DOCUMENTATION AND VIRTUAL MODELING OF ARCHAEOLOGICAL SITES USING A NON-METRIC EXTREME WIDE-ANGLE LENS CAMERA

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ABSTRACT:

Documentation of cultural heritage sites can provide data and records for continuing research, analysis, monitoring, and change detection. Digital documentation allows computational analysis as well as archival recording of objects and sites. It provides a non-destructive approach to artifact or site mapping and measurement. Virtual models of cultural sites can be created from digital imagery, using widely available non-metric digital cameras and video recorders. Software, such as PhotoModeler® allows the construction of three-dimensional virtual modeling of objects, sites, and rooms by using multiple digital photographs. Methods for constructing virtual models currently require multiple photos from varying angles to provide sufficient ground control points as well as ample coverage of the site. Use of an extreme wide-angle lens camera, such as the Nikon fish eye lens, can overcome the need for numerous pictures and allows the capture of more information per image. This can speed the process of documentation while also providing more coverage. Wide-angle lenses have not been previously used due to the difficulty in registering the extreme distortion on the edges of the lenses. A project was undertaken to calibrate such a lens and to test its effectiveness in capturing images for virtual reconstruction using PhotoModeler software. The lens used was a Nikon fish-eye lens, mounted on a Nikon Coolpix camera. Two sites were selected for the test. The first was the interior of a modern building with a large three-story atrium. This site was chosen to initially calibrate the camera and lens for the software. The second site selected was the Salinas Pueblo Missions National Monument, a complex of archaeological sites used to test the effectiveness of the camera, lens, and PhotoModeler software in a cultural heritage site preservation application.

1. INTRODUCTION

An experiment with digital photography and the use of an extreme wide-angle lens was conducted on two sites to test the effectiveness of documenting and recording cultural heritage sites. Archaeological sites are subject to damage, erosion, or loss to modern construction. An inexpensive and expedient method for recording these sites would be highly useful, practical and would mean more extensive documentation. Current developments in laser technology offer outstanding results in measuring and recording sites, but the high cost and necessary technical skill leave this as an unpractical and often impossible alternative. Traditional methods of recording require large amounts of time and personnel. The methods utilized in this project offer a more cost effective approach that requires relatively little effort and few resources. The experiment conducted in this paper began with the intention of providing the ability to document the interior of large buildings with a minimal amount of digital images taken with a moderately priced digital camera, and using these images to build three-dimensional models of the areas visited. This idea was then extended to recording cultural heritage sites, and by upgrading the camera and lenses to provide greater coverage and greater resolution, accurate models could be generated with the integration of photogrammetric software.

The initial experiment involved the interior of a modern building with a large, three-story atrium, providing a challenge to record its very high, vertical walls. The second site chosen was an actual archaeological site with a similar shape and size. The cultural heritage site that was recorded was the Quarai

Mission church of the Salinas Pueblo Complex, a National Park Site located somewhat centrally in the state of New Mexico.

1.1 Technology Background

Cultural heritage sites are numerous, and the need for efficient documentation is essential in the race against site destruction due to development, erosion, and excavation. Close-range remote sensing methods for documentation have included such means as drawings, photography, close-range hardcopy and softcopy stereo-photogrammetry, and laser based LiDAR sensing. Both hardcopy and softcopy photogrammetry have been employed successfully to document cultural features (Turpin, 1979; Cooper, 2002), but the nature of large sites can make a project more challenging and time-consuming. Though LiDAR is proving to be a very fast and accurate alternative for site documentation, it is also extremely expensive. Many cultural sites will be excluded from this process because of a lack of funds. The digital photogrammetry approach offered here involves the use of an extreme-wide angle lens that will allow the capture of larger surfaces of area eliminating the need for copious amounts of photographs, cutting the time necessary to photograph the site and process the images. This approach requires relatively low cost equipment and minimal person-hours providing a comprehensive, economic alternative.

1.2 Background of the Archaeological Project Site

The cultural heritage site chosen for this project was the Quarai ruins of the Salinas Pueblo Missions National Monument. This monument consists of four pueblo ruins located within an 1,110 acre park area. The Quarai pueblo ruins show an early

occupation of around 1300AD and an abandonment 300 years later. Shortly after that, people returned to this area, and under the hand of Spanish religious leaders, the native peoples built the mission church, *La Purísima Concepción.* The church was erected in the early 1630's and in use for approximately 40 years (Wilson, 1993; Gifford, 1988). The ruins include nearly complete walls, up to 12 meters in height that still show the roof beam support holes. The church was built so as to be attached to the existing pueblo (Figure 1 and 2). Although the entire site will need to be documented, this experiment focused on the church itself because of it's size and current state of preservation.

Figure 1. Mission church, *La Purísima Concepción,* associated with the Quarai pueblo ruins of Salinas National Monument.
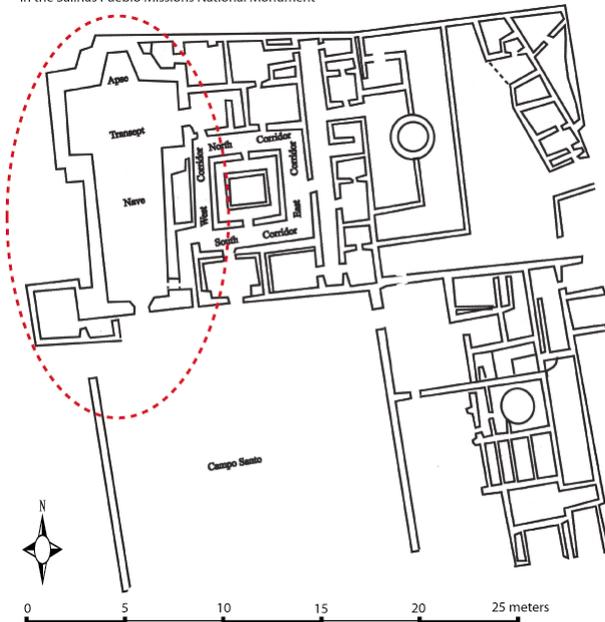

Figure 2. Map of the Quarai pueblo ruins of Salinas National Monument.

2. TOOLS AND METHODS

The methods employed for this process are unique to the photographic equipment that was employed. Technological advances are making digital photography a viable alternative for documentation. Digital photogrammetry is more accessible due to advancements in and availability of the software. This section will discuss the tools used for this documentation experiment and the methods developed to utilize these tools.

2.1 Tools

Two cameras were used in this project, one in each application. The camera used for the first experiment was a Nikon 990 with an FC-E8 fish-eye lens. The Nikon 990 is capable of capturing images at a maximum resolution of 2048 x 1536, or 3.2 effective megapixels. The FC-E8 lens has a viewing angle of 183 degrees, magnification of 0.209x and an 8mm focal length. This provided the ability to capture a larger area without having to take multiple pictures, allowing the reduction of person-hours in recording and processing images. The second experiment utilized a slightly newer model of camera and lens, the Nikon Coolpix 5700 and the Nikon Fish-eye lens FC-E9. The Nikon 5700 has a resolution of 2560 x 1920 pixels, or 5 megapixels, and the FC-E9 features approximately 183-degree coverage with a focal length of 7mm and magnification of 0.2x. These cameras were chosen for the high-resolution capability necessary for detail in documentation.

The photogrammetric software used in the project was PhotoModeler Pro 4.0 by EOS Systems, Inc. This was used to perform the camera calibrations and to conduct the digital photogrammetric processing. It is an affordable, readily available off-the-shelf software package.

2.2 Methods

The process of the digital photo documentation involved three stages. The first involved calibrating the camera and lens to the digital photogrammetric software that was to be employed. The second stage was to acquire the images, and the third was to digitally process them in the photogrammetric software computer program.

2.2.1 Camera Calibration: The calibration of the camera to the PhotoModeler software was necessary to remove the distortions that are inherent in the lens. This process was particularly important for this experiment, as it was necessary to also remove the extreme distortion caused by the fish-eye lens. This particular type of lens had never been utilized with this software before, and therefore a full calibration had to be made, which involved some intervention on the user's part to manipulate the calibration software to see what it was unable to register. This process had to be performed twice, as two different sets of cameras and lenses were used in the project.

2.2.2 Image Acquisition: The digital photographs were acquired by mounting the camera on a tripod at a height of approximately four feet. Because the fish-eye lens captures large areas horizontally and vertically, the photographer can capture whole walls from a near-ground level, making elevation of the camera and operator unnecessary. The photos had to be taken sequentially along a wall if the structure was too long to fit into a single image. The images also had to be overlapping by approximately 60% to allow photogrammetric processing.

2.2.3 Digital processing: First, camera calibration characteristics are entered into the PhotoModeler software program. Then, the images are downloaded into a computer system and ingested into the software as well. Tie points, or ground control points, had to be identified in the pictures that would allow the pictures to be tied together. The operator identifies these points and records them. It is necessary that each of these points appear in at least three of the photos. Once a sufficient number of points are identified and labelled, the automated photogrammetric process can be run. At this point, the software can calculate the measurements and distances between points and also determine camera locations for each of the photos, building a virtual three-dimensional model.

3. APPLICATION

The methods outlined above were employed in two experiments. The first application was in the documentation of the interior of a modern building. This was done to develop methods for application in an archaeological setting. After this experimental site was recorded and documented, the refined methods were applied to the Salinas monument.

3.1 Hibben Center Experiment

The first part of the experiment involved using a digital camera to acquire pictures in a modern building to establish the methods necessary for photo-documentation of a cultural site. The building used was the Hibben Center for Archaeological Research Building on the University of New Mexico campus. Its high-ceilinged atrium-like construction provided a suitable simulation for documenting large and tall structures. The interior space of the building is approximately 16 by 10 meter with a 13 by 7 meter atrium open to the third floor. The perimeter ceiling height of the first floor is 2.7 meters high, while the ceiling of the atrium is 11 meters high. This space provided an excellent example of tall architecture, and provided a simulated experience for documenting large structures in a confined space.

The camera used for recording this site was the Nikon 990 with an FC-E8 fish-eye lens. The experiment involved taking a minimum number of pictures that would still allow for the photogrammetric reconstruction of a three-dimensional model. A total of ten pictures were collected from ground level. The camera was set to macro focus, and the lens setting to extreme-wide angle. The full wide-angle capability, the fish-eye setting, was not used, as this had proved too difficult to calibrate in the photogrammetric software. The extreme wide-angle lens was capable of capturing wall's full height and length from all angles, meaning that 11m high walls could be captured in their entirety from a standard tripod height. Using a constant camera height of approximately 1.5 meters, a straight-on image was captured for each of the four walls, pictures were taken from each of the corners, from two ends of the building and two points near the center of the building facing each end. (Figure 3.)
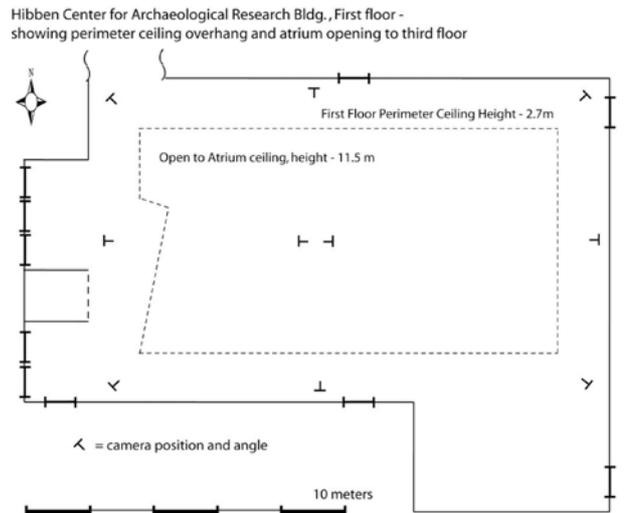

Figure 3. Hibben Center Building layout showing the camera placement and viewing angles for each picture.

Each of the pictures captured the wall of interest in its entirety and additional area beyond. These last two camera positions allowed the capture of the entirety of the building, as the fish-eye lens covers 183 degrees; each picture captured slightly more than one half of the building interior. In all cases, the 15 meter high walls were captured in their entire height, and each straight on picture covered the 18 meter length of the walls, eliminating the need for excessive photos. A minimum number of shots were necessary, however, to capture every detail of the building in at least three photographs in order to tie points together to build the model.

The digital images were then downloaded to a computer and ingested into the PhotoModeler photogrammetric modeling software application. Building the model involved "stitching" the pictures together by selecting common points, or ground control points, between the photos. Each point used had to appear within a minimum of three pictures to be useful for constructing the model. Once ground points were selected, the program was run to build a three-dimensional model. The software utilizes camera calibration information along with photogrammetric algorithms to compute distance and measurements in the photos. With this, the application can build a virtual three-dimensional model with approximate dimensions (Figure 3). The software utilized outputs a model that can be imported into drafting software applications for documenting layout and dimensions.

3.2 Salinas Monument Experiment

The methods developed in the Hibben Center experiment were then applied in an archaeological setting. The mission church in the Quarai complex of the Salinas National Monument was chosen for its size and structure. The walls of the mission church still stand in some places at a height of 12 meters. It has been a challenge for the National Park Service to record this structure sufficiently, as access to these heights are difficult without causing damage to the walls and structures.

The camera utilized in this application was a Nikon Coolpix 5700 with a FC-E9 fish-eye lens in the wide-angle setting. The

photographic process involved many more pictures than used in the Hibben Center experiment. The reasons for this were the size and complexity of the structure. First of all, photos were taken of the exterior as well as the interior of the structure. Also, this application was intended to produce an archival quality documentation of the structure for the National Park Service, therefore, a higher degree of accuracy and representation was desired.

Two sets of photos were taken of the structure. One set was taken for a visual record to accurately document the structure's surface. The second set involved the use of targets that would allow a more accurate selection of ground points in the photogrammetric process. The targets employed were 4 cm white circles on a 6 cm square field of black. These were carefully placed on the walls of the structure, and then successive photos were taken of the walls. The bottom-most targets were set at a known height, using a laser level for consistency, and the remainder were spaced generally at 4-meter intervals, at three different heights (Figure 4).

Figure 4. Front view of the Quarai mission church showing the placed targets to be used as ground control points. The distortion in this uncorrected image is due to the fish-eye lens.

As in the Hibben Experiment, the fish-eye lens was able to capture the entire height of the walls. Photos could then be taken by a photographer using a standard tripod with the camera at a general height of 1.4 meters (Figure 3). Photos were taken at 3 to 4 meter intervals, depending on the complexity of the surface. This distance allowed enough overlap between images for the photogrammetric processing. Most images were taken at a distance of 7.8 meters from the subject. This distance was determined to be ideal in this case, as the camera and lens could capture the entire height of the walls. This was one of the advantages of using the fish-eye lens, as in most of the interior of the church, the walls were only 8-8.5 meters apart.

The images were then downloaded and processed in the PhotoModeler software. The same process was used as for the Hibben Center experiment, but in this case, the photos containing the placed targets were used to tie the pictures together. Once the model was built, the photos of the monument that did not contain the targets was then used to paint the surface of the virtual model.

4. RESULTS AND CONCLUSION

The mission church, *La Purísima Concepción*, in the Quarai complex at Salinas National Monument proved to be an ideal subject for experimenting with digital photogrammetric techniques for documentation of the cultural heritage. The final results also provide an archival quality record for the park officials managing the site. The resulting digital models provide detailed documentation, measurements, and maps that could be used for other research and restoration projects. The virtual three-dimensional model provides a digital document for the park service's records and offers opportunities for educating the general public.

Digital photogrammetric recording of archaeological features can provide accurate, non-destructive documentation of important sites subject to destruction, environmental change, and decay. This experiment has shown that accurate measurements and maps can be generated from this process and that these products can be utilized in other on-going projects. In addition, accurate depictions of the walls and structures are recorded digitally for archival purposes. Furthermore, this process is relatively inexpensive compared to use of laser technologies, making it a viable option for cultural site managers with restricted funds.

5. ACKNOWLEDGEMENTS

6. REFERENCES

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