DIGITALLY DOCUMENTING D-DAY: THE USE OF CLOSE RANGE DIGITAL PHOTOGRAMMETRY AT POINTE DU HOC

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Abstract

This paper describes the progress of a multi-disciplinary team from Texas A&M University to digitally document the command post at one of the most significant historic sites of the D-Day landings: Pointe du Hoc. The methods used to collect survey data for both the production of 2D Historic American Building Survey drawings and for the 3D digital model are described. The processes used to produce the 3D digital model involves collecting survey data using digital photogrammetry and then applying surfaces to that model using modeling software. The results of the first season's survey work are described and illustrated. Finally, the problems encountered with lighting and the digital photogrammetry processing are discussed and recommendations made for future work.

1. Introduction

1.1. Pointe du Hoc historic site

Pointe du Hoc is the most culturally important historic site of the Normandy invasion coast. In the early morning of June 6, 1944, Lt. Col. James Earl Rudder led elements of the 2nd Ranger Battalion in one of the most famous and heroic actions of D-Day (Ambrose 1994). Their mission was to destroy 155mm cannon capable of firing on troops and ships landing on Utah and Omaha beaches.

Pointe du Hoc is a medium coastal battery consisting of a variety of structures such as gun emplacements, casemates, personnel, and ammunition bunkers. Constructed as part of Hitler's Atlantic Wall it was strategically placed between the Utah and Omaha invasion beaches. It was the scene of intense bombing and shelling prior to and during D-Day and was eventually taken by the 2nd Ranger Battalion as part of the D-Day invasion.

The most significant building on the site is the Command or Observation Post. This reinforced concrete structure is a two-storey building and was the control point for the battery. Its significance has led it to become the focal point for remembrance and it now contains a number of memorials; including one to the Rangers that is located on top of the building. Its location, close to edge of the cliffs has made it vulnerable to coastal erosion and in recent years this important building has been inaccessible to the public. The continued inaccessibility of this building has led us to focus on developing a digital model of this building to allow the public to visit the building virtually.

1.2. Digital documentation

Since September 2003, the Historic Resources Imaging Laboratory (HRIL) at Texas A&M University has been investigating the reinforced concrete structures at Pointe du Hoc Historic Site in Normandy, France. Recent interpretation work has focused on developing a digital model of one of the most important buildings on the site; the command post. To develop a digital model three-dimensional data of the object must first be obtained.

Two approaches are commonly used for this type of project. The first one involves 3D scanning, typically using lasers. Until recently, this technique was limited to

small objects such as statues or toys and indoor scenes (Levoy et al. 2000). Recent technological advances have led to the development of scanners which can be used for digitizing outdoor environments. While this method can produce very accurate 3D models, the amount of raw data that is obtained can quickly reach unmanageable proportions, especially for outdoor scenes. Outdoor 3D scanning is further constrained by the requirement for scanning locations which provide unobstructed views of the objects in the scene (Xu and Chen 2003).

The second approach, which will be used in this project, makes use of image-based modeling techniques (Debevec, Taylor and Malik 1996; Debevec et al. 1998; Hawkins, Cohen and Debevec 2001; Debevec 2003). These methods are inexpensive and can capture objects and scenes of any size. They are also well suited for outdoor sites which have limited access, such as the Point du Hoc site.

In brief, image-based modeling involves creating a 3D model starting from 2D photographs of the object or scene, often in combination with interactive modeling tools. Some systems employ computer vision techniques such as computational stereopsis to automatically determine the structure of the scene from multiple photographs. These systems are however limited by the strength of the stereo algorithms used (Debevec, Taylor and Malik 1996).

Recently, a hybrid geometry- and image-based approach for modeling and rendering architecture from images was introduced by Debevec, et al (Debevec, Taylor and Malik 1996). They have developed an interactive modeling program, *Façade*, which allows a user to construct a geometric model of a scene from digitized photographs. The program is designed for architectural scenes, and makes use of constraints that are characteristic of such scenes. The user models the scene as a collection of parameterized geometric primitives such as boxes, prisms, and surfaces of revolution.

Although *Façade* appears to be a promising tool, its utility is restricted to architectural structures. The Point du Hoc site contains structures that range from standard architectural shapes (such as buildings) to very organic shapes (such as the terrain containing bomb craters). For consistency and efficiency, it would be helpful to have a single tool that can be used for the entire site. It is also very important to be able to capture the details of the damage inflicted upon the buildings during the battle in order to achieve our long-term goal of digitally recreating the battle events. Furthermore we have a large amount of point data that has already been obtained from photographs of the scene. It must also be mentioned that *Façade* remains an unreleased research prototype, although a lot of its functionality is available in commercial products.

2. Survey and documentation of the site

The Pointe du Hoc Historic Site was designated a Class A Historic Site by the French Government on 28 February 1955. The site was formally transferred to the American Battle Monuments Commission, a small independent agency of the Executive Branch of the federal government, for perpetual care and maintenance on January 11, 1979. Unfortunately, even up to today, the historic site has very little site interpretation and individual buildings and structures are not even identified. The battery command post, which was a critically important point of the battle, has been inaccessible to the public since 2001, primarily due to erosion of the cliff. Many parts of the historic site are situated close to fragile sea cliffs, and are subject to rapid, destructive geological processes including landslides, atmospheric corrosion of steel reinforcements, and spalling and cracking of the concrete structures.

Although the survey project's primary objective is to comprehensively document, using Historic American Building Survey (HABS) standards, to produce two-dimensional drawings, a secondary objective was to survey some of the buildings using digital photogrammetry which would lead to the development of three-dimensional digital models.

Most of the survey data was collected using simple linear measurement using tapes and electronic distance measurement. The battery command post was also recorded using photogrammetry. It is our intent is to

create both 2D and 3D products for this structure since its existence is in peril due to erosion of the cliff. Figure 1 shows the field drawing used to collect site data for the Command Post.

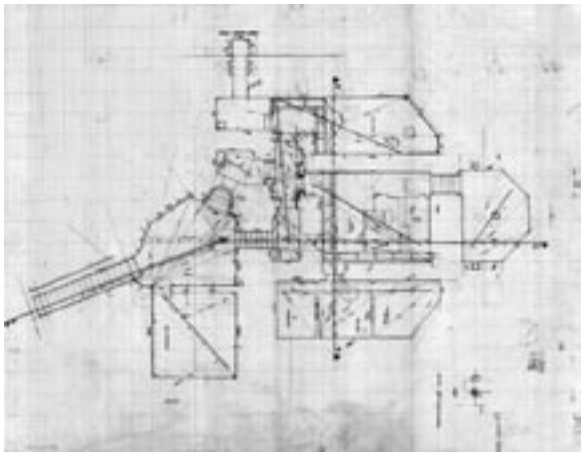

Figure 1: Field drawing used to collect 2-D data for the Command Post.

2.1. Digital reconstruction

An initial decision was taken to produce one digital model of the whole building both external and internal by processing all the images to obtain both exterior and interior measurements. Over 300 images of the command post were taken during June 2004 using a low cost ($500) Sony DSC V1 digital camera with a 0.45X wide angle lens. The interior of the command post has minimal interior lighting and exposures of 30 seconds were used in many rooms. Processing of the images began on return from Pointe du Hoc in August 2004. Obtaining three-dimensional measurements from the images is done by marking the same point on the building on at least three digital images taken from different positions, and then when a sufficient number of points have been marked on the images, computer software is able to locate the three dimensional position of the cameras. Once the camera positions are located, a series of mathematical calculations locate the position of all marked points. These points are then used to create a digital model of the building.

Our goal for the digital reconstruction was to create as accurate a three-dimensional model as possible while allowing some flexibility in the final presentation for overlaying interpretation and historical information. We started with the Ranger Memorial, a monument dedicated to the soldiers who fought at Pointe du Hoc. The Memorial also contains a wide variety of structural elements that allowed us to try various modeling and reconstruction approaches and refine our techniques.

Figure 2 illustrates the process of going from the photographs to the final three-dimensional digital model. As already described, we import the photographs into PhotoModeler and obtain 3D geometry information for manually selected points in the scene. These points are then exported to a file and imported into Maya, a commercially available 3D modeling and animation package. The surfaces are created in Maya using the photographs as a reference. Textures based on the original photographs are then applied. After some fine-tuning of the model and the textures we obtain the final rendered output.

For 3D modeling of the kind we are dealing with, two approaches are commonly used: NURBS modeling and polygonal modeling (Foley et al. 1996). NURBS modeling involves the use of B-spline surfaces and is typically used for modeling organic looking objects which have a lot of smooth surface elements and not too many sharp edges (Giambruno 2002). Polygonal modeling involves modeling the surface using simple polygons, typically triangles and/or quadrilaterals (Giambruno 2002). It is well suited for objects with sharp edges, while allowing enough flexibility to handle somewhat smoother elements as well. It is also simpler compared to NURBS modeling and is ideal for real-time and interactive applications, since the graphics hardware deals directly with polygons only. Another significant advantage of polygonal modeling over NURBS modeling is that it allows for increasing the mesh density (number of polygons in a given area) locally in high-detail areas without affecting other areas.

We first attempted to model the memorial using NURBS surfaces. However, this approach could not handle the rocky appearance without introducing other artifacts. So we chose to go with polygonal modeling. Our initial

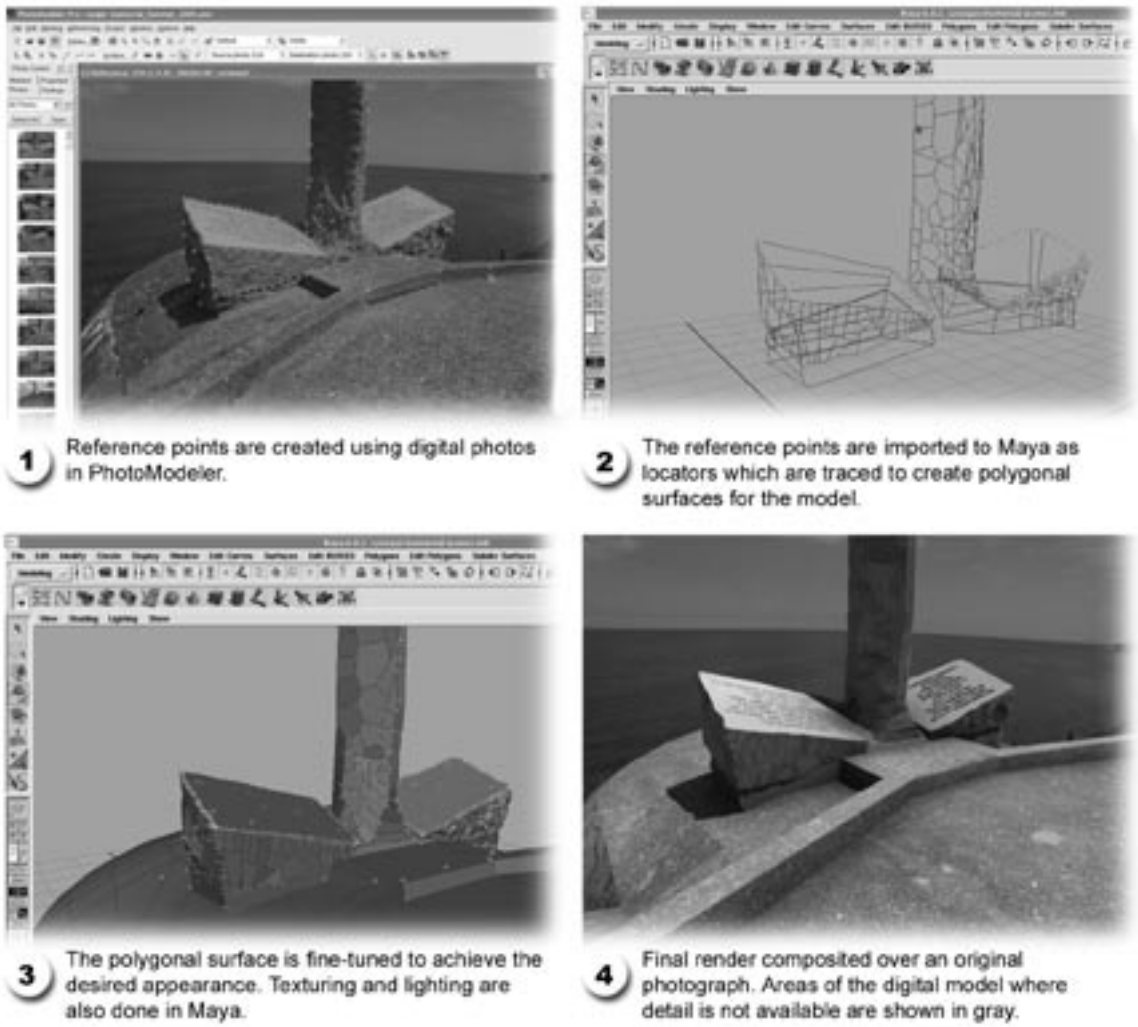

Figure 2: Digital reconstruction process.

attempt to model the surface using quadrilaterals only did not produce satisfactory results. We switched to using a triangular mesh which gave better results but still had a few artifacts. By fine-tuning the mesh to minimize high-valence vertices (vertices which have more than 4 edges incident on them) we were able to deal with the remaining artifacts.

The final step was to apply material properties to the surface. We started with an existing shader that mimicked the appearance of rock. We combined a fine-tuned version of this shader along with displacement maps to produce the final rendered image.

3. Conclusion and future directions

Figure 3 shows a final rendered version of the digital model. The digital model of the Ranger Memorial and its immediate surroundings has been composited over an actual photograph.

For documenting our progress and publicizing the work, we have created a website for the visualization project (URL available upon request). The website includes relevant information about the project and latest updates to the digital model in the form of still images and animations. An interactive virtual tour of the site will also be available once the digital model is complete.

Figure 3: Final rendered version of the 3D model composited over an original photograph.

Lighting at the site turned out to be a very important issue in the process. Not all photos were taken at the same time and matching the appearance based on photos with different exposures took some time. Some photos were taken in bright sunlight, causing harsh shadows leading to reduced detail in those areas. The initial photos were also not well suited for extraction of textures, and we have attempted to address this issue by taking new images during June 2005.

In hindsight the development of a single model proved problematic as the processing time increased as images were added, becoming excessive. Problems were also identified in a number of rooms due to poor lighting. The poor lighting made it very difficult to identify the dark corners of the rooms, which was essential for developing the 3-D model. These two problems caused us to re-evaluate the photogrammetric process and the building was photographed again in June 2005 using temporary lighting on the interior. It was also decided to break the processing down into smaller more manageable projects. External images will be processed as one project and each room will be processed as an individual project.

The HRIL intends to develop a series of 3D models of the command post that will provide the public the opportunity to experience this building virtually. Ultimately we will use historical documents and contemporary reports to try and recreate the appearance of the building at the time of D-day.

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