (Peterson, Fracchia et al. 1996) . In archaeology, computers are primarily used for four purposes: the creation of databases, image processing, artifact modeling, and statistical analyses (Oikawa 1992) . Studies in data visualization and solid modeling have increased, in part due to available technology. The ability to visualize spatial relationships in archaeological sites has obvious value in anthropological research. A model provides the means to organize vast quantities of spatial information which otherwise could not be coherently displayed together.

It is now possible to use computers to create three dimensional virtual archaeological sites from existent excavation data. Computer models and animations have been made for numerous sites including the temple precinct of the Roman town of Bath (Wallis, Bowyer et al. 1990) and the Temple of Amon at Karnak (Egypt) (Boccon-Gibod and Golvín 1990) . A 1981 Nova series presenting a fly through of the Giza Plateau computer model provided an interesting educational tool for those unfamiliar with the site (Sanders 1997) . Current projects include the 1995 Pompeii Forum project involving the surveying and use of on-site AutoCAD modeling with single-photo photogrammetry (Foster, 1985) , or the Homo Fovi Research Project (Gann, 1884) using Autodesk's 3D Studio to render a 150-room pueblo site near Winslow, Arizona. These projects have shown promise, not only in aiding public interpretation of a site, but in helping researchers visualize and understand the site data.

Computer models and animations are the closest we can get to a present day understanding of ancient space through primary experience. A reconstruction of the temple precinct of the Roman town of Bath (Wallis, Bowyer et al. 1990) revealed information only apparent through such experience. When the model was examined from several viewpoints, views of the magnificent Sulis Minerva from one entrance of the precinct were especially impressive. In contrast, views from the top of the steps of the temple towards the entrance provides a weaker image of the attendant structures shrinking away (Reilly 1992) . Similar models such as the Lancaster University Archaeological Unit 1985

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reconstruction of Furness Abbey and the 1989 model of Langeliffe Limekiln (Wood and Chapman 1992) provided useful tools for checking reconstruction ideas, simulation of structural systems, and communicating results to others.

The sheer visual impact of computer models, renderings, and animations often distracts attention from other important issues involving the creation of a system to successfully maintain enormous volumes of three dimensional data. Often, computer models are seen as sophisticated presentation tools (Reilly 1992). What makes these pictures impressive however, is not their graphics, but the process of recording, analysis and interpretation that is required to create them. To create a virtual picture of the site, one must collect and resolve essentially all spatial information, as well as surface treatments and lighting conditions.

In Fall 1995, Scott Simmons, then a doctoral candidate in the University of Colorado department of Anthropology, came to us to explore possibilities of visualizing archaeological data from Ceren, an ancient village in El Salvador. Using three dimensional computer modeling we attempted to construct representations of the original site. What started as a simple exercise in three dimensional site visualization and essentially, the goal of better graphics, using architectural computer graphic modeling methods led us over the next six months to explore interesting questions in archaeological interpretation.

Computer models required a level of resolution and unified information that had not been achieved in the original Ceren data. Due to limitations in traditional paper based methods of archaeological site visualization, modeling required full collaboration between both architects and anthropologists to resolve and organize the data.

This paper reports on our experience and initial findings. The paper is organized in five sections. The following section gives an overview of household archaeology at Ceren and current two dimensional paper based methods of archaeological research and recording. Next we describe several problems with archaeological site visualization that our modeling project of Ceren made apparent. We describe our modeling project in detail, and identify ways in which computer based visualization can help resolve questions about archaeological sites. Finally we conclude with a discussion of lessons learned from this project.

CEREN AND HOUSEHOLD ARCHAEOLOGY

Ceren

Ceren, a pre columbian agrarian village located in western El Salvador, was buried 1400 years ago due to a sudden volcanic eruption. Having had little warning of the impending disaster, residents of this small agricultural village fled from their households, leaving all belongings behind. Covered entirely in ash, nearly all household artifacts from Ceren were preserved (Simmons 1996).

The major focus of research at Ceren is a field of anthropology termed ‘household archaeology’. The study of prehistoric household remains in Mesoamerica is still in its infancy, as most research has centered on the large temple-pyramids, richly stocked royal tombs, and the ball courts built for and used by a small elite fraction of the population (Sheets, Beaubien et al. 1990). Until about 20 years ago, without rural prehistoric households to study, our knowledge of the lifestyles of the pre columbian peoples of Mesoamerica was almost nonexistent (Simmons 1996).

Understanding the cultural and biological bases for how and why people organize their lives is a central theme in anthropological research today. For this reason, Ceren offers an important contribution to modern anthropology. First, because the villagers did not have time to take any of the objects they used, we are provided with an unusual glimpse of everyday objects used in domestic activities. Second, the volcanic ash deposited on the households helped to prevent the decay of objects. Even small mouse bones and corn kernels were preserved. The richness and quality of this information provides archaeologists with the ability to reconstruct daily patterns of household organization in a manner that has not been possible before (Simmons 1996).

Traditional Methods for Archaeological Data Display

Archaeological excavation exposes objects in the places where they were left in the past. Traditionally, archaeologists record all location data in layers as artifacts are exposed (Reilly and Rahtz 1992). Often these artifacts are mapped in the field one layer at a time. As objects are exposed, a series of photographs are taken as part

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of standard archaeological recording procedures. Traditional recording methods involve sketching the objects in two dimensions, analyzing the layered data, and constructing two dimensional elevation drawings (Simmons 1996).

At Ceren, site information consisted primarily of simple two dimensional plan drawings. Vertical heights and scales were demonstrated with charts of object dimensions. A compilation of axonometric views and artists renderings of the site were also used as visual aids. Figure 1 illustrates three common pieces of information provided for modeling: a standard plan drawing with included artifacts labeled by their F-S (field specimen) number (top left), an artifact dimension chart listing found artifacts for structures by their F-S number (top right), and a basic dimensional chart listing structural dimensions for the building (bottom).

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**Figure 1.** Standard information provided for modeling

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**LIMITATIONS OF CURRENT ARCHAEOLOGICAL RECORDING TECHNIQUES**

As we began to work, we realized that the site data from Ceren did not provide sufficient information to construct three dimensional models. It soon became apparent that the process of constructing the models would require the assistance of anthropologists to resolve questions that arose from the data.

We were provided archaeological field data for Ceren including charts of measurement data, plan drawings for horizontal object placement, several axonometric drawings of buildings and two artist's renderings of the site. At first we were unable to model Ceren due to four limitations in this provided archaeological information, as follows. First, the recorded archaeological information offered inconsistent interpretations of the same object. The manner in which the data was recorded in many cases was not conducive for modeling. Second, many drawings were simply incorrect; they did not correspond to the source data from which they were made. Third, the charts and drawings did not adequately describe spatial relationships between forms. Finally, the data provided an insufficient supply of three dimensional information. We consider each of these limitations below.
Different Interpretation of Similar Objects

Because research at Ceren has extended over a vast period of time and encompassed different individuals in specialties within and outside anthropology, records and displays for Ceren have continually changed. Therefore, a flexible and dynamic format for displaying information is needed. However, the two dimensional drawings made at Ceren do not supply such a format. They must be redrawn as changes are made, they cannot be worked on collaboratively, and they often yield only a single, individual, point of view.

For example, two drawings of the same object made by different individuals often reveal quite different understandings. Surprisingly, concise agreed-upon forms for many of the objects found at Ceren were simply not available. To construct the three dimensional model from these divergent drawings we needed to resolve inconsistent interpretations. For example, all the plan drawings made for Structure #1 displayed only ceramic artifacts found on the structure floor. However, separate charts describing measurements of ceramic artifacts found in the same building included a number of artifacts that were not shown in plan. Figure 2 shows a list of artifacts found within Structure #1 along with the archaeologists corresponding plan drawings. Many ceramic artifacts listed were not drawn in the plan, likewise, some ceramic artifacts drawn were not listed. Thus the list of ceramic artifacts and the plan drawings yield inconsistent information. In order to model Ceren, such inconsistencies had to be resolved by finding dimension information in the original site excavation data.

![Artifacts located in both plan and dimension chart are highlighted to the left.](image)

![Artifacts in the plan, for example Pots labeled "F" in Area 0-1 are not available in the dimension chart above.](image)

**Figure 2. Inconsistent artifact data, Structure #1**

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Inaccurate Display Drawings

Many scale drawings were incompatible with original measurement data. Drawings of site excavation data depended on an individual excavator's skill at recording information accurately. When we compared the site drawings (some of which had been published in research reports about Ceren (Sheets 1992)) with the original measurement data we found that the drawings were incorrect. Figure 3 (left) shows a plan drawing for two artifacts that, when compared to measurement data, was found to be significantly out of scale. Figure 3 (right) shows the computer model made from the original measurement data.

![Figure 3. Original published scale drawing (left) versus final model (right) based on measurement data (bottom left, in white). Structure # 11.](image)

Inadequate Information About Spatial Relationships

Collected site data are often difficult to visualize without three dimensional pictures. The data are simply a list of dimensions and do not reveal how objects are related in space (figure 4). For example, in Structure #11, data regarding the height and width of a wall were listed in a chart. Data regarding the height and width of its corresponding column was listed likewise. From studying dimensional charts (figure 4 top) it is clear that there is a twenty five centimeters height difference between various columns and walls. Without a three dimensional picture the reason for this height difference is unclear, and in the artist's renderings made and published in Ceren research data, simply ignored (figure 4b).

Inadequate Three Dimensional Information

A final problem we experienced with archaeological recording techniques was simply the lack of complete three dimensional information. Archaeological site drawings only show one layer of information. A plan drawing displays horizontal placement of found artifacts. Measurements charts display the width and height of objects. The final published plan drawings of Ceren displayed only the positions of artifacts where they were found. However, because many artifacts had fallen, this found position was not necessarily their original position. To construct a three-dimensional model of the site as it appeared in daily life, we needed to resolve the original placement of all questioned artifacts. Because the two original dimensional drawings do not require specific analysis of where these artifacts had been placed (in the vertical dimension, before they fell to the ground) we were unable to model these artifacts without additional information resolving their original placement. Figure 5 below shows the plan drawing for Structure #11. Several objects are drawn overlapping each other, for example F-S 266, F-S 247, and F-S 238. Their original vertical placement is unclear.

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Figure 4a. Two dimensional wall height data. Structure #1.

Figure 4b. Artist's Rendering of data in Figure 4a. Structure #1.

MODELING CEREN

Using Form-Z, (a solid modeling and rendering program) (auto-des-sys 1990) we modeled seven of the twenty five potential households identified by ground penetrating radar (Conyers 1995). The modeling included topographical site information and over one hundred artifacts found on site, from pot shards to chili peppers. We received, discussed and evaluated information for model construction from our anthropologist collaborators.

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The large number of artifacts to be modeled with relatively low-end hardware (Power Mac 7100's), required we build models as economically as possible. For example, we modeled poles as square columns and then smoothed them during rendering. This gave the appearance of a curved surface without the modeling costs of additional poly-lines.

We made test renderings for all materials, lights and textures. We evaluated the test renderings with archeologists who used their personal experience at the excavation site to help us choose appropriate texture maps for the rendering. In addition to the archeologists' personal experience, we used slides taken on site during excavation as well as angle information to model probable lighting conditions at Ceren.

In order to construct three dimensional computer models of Ceren we needed to resolve inaccuracies and inconsistencies in the data we were given. Through conversations with our anthropologist colleagues, we were able to fill the gaps in site data and obtain the information we needed for three dimensional modeling. Following are four examples of this process of resolving problems with source data to construct the model.

![Diagram of a site map with labeled areas and measurements.](image)

Figure 5. Vertical object placement.
Structure # 11.

**Resolving a Higher Shelf**

In one model, information for a possible higher shelf existed, but was not drawn due to ambiguity about its position. We worked with Simmons to resolve possible placement. Although two dimensional drawings could ignore this information, three dimension modeling requires all information including ambiguities and inconsistencies be analyzed, resolved and presented. Constructing Ceren's three dimensional models required a specific, finalized placement of both the shelf and its artifacts, which was not apparent in the original archaeological drawings.

Figure 6 shows a computer reconstruction of Structure # 11 with a back shelf. All inconsistencies as shown in Figure 5 (plan drawing for Structure #11) were resolved through the creation of the model and the placement of the higher shelf.

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Inconsistencies in Wall Heights

Modeling Ceren made measurement inconsistencies in wall heights visually apparent. Through building a model we found that in several places columns were significantly lower than their connecting walls (Fig. 4a). To construct the model we needed to resolve this difference of heights, and this led us to question the reasons for this height difference. Through discussions with archaeologists (who re-examined their excavation data), and by viewing these walls three dimensionally, we concluded that the height difference between the columns and walls was due to previously un-represented window openings. Located in places reaching the most sunlight, and used in structures requiring greater circulation (kitchen and living structures) these wall height variations probably provided valuable light in areas of use. The use of a three dimensional computer model made such object relationships visible. Figure 7 provides two views of the Structure #1 computer model. In contrast to original published renderings of structure #1 (Fig. 4b), the wall height variations are clear.

Collaborative Model Construction

Because we used computer based techniques, several members of our team were able to work together on a single model. Unlike a paper drawing or a physical model, a single computer graphics model can be continuously modified and refined. Thus, several individuals can collaborate on one piece. Structure #7 at Ceren was modeled by several members who, working separately on different parts, combined their individual information into a single model of the structure. Figure 8 shows the computer model of Structure #7. Pots and artifacts were modeled by one individual and imported on layers. Basic structural elements were likewise modeled separately. Finally, one member of the modeling team combined all layers to apply texture maps and create views.

Accuracy and the Value of Multiple Views

Constructing the computer graphic models required specific dimensional input. This resulted in our models being significantly more accurate than previously made drawings. Object accuracy can be tested by comparing coordinates in the computer model with field excavation data. Computer models also enable the archaeologist to produce a diverse range of views without costly reconstruction (Peterson, Fracchia et al. 1996). As the research team calls for various plans, sections, elevations, and perspectives, they do not need to be redrawn, but can be easily and rapidly produced from a single model.

The use of different views can be used to test artifact placement and establish theory. Figure 9 below shows two different views of the Structure #2 computer model. Such views helped researchers understand object placement.
Figure 7. Structure #1 computer model with wall height variation.

and orientation within the structure. Smaller objects are placed towards the center where they cannot easily be reached and stolen through the gaps between surrounding columns. Larger objects, which cannot fit easily through the outside columns, are placed along the wall's edge.
DISCUSSION

Through modeling Ceren we found several limitations in the traditional paper based recording and representation techniques used by archaeologists. Primarily, the archaeological site information collected was displayed in ways unsuited to constructing three dimensional models. Two dimensional representations used by archaeologists do not require them to resolve the size, position, and shapes of all artifacts. Two dimensional drawings can omit some information such as vertical placement and height. Three dimensional modeling, however, requires resolution of all artifact placements both horizontally and vertically.

Models display more information; therefore they call for more information. Often the construction of the models requires resolution of ambiguities and inconsistencies in available two dimensional data. Originally we assumed that we would just construct models from provided site information. Instead we soon realized that we would have to work together with our archaeologist colleagues translating site information into visual images. Thus the process of building the models entails far more than the mere production of graphics, it required complete and careful analysis of all forms and their relationships.

In summary, we found that the use of computer graphics modeling calls for better records and more careful and detailed analysis of excavation data particularly the analysis of three dimensional placement and spatial relations. Because the three dimensional computer model forces the resolution of ambiguity and inconsistency, what began as a simple project in the production of graphics developed into a project entailing interpretation, data analysis, and ultimately new discoveries in preliminary research at Ceren. Perhaps most importantly, the case of Ceren taught us that computer graphics modeling can apply current architectural design tools in fields such as archaeology where innovative and versatile visualization methods are needed.
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