Temple Site at Phimai: Modeling for the Scholar and the Tourist

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Abstract "Some archaeologists have rightly criticized the tendency of computer-based visualizations to be driven by the need to demonstrate advanced graphic techniques, rather than by archaeological considerations" [17, p.2]. An accurate representation of an archaeological site depends on the quality and completeness of the archaeological data. In the absence of complete site and historical documentation, the modeling of these historic sites can be a response to the demands for website content, VR worlds, instructional video, and CDROMS rather than accurate representation. This paper expands the discussion of methods for modeling significant archaeological sites to include the limitations of data, data interpretation, application software, and hardware and display devices. As illustration, the computer reconstruction of the temple site in Phimai, Thailand will serve as a specific case study to highlight many of the issues faced during an architectural reconstruction project. Issues of time, scale, geometric representation of form, and image resolution of surface detail will be discussed. A second goal is to consider the needs of government departments, ministries and museums to promote tourism and stimulate museum attendance. Finally, some recommendations will be given to enhance the communication process between computer modelers and archaeologists that may help guide future efforts.

Background

This paper documents the creation of a computer model of a temple site in Phimai, Thailand. A United Nations World Heritage site, this walled complex of reconstructed temples, libraries and ancillary structures is considered the most important Khmer monument in Thailand. Located 60 km south of the modern capital of Nakhon Ratchasima (Korhat), Phimai was a center of royal patronage of Suryavarman II (1113-1150) and Kauavarymam VII (1181-1219). Aymonier first inventoried the site in 1901. Documentation of the site continued under Philippe Groslier, the last French conservator of Angkor. Thailand's Fine Arts Department under the auspices of Prince Yachai Chitrabongse completed the reconstruction from 1964 to 1969 [20, pp. 33, 233]. Visitors today have a unique opportunity to experience a complex of temples in various states of reconstruction. Adjacent to the site, the Phimai Museum contains many of the artifacts and architectural sculptural elements that were retrieved.

A plan to promote the site through the use of an educational video and website was the impetuous behind the creation of the computer model. In the summer of 1999, the author created a simple computer model of the site. The test model was used to generate images, animations, QTVR panoramas, and interactive VR worlds, which would form the basis of a multimedia presentation. During the fall of 1999 a site visit was conducted to collect data and discuss the scope of the modeling effort with the Museum staff at Phimai and Dr. Walter Jamieson, the Director of the Urban Management

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Program at AIT who oversaw the creation of the educational video. The computer model of the temple site at Phimai began as a demonstration project to illustrate the value of new media in the promotion of an historic site. During a visit to Thailand in the fall of 1999 material created in the summer was presented to staff members at the museum in Phimai and to students and faculty in lectures given at the Urban Management Program AIT and at the School of Architecture, Klungorhum University in the fall of 1999. These initial presentations established a dialogue on the potential uses of computer modeling and assessment of the type of information that would be needed to create a more detailed model of the temple site completed in the fall of 2000 (Fig.1). A key issue was how images, animations and VR could be used both for both to educate and to create a heightened awareness of Phimai as a tourist destination. A central question emerged during the course of reconstructing the temple site; can a single model serve both the needs of scholars and tourists? The experience gained from modeling the temple complex at Phimai can be used to address this question. The examples from the Phimai case study follow an introduction to the issues associated with the computer modeling of historic sites.

Fig. 1 – Reconstruction of the temple site at Phimai (author).

Computer Modeling of Historic Sites

In archaeological and architectural research, computer models have been used for decades as tools in the preservation and analysis of physical data [3, 6, 8, 11, 16, 24]. Some of the most impressive reconstructions, such as the reconstruction of ancient Rome, provide panorama views in 3D using 3 projectors. These impressive displays provide museums with a major attraction but are beyond the reach of many museums and universities [11]. Modeling efforts can also assist archaeologists and museum curators in the reconstruction of sites in a non-evasive environment. Various interpretations can be tested without endangering sensitive sites or subjecting individual architectural or sculptural elements to potential wear from excessive manipulation during the reconstruction process. Where important cultural sites are subject to destruction from excessive visitation virtual representations of the interior space of the caves of Lascaux [8, p. 10, 22] and the Tomb of Nefertari [8, p. 63] offer an alternative experience and perhaps the only public access to these monuments in the future.

In addition building virtual environments can be important in cases where safety and accessibility are key, offering an alternative to actually visiting the site. For older tourists and those with physical disabilities, VR can offer some the experience of

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otherwise inaccessible sites. This is of particular value for sites where the addition of ramps or elevators is not possible or is destructive. Even when individuals can make the journey, constraints of time may not permit the inspection of an entire site or complex. A virtual visit from a website or at a kiosk at an interpretive centre would enable both tourist and scholar to make more constructive use of limited time [2, 4, 10, 17, 24].

Ultimately, the demand for interesting and exciting public presentation may dictate the look and content of the virtual experience. Here, the demand for realism can result in taking creative license during the interpretation of historic data. The need to having fully detailed re-creations may result in the addition of features that may be incongruous with the archaeological reconstruction. In these cases, virtual constructs may take a life of their own, potentially misrepresenting the history and content of a site to future generations [14, 17]. Though a justifiable concern, reconstruction based on an incomplete record has been part of architectural interpretation since the Renaissance. As in the past, drawings and models were important vehicles for considering how the ancients built their monuments. Like the drawings of the Roman ruins by the Renaissance architects (e.g. Bramante, Serlio, Palladio and Vignola) these virtual constructions may kindle excitement and interest in these ancient sites [15, 21, 23]. With the need to solicit public support for preservation and archaeological investigations, some artistic license may be important to create a complete and credible 3D reconstruction of a site [9].

Computer Modeling: Constraints on Real Time Rendering

Selecting the appropriate strategy must begin by considering the intended use of the model. An interactive digital world differs from digital images used to create animation sequences for videos intended for museum and educational programming on TV. Images and animations from highly detailed computer models can be spliced into video to create a message that is the outcome of predetermined production values and carefully crafted storyboards. These programs produced for educational TV and museum audiences can serve to highlight and introduce audiences to the historical and cultural significance of a site. Interactive 3D worlds offer a more exploratory framework for the analysis and presentation of archaeological data. Sites and monuments can be inspected from multiple viewpoints and in different time-periods [3, 11]. Participant also have the opportunity to examine the primary source data used as the basis for building the environment. Databases containing text, images, sounds and objects can all be queried within this VR space. The possibility of moving in time or even exploring different interpretations of the evidence offers a unique advantage over static displays [4, 13, 17]. As an educational tool these virtual worlds may provide the scholar, student, and museum audience with an exciting and captivating environment, usually only reserved for gamers.

Advances in personal computing have produced PC's with performances now exceeding desktops by two orders of magnitude compared to the computers of the 1980's. Still, limitations in data storage, computation, and video display prevent creating a model accurate in every detail. Some generalization of site detail is necessary, if modeling projects are to be completed during a reasonable period of time. This is particularly true of sites that are complex in form and sculptural detail. The task of representing every architectural element (wall relief, entablature, frieze, column

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capitals and wall moldings) will surpass the resources available for modeling. One strategy is to model only selective areas in full detail. For example, a computer model intended for museum display may depict the detail in view of the virtual camera lens at resolutions needed for a TV or computer display. In these cases the project's storyboard can be used to focus on the modeling efforts.

Creating models for animations and VR worlds make specific and uniquely different demands on hardware and software. In contrast to building models for VR space, for animation less constraint is placed on the level of geometric complexity, lighting, and texture mapping (texture maps are images attached to the surfaces of geometric wireframe) [18]. In addition, each image in the sequence does not be rendered in real time nor be displayed at rates of 30 frames per second as is needed to create a sense of realism in a VR space. Complex scenes that make up special effect sequences can consume minutes or hours of rendering time that when subsequently assembled into animation, last only a few seconds. Carefully orchestrated paths and predetermined behavior can be orchestrated for the viewers in animation. The time and creative talent of the modeler only limit the realism of shadow, light, geometric detail and texture. Rendered images for such detailed models, can be incorporated into video productions or even played in stereo to give audiences a sense of depth. For archaeological presentation, the value of these models is their high degree of realism. With 3D scanning technology 3d meshes of actual objects and sites that are accurate to 2 mm potentially can be imported into a computer's model space [5]. When images are photometrically placed on these meshes, computer rendering can give a highly accurate appearance of the actual object [19]. The use of this approach though offering great accuracy, can present a serious obstacle. A 3D mesh of a single object, such as a piece of sculpture, can result in a mesh containing hundreds of thousands vertices. With models potentially containing meshes with millions of vertices, the demands of rendering can exceed the computing capacity of today's graphic workstations.

Balancing the need for detail against performance is always a constraining factor in the design of a VR environment. Constraints on the number of polygons and the size of texture maps that can be rendered in real time can make a model look like a crude 8 bit video game as made just a few years ago. If the model is intended to give the observer a sense of the architectural space, it may be possible to reduce the complexity of the geometry and sculptural detail that actual exists on the site. Nonetheless, if the objective is to create a sense of depth for the viewer, projecting in stereo will cut performance in half. Developers of computer games have traditionally relied on simplified geometry or low-polygon count models as one strategy to create VR worlds with high frame rates. In these worlds, the highly detailed models produced from 3D scans are unlikely to be used with any success. The other limitation of texture mapping is the restriction placed on the size and number of maps used in a scene. Game designers have traditionally employed only a few coarsely defined textures to reduce the demands on the computer CPU's and video cards when rendering in real time. In video games with rapid movement and action, the need to create highly textured backgrounds may not pose a serious problem. Building a VR application that can perform within acceptable ranges must consider hardware performance. In the future, VR may be useful as a visual window to access databases containing every attribute of every object on a site. However, at present, constraining the scope and goals of a modeling project may be an important

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consideration needed to insure success.

The Modeler's Dilemma: Data and Detail

Critical to all reconstruction efforts is the availability of data. Constructing a database of every artifact with all of its cultural, geometric and material aspects is costly in time and must be a long-term goal for most archaeological projects. Building a model of a site complete in every detail poses a daunting task. This is particularly true, if the model will serve as a virtual surrogate for the actual site. Architectural reconstruction documenting the form and placement of every block of stone can be likened to solving a 3D puzzle. Building a model that is geometrically consistent and accurate requires at minimum a plan and elevation. Most objects demand multiple elevation views: left, right, front and back. Sections and detail drawings revealing construction techniques and architectural detail are essential for an accurate reconstruction. Different scales, format and styles of recording will make reconciling differences in actual measurements difficult. Rarely are drawings complete for every aspect of a site. This is especially true of elevation drawings that do not have sufficient detailing to ascertain the exact dimension or geometric shape of architectural details such as column capitals, cornices and various moldings. Photographs of facades and surface detail and ornament become essential, especially if models are to be used for walk-throughs in a VR environment. However in using image data, resolution camera lens distortion and viewing angles may be limiting factors in extracting useful information especially when the photograph or image was not intended for use in architectural reconstruction. Oblique photos, photos with extreme perspective distortion and photos without reference to use of a visible scale in the image can introduce error into the measurement process [7]. In cases where structures and other 3D objects exist, detailed drawings, or high resolution 3D scans of the actual object or site will guarantee an accurate geometric and surface reconstruction.

In the absence of detailed data on a site the reconstruction process must be based on information drawn from historic sites that share a common cultural and artistic tradition. Another approach is to model areas of the site lacking detailed documentation as a massing study, eliminating any architectural or sculptural detail. If the model is to be viewed at a map scale the shows the location of important monuments on the landscape, a 2D plan may contain sufficient information to create a crude massing model as a simple extrusion of plan elements: walls, columns and base. Though when data is lacking this approach may be considered less misleading, the museum attendee may be confused regarding the meaning of the image. Without architectural detail, massing studies are difficult to read as 3D spaces. For those viewing the reconstruction as an animated walkthrough, whether the site was left in an unfinished state because of historical events may arise as a question.

Geometric Accuracy: Lessons on model building, The Phimai Experience

Familiarity with the data on an historic site is a given prerequisite in most modeling exercises. Several trials may be required to resolve incongruities that exist between historical documents of site data. The model of the Phimai site was based on drawings constructed at different scales. Most of these illustrations appeared only in articles and monographs and few drawings had scale bars or dimensions. Scaling drawings based on a common dimension such as the distance between piers and columns, resulted in some

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discrepancies in plan and elevation. As with most reconstructions, areas of the site that are currently in partial ruin pose a challenge. At Phimai the model was based on reconstructed structures and on other Khmer complexes that predate Phimai. One significant issue confronted during the modeling effort was how to span distances that were greater than those found within the temple site reconstructed in the 1960's. The original builders of the Phimai complex did not employ the Roman arch. Only corbelled arches of sandstone were used to span corridors of galleries and the naves of temples. Using the geometric proportions and maximum spans of existing arches at the Phimai site and similar complexes can serve as a guide in reconstructing the vaulted corridors, rooms and naves.

Representing sculptural detail that was destroyed and removed over the centuries poses a significant challenge. Even if an edifice was left intact, each element must be modeled as a unique object. For the scholar, an accurate virtual representation would provide an invaluable resource for future research and reconstruction. Clearly, where the iconography is critical to understanding the site, modeling accurate detail at the level of individual capitals, lintels, pediments and sculpture will require detailed drawings and photographs of each element. Unfortunately, time, and computing limitations make such an approach extremely difficult. One strategy used in modeling the Phimai site was to create a generic version of unique architectural elements. Adopting this approach insures that projects intended for public education can be completed within a reasonable period. Where elements are composed of flat planes, such as lintels, a simple geometric primitive can be used to represent a lintel or column shaft. In the reconstruction of Phimai, where information existed on the profiles of cornices capitals and base moldings, lofts (extrusions along a path) were used to add detail to the model. Photographic images served as the basis for creating the image maps that represented the carved relief. Unfortunately, photos did not exist for entire areas of the site. In these cases the profiles and textures from other parts of the site were used as a guide to make the model consistent in detail throughout. Unfortunately, time and resources were not available to recreating an accurate reproduction of the sculptural detail based on 3D scanning.

In the Phimai reconstruction, the 3D envelope of the architectural form was represented by a simplified 3D mesh. The obvious advantage of relying on the external skin as a representation of form is the reduced demand for computing. An alternative to this approach is to create a model that requires the assembly of each block in a vault or arch. This strategy would have permitted the testing of the construction methods used by the builders of Phimai. Within a virtual laboratory the maximum spans for lintels and arches based on the construction techniques of the period could be examined. Testing of the proposed virtual reconstruction using structural analysis techniques such as finite element analysis could have helped clarify possible reconstruction scenarios. Structural analysis techniques might also determine if wood roof trusses rather than stone vaults were used to span many of the complex's buildings. For example, the spans that cross the spaces in the library and granary would have been difficult to achieve using sandstone-corbelled vaults. Structural analysis may confirm that a wood roof would have been the only choice in spanning the distances. An architectural reconstruction that is accurate to the level of a single building block would also allow investigators to consider how to reassemble masonry ruins. For example, missing elements can be

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determined and cut before to the actual reconstruction begins. [1].

Accuracy in Surface Detail

Most modeling and rendering applications like 3Dstudio VIZ that was used in this project, enable the use of images as bump maps, that give the impression of relief when the object is rendered. The advantage of this approach is that rendered images have the appearance of the material without adding a high degree of geometric complexity to the model (Fig 2).

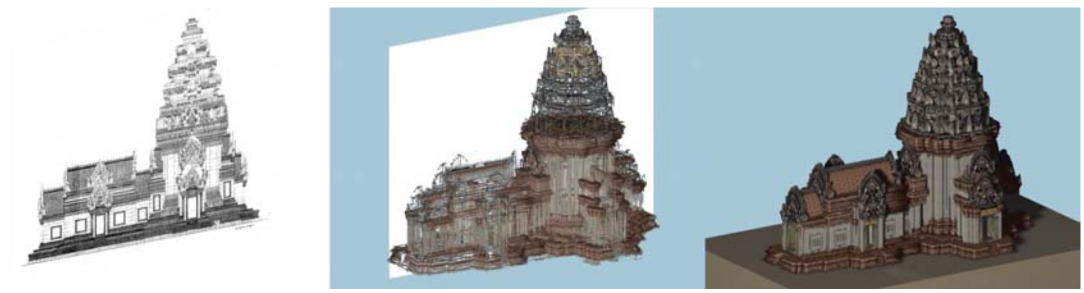

Figure 2 - Elevation, wireframe, texture-mapped view of the computer reconstruction of the central sanctuary, Phimai, author.

Surface texture is achieved in computer models by electronically pasting or wrapping an image onto the surface of a geometric form. Today's applications permit the combination of multiple channels or layers in creating these materials. Each material can posses specific properties: ambient color, specular color, opacity, reflectance and bump are but a few of the parameters that can be controlled by the models [18]. Creating an accurate surface treatment is both an art and science. If the goal is to show the monuments as they existed centuries ago, as in the case of Phimai, current photos of surface detail must be renewed or reversed in age. Samples of cut quarry stone ca help in establishing the color and luster of materials as they once appeared in the past. For sculptural detail, well preserved examples of carvings can serve as the source for creating surface textures.

The final rendered appearance of any computer model will depend on the lighting treatment and effects. In many computer-modeling applications this is a product of the creative efforts of the modeler, rather than a strict application of science. Although applications like Lightscape can create accurate representations of light, most applications rely on the modeler's skill at the placement of lights in the space for a convincing image. In addition, when many interior spaces are light accurately, produce images that are too dark and without definition to be projected or viewed on a computer or TV screen. In the Phimai reconstruction, materials such as stone, grass, cut stone and pathways were based on photos of the site. A surface treatment accurate to the level of individual objects, such as a single carved stone block, was considered unnecessary. Instead, lighting of the model was made consistent with photos taken of the site and the interior spaces. An early decision to reduce the geometry of window screens by substituting image maps meant that the light from the windows would have to be

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simulated through the addition of projected lights (Fig.3). In retrospect, the additional geometry may have been a more reasonable solution, given the increased rendering time with the addition of each light. Ultimately issues of appearance took priority over other concerns. For example, rendering a stone path created undesirable "effects" when viewed on a video display and was later replaced by a cut-stone path. In creating a computer model for video, judgement on the level of geometric detail, resolution, application of texture maps and the use of lightning must be considered relative to project goals.

Fig. 3 - Interior perspective, wireframe, phong shaded, texture mapped view of the computer reconstruction of the central sanctuary, Phimai, author.

Accuracy in Portraying Time

Computer modeling can show the various time periods of a site. Where data exists it is possible to show earlier phases in the development of the site as ghosted forms. This would allow the viewer to see how single sites may contain the efforts of early construction programs just beneath the wall, or floor of an existing building. Even in a VR environment the ability to select various scenarios would give the viewer an opportunity to see a city over time [3]. Future work at Phimai may to show the development of the temple complex over its history. However, present resources made attaining this goal outside the scope of this project.

Modeling and VR

Given the limitations of desktop computing, achieving acceptable frame rates when exploring a VR environment depends on eliminating complexity. Modeling architectural forms with all of their detail can result in models with a vast number of polygons and vertices, making rendering time too slow to walkthrough in real time. One strategy for modelers of VR environments is to break up the model into a series of rooms. When standing in one part of the model or room, all other parts of the model are eliminated from the computer's memory. Another strategy for reducing computational demand is level of detailing (LOD) switching. With LOD, coarsely defined models are replaced with more highly defined versions when the viewer is in close proximity to the object. To create a smooth visual transition, as many as five different representations of the same object are needed in a VR space. For the representation of archaeological and architectural sites, LOD answers the need to have detailed models of artifacts for inspection at close range.

As an initial test, the geometry from the Phimai model was extracted as a 3DS format from 3Dstudio VIZ and imported into a VR application, WorldUp by Sense8.

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Given the importance of details such as cornices and sculpture, the model's polygon count was not reduced or simplified. To increase frame rates, fog was used to mask objects in the background. By combining fog with a clipping plane set at the maximum viewable distance, it was possible to effectively mask out objects that were beyond the maximum field of view. To improve navigation in the model, music tracks were attached to major locations within in the model. By employing stereo sound, the directional sense of the viewer is improved [12]. By using prerecorded narration, the participant may have a virtual tour of the complex.

Fig. 4 - Views from the VR model, author.

The results of this initial test show much promise. In this project a PC with a Pentium PIII 733 CPU, 512 mb PC133 RAM, with an ASUS 7700 video card that incorporates the NVIDIA 32MB chip was used to develop and view the VR model. In creating the VR environment a portion of the model created in 3DStudioVIZ video was imported into Sense8 WorldUP, a VR application. By relying on camera clipping no more than 30% of the model's 200,000 polygons would be rendered at any time. Using the Open GL viewer supplied by Sense8, it was possible to sustain 8-10 frames per sec (Fig. 4). Currently, CPU's are now available in graphic's workstations capable of doubling this frame rate. This test demonstrates that it is now possible to render complex models in real time with computers costing less than $3000 US.

One issue faced in this test was the distribution of the model from a website. Free viewers are available from Sense8 making it possible to share the VR model to anyone on the net. However, with a model of over 10MB, modem access would face excessive download times. Some experimentation with parceling the model into a series of experiences is being attempted. However, given the size of sound files needed for the virtual tour, this approach will still require users with modems to wait several minutes for each download.

Summary and Conclusion: Computer Modeling for the Tourist and the Scholar

Resources in both time and money may always be the limiting factor in modeling historic sites. Perhaps, the most significant issue is whether the model is to be used as a window for viewing data over the lifetime of an archaeological or architectural reconstruction project. Under these circumstances data will need to flow seamlessly from database to model. Attributes of every object must be preserved and linked to their geometric representation in the model. A significant advantage to this approach is that researchers would have the ability to query every aspect of the visual form including, the location and scale of the object. Extracting data from these spatial models for statistical analyses could then be done within a GIS or CAD application. One

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significant advantage to this approach is that as new artifacts and site data is acquired on the site, they can be catalogued within the model. As new technologies of 3D scanning permit the capture of entire sites or objects, these new data can be referenced within a larger spatial database. In the future, VR applications that access large database may offer the greatest opportunity to query archaeological data. However, at present both VR and CAD/GIS environments suffer from a lack of a high degree of realism in rendering.

When a model is to be primarily used as a promotional or educational vehicle, maintaining an interactive database may not be crucial to the success of the project. In modeling a site for a public-educational video or web site, getting out product that "looks right" may be the most important consideration. In these cases, when materials are required for tourism and public education, data flows one time into the model. Rendered images from a model rather than creating a database of every artifact on the site may be dictated by the project. As in the case of building the model of Phimai, the immediate need for educational content for a video overrode any consideration of creating a spatial database of the site to support future research projects. The demand for a high degree of realism resulted in a strategy that limited detail to that portion of the model rendered in close up shots in the final animation. The maps and geometry used to create the CAD model of the site though not an exact copy were sufficient to produce the needed images for the educational video.

Advances in the future in graphics cards and developer's tools will eventually free the designer of VR worlds from the constraints of existing hardware to render complex scenes in real time. At the present time, if the desire is to create environments for education and museums then producing exact copies may not be a high priority. In these cases a simplified version of the architecture and artifacts may serve the goals of museum directors and government officials in need of content for 3D web pages and interactive VR worlds. Test models of the Phimai site demonstrate that with the next generation of video cards, it will be possible to produce accurate virtual copies capable of real time stereo walk-throughs on a consumer PC. In summary, accurate models for archaeological research, must be part of a long-term commitment to database creation. Unfortunately the ability to merely translate seamlessly data into geometric models is not possible with commercially available software. To answer the original question, can a single model serve both the needs of scholars and tourists? Different modeling strategies may be dictated by the goals of the project. Models designed for public education and promotion may have to be created for the expressed purpose of satisfying the need for images web pages and VR environments, while models intended for research purposes may be more constrained by the need to manipulate large databases.

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