3D MODELING AND PHOTOGRAMMETRY-SUPPORTED GIS IN ARCHAEOLOGY

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ABSTRACT

Archaeologists collect an incredible amount of information. If used appropriately, Geographical Information Systems (GIS) can play an important role in the archive and analysis of such data in digital form. Additionally, correct location, relative positioning and 3D dimensioning of artifacts, features and objects in general can be easily done with photogrammetry-supported GIS. The paper reflects an example of how to acquire such data with a common 35mm photographic camera, and how to create 3D models in a cheap and effortless process. Data cases collected and modeled by the author are presented, with photos taken without much rigor, to simulate the case of an archaeologist not familiar with photogrammetric techniques and constraints. Intergraph and ESRI software existing at the author's institution were used in the modeling, archiving and analysis process. Unfortunately aerial photography for the site was not available and a map had to be used instead. Weaknesses and strengths of the approach are discussed. The method is not a substitute for archaeological techniques of data collection, but it can supplant some of them with advantages in time costs, type of archiving support and details in the information collected.

1. INTRODUCTION

Archaeology reflects the amazing diversity of human life across the globe. As such, archaeological data is becoming increasingly relevant and a crucial part of some scientific research, not only within the area of archaeology. Archaeologists collect an incredible amount of data that if recorded in digital form can be faster circulated to other interested parties. Once in digital format, data is also easier to manipulate and analyze in order to meet specific goals. Data extraction requires a meticulous, scientific approach, and it cannot succeed without the creative imagination and genuine enthusiasm of archaeologists in the field.

Scientists now use Geographical Information Systems (GIS) to keep records of extensive data sets as well as manipulate and analyze that data. GIS and GIS related techniques, hardware, and software are being used to develop faster, more consistent and cheaper methods of data manipulation in multidisciplinary sciences. Most of the new areas of knowledge embracing GIS are not precise sciences. These researchers and technical staff have come to realize the advantages of using computer based technology. When the sponsoring institution supports and stimulates GIS usage, integration of such techniques into non-technical areas of expertise becomes easy to achieve with gainful results.

The California State Polytechnic University at Pomona, CA, hosts the Intergraph and Trimble Mapping Center of Excellence and a Center for GIS Research (CGISR). The institution's extensive technological resources grant access to a wide variety of software and hardware from Intergraph, Trimble and ESRI. The on-going effort to establish a campus-wide GIS awareness encompasses areas such as business, agriculture, politics, etc., through seminars, workshops and integration of GIS-supported courses into existing curriculums (Turner and Neto, 2000). Hence, the Deans and the President enthusiastically support the innovation and multidisciplinary application of GIS at Cal Poly Pomona. With this aspect in mind, and after exchanging ideas with new faculty in the Department of Geography and Anthropology and colleagues from Surveying Engineering, the author combined her photogrammetric and GIS background to test its application to archaeology.

Terrestrial photogrammetric techniques can be used to build 3D models of artifacts, facades of buildings and site views. GPS can be used to reference the site without much effort. All data can be archived and manipulated in a GIS environment. The three-dimensional visualization of the data helps the user to better understand the concepts involved, especially during data manipulation and analysis (Darmody and Cartwright, 1998). Such a system will be henceforth called a photogrammetry-supported GIS environment. The system also speeds up the data processing course of action and has all the well-known advantages of adopting digital recording techniques (Turner and Neto, 2000).

This paper presents a case study carried out by the author in September and October 1999, in Bodie, California, USA. The data collected and used for the research is presented next, followed by the procedure and the strengths and weaknesses found during the study.

2. DATA SITE

Bodie is a State Historic Park in northeastern California. "The town of Bodie rose to prominence with the decline of mining along the western slope of the Sierra Nevada. Prospectors crossing the eastern slope of the Sierra Nevada (…) started a wild rush to the surrounding high desert country" (California State Parks, 1988) and Bodie was born. Bodie was named after Waterman S. Body, who discovered gold there in 1859. As an old mining town, it had a population of about 10,000 by 1879. However, as quickly as people came to Bodie, they left once the mines were exhausted. "Whatever the case, the streets are quiet now. Bodie still has its wicked climate, but with the possible exception of an occasional ghostly visitor, its badmen are all in their graves." (California State Parks, 1988)

Figure 1. Location of Bodie in California.

After the gold rush was over, Bodie became a ghost town with only a small percentage of its buildings and artifacts left in tact. Devastating fires and impoverished emigrants practically razed the town. In 1962, Bodie became a state historic park under the auspices of the Tahoe Sierra State Parks Association. But, this did not automatically ensure all structures and artifacts would be properly preserved (California State Parks, 1988). Most of the structures are kept in place with wooden trunks and/or boards acting as reinforcements. The author visited the site in September 1999 and collected data with the intent of studying the feasibility of using photogrammetric-supported GIS to create a database of the site, with 3D models of the remaining buildings and artifacts. For the purpose of this paper, a case study was considered with the data set described below.

3. DATA

The data set is comprised of maps, GPS measurements and 35mm photographs of some buildings. The data was acquired assuming the case where the person taking the photographs or collecting the GPS data did not have a background in surveying or photogrammetry, since this would likely be the case of most archaeologists collecting data on the ground. However, it was assumed that the person taking the photos had been instructed to take two photos of the buildings from different perspectives, as to create a source that would allow photogrammetric restitution. The photographer does not need to fully understand these concepts to be capable of taking photos for later stereoviewing and modeling. Additionally, a simple, manual Minolta 700x, 35mm camera was used to take the photographs. Some measurements were ascertained from the buildings chosen to use as examples for the 3D modeling. The measurements are summarized in table 1. Figure 2 shows a map of

the remaining buildings of Bodie, almost all closed for safety reasons, with close ups on the two buildings for the 3D modeling. The photographs taken of the Methodist Church and Conway House are presented in figures 3 and 4.

Object	Window width	Door width	Step width	Front of bldg.	Height of church door
Conway House (No 43)	2.62'	2.62'		19.2'	
Methodist Church		5.25'	9.51'	274'	≈ 10' door
Little house (on church's photo)				7.2'	≈ 16.4' to top tr.
Focal length = F/2.8	Negative dimensions = 36mm x 24mm				

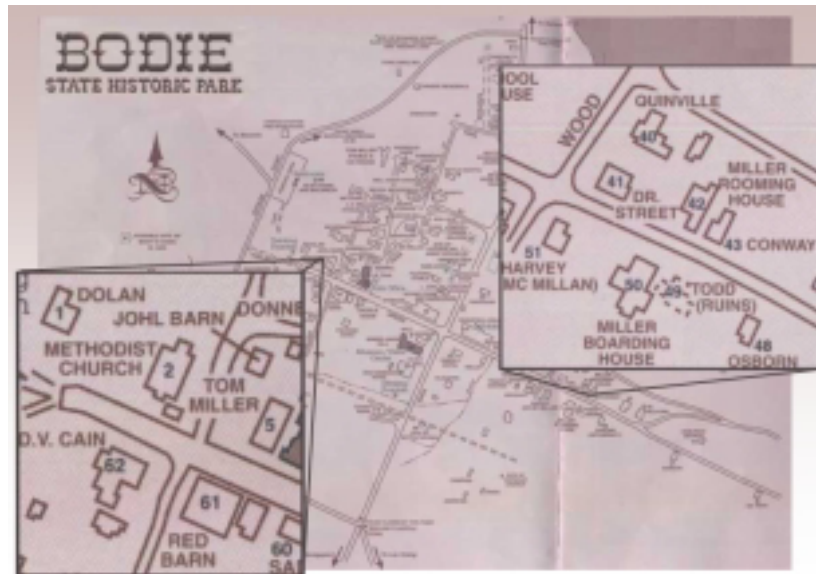Table 1. Measurements and photographs' data.

Figure 2. Map of Bodie and locations of Methodist Church and Conway House.

Figure 3. Photographs of Bodie's Methodist Church.

Figure 4. Photographs of Bodie's Conway House.

A Trimble GPS GeoExplorer was used to extract GPS positions in Bodie for the map orientation and data referencing.

4. DATA PROCESSING

The GPS data was corrected using CORS control points and data downloaded from the USGS/NGS' CORS web site. As expected, the data before the correction had some large inconsistencies that disappeared after the correction was run. For this process, Trimble GeoExplorer software was used. Since no thorough survey of Bodie was done, the map provided by the State Historic Park was scanned at 600dpi and used for the study. The author referenced the digital map using the GPS data on Bentley's MicroStation CAD software, which became the support for the GIS data referencing.

All photographs (figures 3 and 4) were scanned at resolutions 72, 300, 600 and 1200 dpi. A common flat bed scanner was used in the process, since that is far more affordable than a photogrammetric scanner. The 3D modeling of the houses were first attempted using the 300 dpi digital images, and the 72 dpi serving as viewing copies. Multi-scale representation was adopted in this study (Li, 1998).   Intergraph Photogrammetric stations and Intergraph's photogrammetric software were used for processing the photographs. All the data relative to the film used was introduced during the model management setup, followed by the internal orientation, for which the corners of the photographs were used. For the relative orientation, conjugate points in the facades were used, as to be in the same vertical plane. The hardest part to complete was the absolute orientation of the 3D model. For this, the reduced amount of measurements was barely enough and only an experienced operator is capable to overcome the data deficiency. An example of the photogrammetric screen and one of the models is presented in figure 5.

After the model was completed, it was extremely easy to make stereo mensuration and analysis of the buildings. 3D visualization helps better understand real world characteristics and features and collect the data related to the objects visualized. An Oracle database can be created with the features being directly collected into the appropriate fields in the form of digital data. The author compared photos scanned at 300, 600 and 1200 dpi and found with no significant differences except for the relative difficulty that a system might have in roaming when very large images are adopted. For this case, the photos scanned at 600dpi were preferred, providing the necessary detail and occupying only about 40MB of memory each.

Since Archaeology at Cal Poly Pomona is in the Department of Geography and Anthropology where ESRI ArcViewGIS was adopted for GIS projects and research, all data was then transferred to this system. Bodie's referenced map was used as support for all other views and data. Houses, streets and specific features were added to the database. Attributes were inserted and links to the 3D models were also created. Figure 6 shows an example of an attribute table for the Methodist Church. The condition of the houses, windows, history, restoration data, etc, can all be archived in the database. Mining areas and artifacts found can also all be specified in the database. Analysis of the area can then be easily carried out using the available tools in ArcView. The 3D model is opened in Intergraph Stereo Mensuration kit, allowing for 3D inspection of the feature.
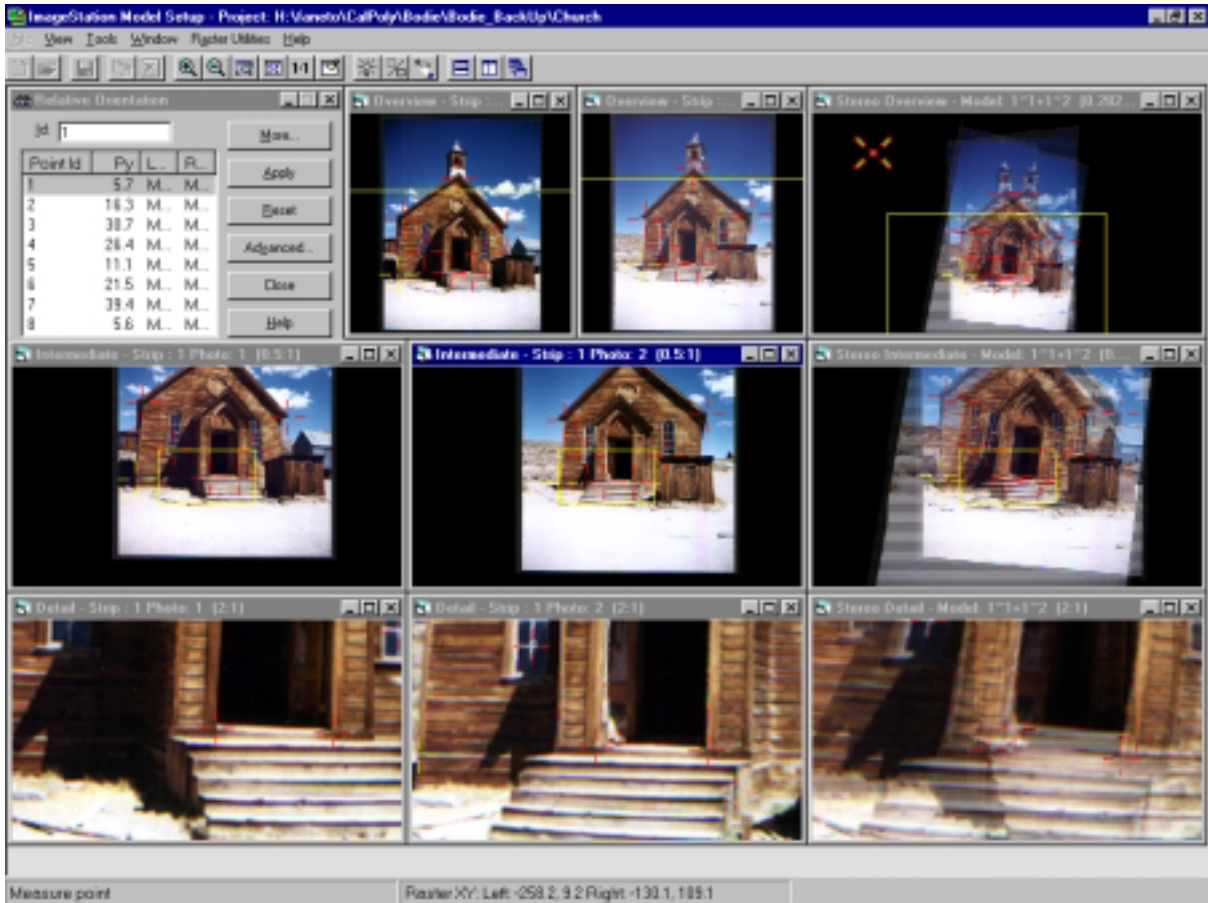
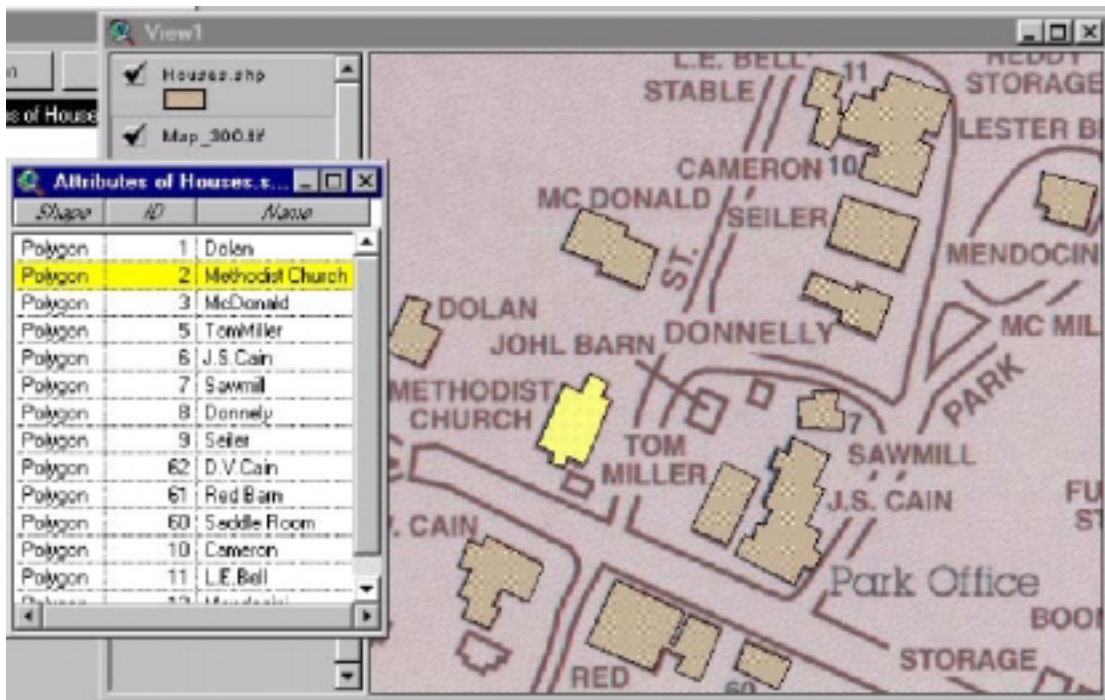Figure 5. Orientation of a building façade in the Intergraph Photogrammetric Station (example).

Figure 6. Example of view in ArcViewGIS, showing part of attributes table for Bodie's Methodist Church.

5. CONCLUSIONS

The goal of this study was to present alternative techniques using photogrammetric-supported GIS to build 3D models of features, buildings or artifacts and create digital databases in an archaeological or cultural heritage context with minimal costs. Photos can be taken without much rigor, to simulate the case of an archaeologist not familiar with photogrammetric techniques and constraints. Intergraph software existing at the author's institution was used for the relative orientation of the model and formation of the stereomodel. However, similar software could have been used instead.

The 3D visualization of the buildings or artifacts gives the user a real time simulation of the world or area to study, without having to be *in locus*. The process of storing data in digital format opens a door to faster and a wider range of manipulation and analysis processes at relatively low cost. Additionally, archaeological data in this format will be easy to transfer between institutions and researchers interested in the same study area without loosing its valuable 3D perspective.

If aerial photography exists for the area being surveyed, these images should be used as well. Existing maps and/or GPS can be used instead, or combined with photography. In wide-open sites such as the case of Bodie, where GPS data does not need to be accurate to the sub-meter precision, single frequency receivers can be used. In cases where small artifacts need to be more precisely located, better receivers of GPS processing techniques need be adopted, or other field surveying techniques such as the grid commonly used by archaeologists. Photographs taken of the grid with the artifacts visible can be used to build the 3D model and record the data in digital format.

The process is easy to implement on site and very cost effective, once hardware and software are available. The author is working with archaeologists at Cal Poly Pomona to implement the system for further testing in archaeological sites in South America. Meanwhile, a more extensive database for the site of Bodie will be developed in the near future, using the techniques described in this paper as a simple process for archaeological data collection, maximizing the information collected, creating 3D models from 35mm cameras, and using photogrammetry-supported GIS for data manipulation and analysis.

6. ACKNOWLEDGEMENTS

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