White Paper Report

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White Paper

National Endowment of Humanities Digital Startup Grant no. HD-50482-08

'Digital Documentation of a Provincial Town in Ancient Egypt'

Project Director: Dr. Nadine Moeller

Grantee Institution: The Oriental Institute, University of Chicago

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I. The main objectives of the project

The project aimed at utilizing and improving existing inexpensive digital technologies for recording archaeological remains. The main focus was documenting excavated settlement remains and small finds (such as figurines) in the most time-efficient way without loosing the precision and detail achieved by the traditional manual recording techniques that consist foremost of technical drawings and photography. Another important objective had been to develop a way of recording the data in three dimensions instead of the usual two dimensional views generated by manual drawing methods. Since archaeological fieldwork is a destructive process, it is crucial to carry out the recording and documentation as accurately as possible. The development of digital recording tools is a major step forward in the way we document excavated architecture as well as related objects. The settlement site at Tell Edfu in southern Egypt served as the main study case with much data, such as the numorous wall remains made of sun-dried mud-bricks, as well as providing a challenge for rather harsh light conditions with strong sun-shadow parts.

The technologies used included panoramic photography and photogrammetric photography. For panoramic photography we used Canon cameras (model Rebel XSi), fiberglass tripods, panoramic head, Kaidan QuickPan Professional, PTGui software, and Adobe Photoshop CS4 Extended. The photos were also used with Microsoft Photosynth, a software program that can be used for stitching photos together in order to recreate 3D scenes. Photogrammetric technology involved RAD marker placement, photography and PhotoModeler software for 3D reconstruction.

II. Panoramic photography

Panoramic photography focused on capturing digital images for the purpose of stitching them into large-scale panoramic images providing excellent views of excavation area. This creates a detailed overview of the ongoing progress of the excavation which enables the archaeologist to easily see the overall connection between wall remains and the stratigraphy (built-up of archaeological layers). It is also a really useful presentation tool that can be used during lectures and public presentations and is suitable for an audience who has not been able to physically visit the site. This technique also showed great results in capturing the changes and the ongoing progress of the excavation from one season to another. Several challenges were met and solved while using this technique:

1. Capture had to occur in sunlight where many shadows were present. The camera was adjusted and several shots were taken at different exposures. We have experimented with High Dynamic Range Imaging (HDRI) for panoramic photography but we were not successful as the focus changed on many

close proximity shots. The PTGui software currently does not support images with various focal lengths but other programs like Autodesk Stitcher do, which would be worth testing in the future.

2. Several positions and distances were tested. The camera on the tripod was positioned close to the excavation area but also on a higher ground overlooking the site (the 35 meters high pylon towers of the temple were an excellent spot for overlooking the entire site). We also took some shots at a 50 m distance to the excavation area which turned out to be excellent.

3. For close shots we used wide-angle lenses with closer focus to allow for capture of great detail in close proximity (fig. 2). Auto focus was mainly utilized and with longer distances, larger areas were captured with a greater number of photos being stitched together, which still permits to see the necessary details.

4. Some abnormalities due to direct sunlight were detected (see fig. 1). Our goal with panoramic photography was to achieve rapid processing and utilizing as many automated software processes as possible. This was successful with both using PTGui and Adobe Photoshop. We were able to automatically create panoramas with PTGui and manually adjust them in the University of Chicago humanities computing lab after returning from Egypt by using Photoshop.

Fig. 1 Images showing anomaly created by strong sunlight and the adjustment below after using Photoshop

As seen above, there are drastic changes in the quality of the panorama produced by PTGui alone and the panorama produced by PTGui and Adobe Photoshop CS4 (fig. 1). The discoloration, unwanted shadows, dark spots and lens glares were removed by using Photoshop. Overall, the panoramic photography proved successful in hands of professionals as well as technology novice assistants. We encourage project staff to continue in capturing large panoramic images of areas prior and post excavation. In the future we see panoramic images being utilized in 3D reconstructions. Autodesk Stitcher and Autodesk

Fig. 2 Panoramic overview of the excavation area showing several grain silos in the foreground

Modeler are prime examples of this technology, which were released in 2009 and therefore we were not able to test those programs within the available time-frame. However, we are planning to use Autodesk Stitcher since it detects and corrects the above mentioned anomalies much more efficiently.

As already outlined in the interim performance report, the new stitching program developed by Microsoft called Photosynth which is currently only available online (http://photosynth.net/default.aspx) has also been successfully used for the photos taken on site. The resulting 3D views can be found on the project's website http://www.telledfu.org/results/2008. They provide a great alternative for display on the website in comparison with the actual panorama photos which often have a large file size (> 100 Mb).

III. Photogrammetric photography

This technology was quite new to our project team. Even though deployed in the manufacturing industry, the costs of the professional system are generally out of reach for small-scale archeological projects. We aimed at a cost effective solution which would work in difficult environmental conditions. Photogrammetric technique generates point cloud data from combining series of stereo photographs. The process involves calibration, placing coded RAD markers, and taking multiple sets of dual parallel images. The project's technical staff (led by Lec Maj) chose PhotoModeler as a relative inexpensive software solution, which has a great technical support to generate point clouds, create wireframes, and reconstruct object with overlaid images. The object we used as a trial is a clay figurine (ca. 1700 B.C.) found during the excavations. It is about 18 cm long. The following figures (figs. 3-6) are showing the various stages of completion in the creation of a 3D image of the object:

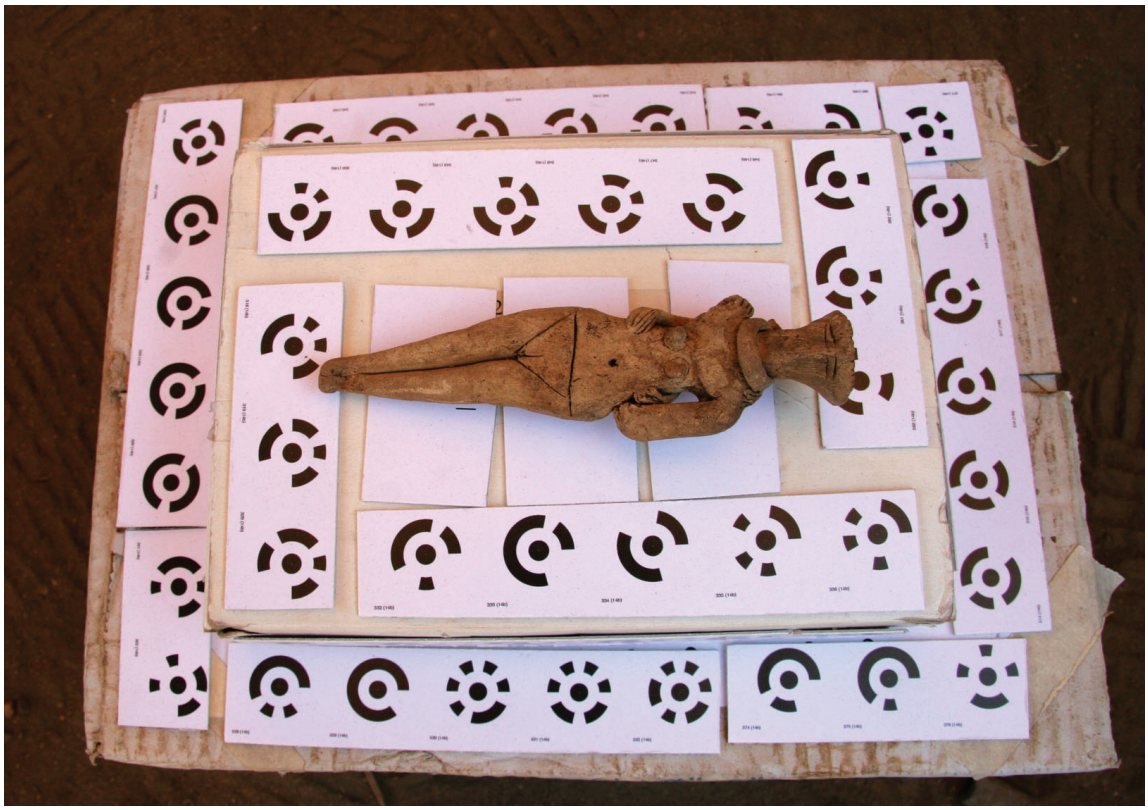

Fig. 3 The set-up with coded RAD markers placed around the figurine

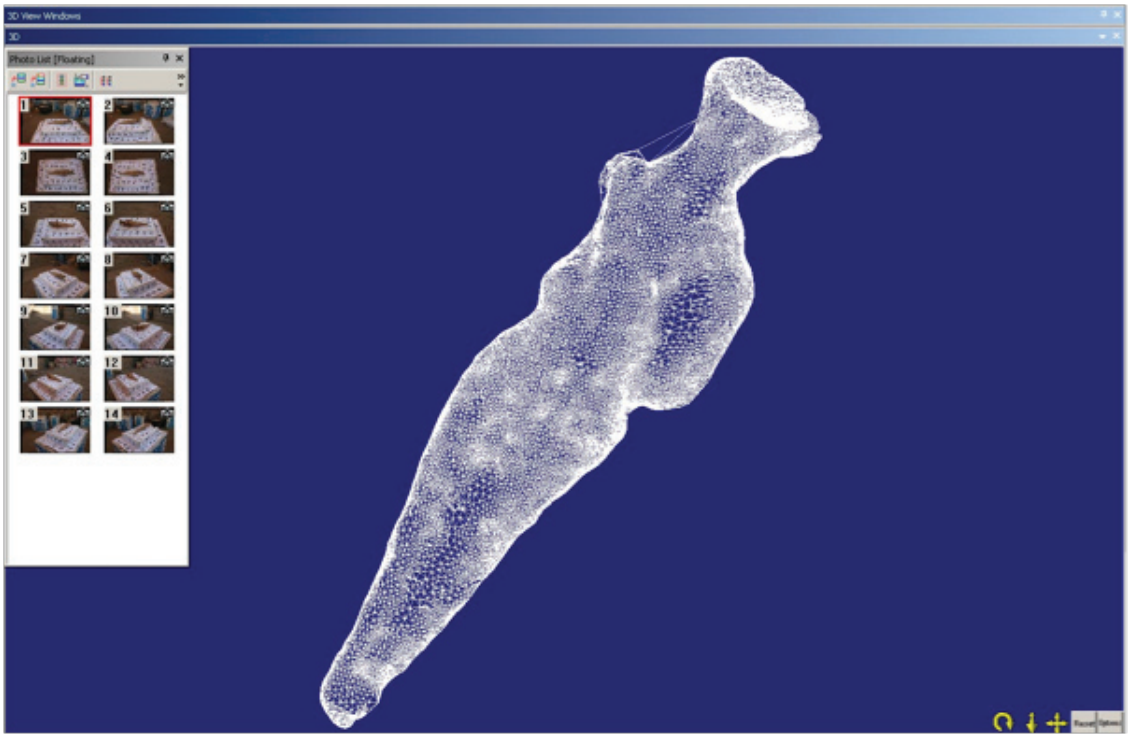

Fig. 4 Wireframe generated from 14 photographs (front side)

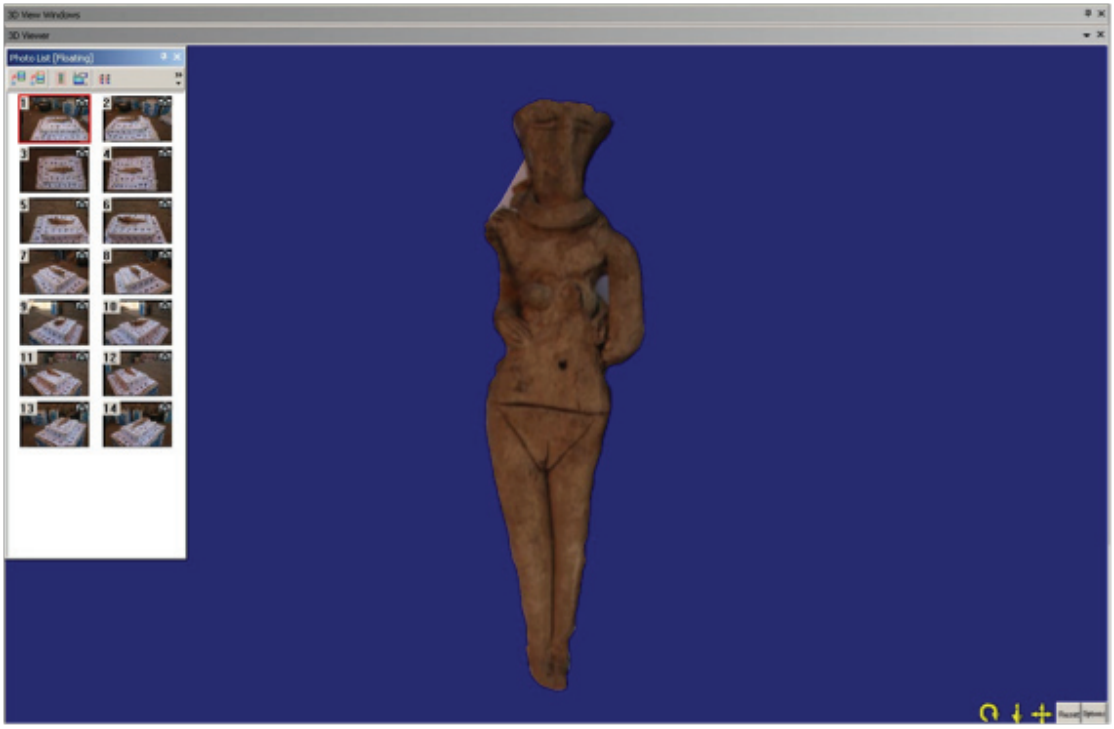

Fig. 5 Generated figurine with overlaid images (front side)

Fig. 6 Details of the figurine from various angles (front side), created by Photomodeler

The project team was able to reconstruct the front and back of the figurine by using PhotoModeler (fig. 6), which is a very promising result that can easily be taken further during the next field season. Certain issues still need to be solved in order to create a single object that can be rotated in 3D. Doing this will only require to take another set of high resolution photographs where the figurine will be fixed to a rotating device. The only reason why this has not been done yet is because currently the object is kept in an Egyptian storage room and will only be accessible during the next field season. However, the creation of a 3D image of the figurine with Photomodeler can be considered a success and will certainly be an important tool for the future. Apart from drawing archaeological objects by hand, we will create 3D models of important objects discovered during the excavation. These images are a very accurate model of the real object and can also easily be used in PowerPoint presentations.

A second trial focused on the remains of a Ptolemaic house (ca. 250-225 BC) made of dried mud-bricks of which the foundations and parts of the vaulted cellar are well preserved (figs. 7, 8). The conditions for this trial were much more challenging in comparison to the figurine because of constantly chang-

ing light conditions which were impossible to control, and the house was too large to be covered with a sun-shade. Various attempts were made to use full sunlight and making the necessary adjustments to the camera in order to capture images. This proved to be successful and resulted in numerous good quality photographs and low residual (below 2 pixel, see accuracy results listed in Appendix), which permitted the creation of sizable point clouds.

Fig. 7 Ptolemaic house remains used for photogrammetry

Fig. 8 RAD markers placed on mud-brick walls of Ptolemaic House

Unfortunately, the project team was unable to proceed further as the PhotoModeler software became unstable with large amounts of images and high-resolution photographs. It was not feasible to generate a detailed wireframe with this software and the available hardware. One of those attempts can be seen in fig. 9, where parts of the staircase of the house are visible but unfinished.

As a solution to these issues, the project team has opened up communication with other institutions in Europe to assist with custom designed software that allows for better capturing and processing solutions when recording entire buildings and larger areas. One of the contacts has been Dr. Fabio Remondino from the Fondazione Bruno Kessler based in Trentino, Italy. His research unit focuses on 3D optical metrology which includes research on 3D modelling systems, see http://3dom.fbk.eu/en/home. A future collaboration with this research group would be an interesting possibilty. The special environmental conditions at Tell Edfu in Egypt and the predominant presence of dried mud-brick architecture certainly provide challenging data for the further development of 3D modelling and recording processes with a focus on archaeological remains.

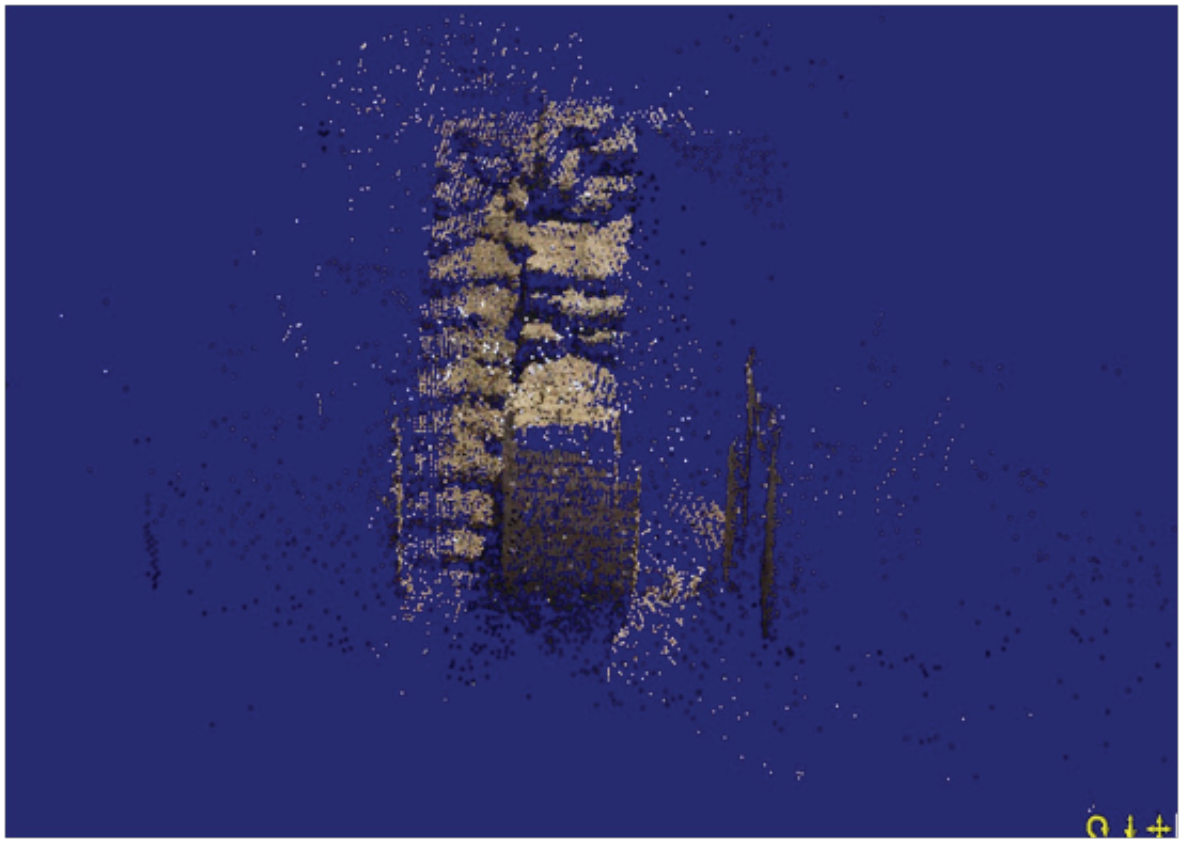

Fig. 9 Point cloud of stairs and side walls

Another alternative is laser scanning which is very effective for stone architecture especially when latter is also decorated. A good example for a successful 3D recording project has been carried out at Karnak temple in Luxor, Egypt, where laser scanners were used for decorated stone surfaces, see http://www.atm3d.com/v5/pdf/opet.pdf and http://www.atm3d.com/v5/pdf/colonne.pdf. The precision and detail that was recorded on monumental stone columns in the Hypostyle Hall of Karnak temple is another fantastic example. For the Tell Edfu Project where most of the structural remains are made of sun-dried mud-brick, this precision and detail of the surface texture is not necessary because there are no inscriptions or decoration to record. Also budget considerations as well as logistical problems (such as electricity supply) would be an issue for using a 3D laser scanner. Additionally, other structured-light 3D technologies may only be effective when capturing at night, again not a feasible solution for Tell Edfu since the site is inaccessible after 5 pm. For both alternatives the equipment is costly and process time very long, which would make this less efficient than drawings by hand. A more promising solution that could be adopted by the Tell Edfu project team is using the photogrammetric technique with a model helicopter. The cost of this solution would be higher then for the hand-held photogrammetry and also requires Egyptian government permission, which can be difficult, although the capture time over large areas would be rapid.

As a conclusion, the 3D modelling process using photogrammetry which offers a viable alternative to the manual recording of archaeoligcal remains needs to be developed further. The best option at the moment is to start a collaboration with 3D modelling research groups that have experience with archaeological data in order to further test and develop software that is able to deal with the difficult and often varied environmental conditions on site as well as large amounts of raw data. The NEH digital start-up grant has allowed the project team to test various methods using photography and 3D modelling software, and a part of the results have proven very successful. Further research continuing the project's objectives is planned for the future.

Please refer to appendices for additional information. The technical personnel involved are always open for consultation and collaboration. We thank the NEH for the generous support in these investigations.

Nadine Moeller, Lec Maj

Appendix

1. PhotoModeler Project manual (by Lec Maj and Khirul Ezar Khir)

1.1. RAD Coded Targets

a. PhotoModeler software generated 250+ unique circular 1” outer diameter RAD targets for laser printing. Targets were printed on thick adhesive paper, laminated, and mounted on circular wooden buttons. Buttons were prepared with pins by driving a single ¾” staple / nail thought the button. This type of marker was inexpensive, durable in heat/rain, and would not fall off in the field.

b. Targets, which looked as large pushpins, were pinned into the dry mud brick. Targets were separated to include more then 5 in each overlapping image.

1.2.Calibration 2D photographs

a. For calibration purposes, a large 1 meter squared grid was printed from vendor provided PDF file onto sturdy water resistant fabric.

b. Calibration grid was placed on floor and photographs were taken at 45 degrees to the floor.

c. The camera should be ‘rolled’ 90 degrees (left and right) from the subject when taking photos. This process helps solve the principal point.

d. Total of 12 photographs are taken, from each calibration grid side 3 photographs (straight on, rolled 90 degrees left, rolled 90 degrees right)

e. It was important to encompass the entire calibration grid and manually lock the focal length for duration of the project.

1.3. Orienting and Field Calibration

a. Run PhotoModeler and select Automated Coded Target Project > RAD Project then select the 2D photographs to be used to create a Dense Surface Modeling (DSM) surface. The software should automatically detect the coded targets on the photographs.

b. Usually, the software will miss some coded targets on the photographs. These missed targets can be marked manually using the Sub-pixel Target Mode tool.

c. The software might mismatch coded targets in the automated process. Targets that are mis matched will cause large residuals in the Point Table – Quality table. These mismatched target s must be corrected manually. On the Point Table – Quality table, right-click on a marked target point with a large residual and click on Open Photos Showing Selected. The software will show all the photos with the marked target of interest. If a mismatched target is found, right-click on the marked target and click Unrefence Selected.

d. Once all coded targets have been marked and referenced, click Project > Process > Options and check the boxes for Orientation, Global Optimization, Self Calibration and Process Con straints. Oriented photographs will have a camera icon on its thumbnail.

1.4. Idealizing

a. Once the 2D photographs have been oriented, they must be idealized by running Project > Idealize Project. The idealizing process removes lens distortion and principal point offset ef fects from images. It also removes and adjusts the associated parameters from the camera.

b. Once the project has been idealized, it should be processed again (step 3d) without the self

calibration option checked.

c. After the photographs have been idealized and processed, each marked target should have a low residual in the Point Table – Quality table.

1.5.Trimming

a. The DSM Trim Mode tool is used to outline the subject, which is a figurine in this project. By trimming the photographs such that only the areas of interest are in the outlined region, the dense surface will be created much faster and the result will have less flying debris.

1.6.Creating DSM surface

a. Select photographs in pairs whose images are parallel to one another.

b. Setting a low Sampling Rate will make the process take much longer but the dense surface created will look better.

c. The quality of the dense surface created depends on the quality of the 2D photographs and the residuals of the coded targets.

d. We tried generating a dense surface without trimming the subject but the results were poor. The process also took much longer.

1.7. Adding Texture

a. The photo texture of a triangulated point-mesh is generated from a single photo. However, the triangulated point-mesh can be converted to a regular surface and a multi-photo texture material can be used on this converted surface.

1.8. Figurine

a. As seen above, the PhotoModeler software worked well with the small figurine. However, the figurine was taken lying down so two separate 3D surfaces were created. It was difficult to merge the two surfaces together because given that they were created from 2D photographs, the edges of one surface might not necessarily fit with the edges of the other surface.

b. We tried to use the XOS Rapidform software to merge the two sides together but the 3D surfaces were not of the same size and the edges of the surfaces did not match 100%. Adjustments could be made to scale and merge in other software (GeoMagic Studio) not available to the project team at the time of project.

c. By taking photos of the figurine in an upright position, the PhotoModeler software should be able to create a 3D model without the need to merge separate surfaces together.

d. What kinds of surfaces would work well with the PhotoModeler software? Matte vs glossy sur faces, simple vs detailed surfaces. For example, as seen above, the more detailed parts of the figurine (its chest) did not come out well, see fig. 10 below.

1.9. Ptolemaic House

a. The 3D surfaces of walls and other architectural structures generated by the PhotoModeler software were not as promising. The 3D surfaces were of low resolution and had much debris even when the 2D photographs were oriented, idealized and trimmed.

b. Also, the PhotoModeler software often crashes when processing large projects (for example if there are many photographs used or if the sampling rate is too small) and any unsaved data will be lost. Hence, each project is saved after each major step, like after it has been oriented, idealized, trimmed etc.

Fig. 10

2. Photomodeler accuracy results (by Lec Maj)

2.1 Ptolemaic House

Part 1 Interior
Highest Residual : 0.8384 pixels
Oriented 34 photos

Part 2 Stairs
Highest Residual : 1.52 pixels
Oriented 47 photos

Part 3 Back West of Stairs
Highest Residual : 1.5 pixels
Oriented 46 photos

Part 4 Top of Roof
Highest Residual : 1.22 pixels
Oriented 40 photos

Part 5 North Exterior Wall
Highest Residual : 1.49 pixels
Oriented 48 photos

Part 6 South Exterior Wall
Highest Residual : 1.66 pixels
Oriented 30 photos

Part 7 West Exterior Wall
Highest Residual : 1.08 pixels
Oriented 48 photos