CHAPTER 289

Shoreline Analysis Using Digital Photogrammetry

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Abstract

This paper discusses the application of digital photogrammetry to the analysis of shoreline change with examples from Holden Beach, NC. Beach cross sections are generated from a three dimensional stereo image. These profiles are then used to determine shoreline position and erosion rates. The paper compares these rates of shoreline change with those determined from the more traditional methodology based on the two dimensional interpretation of the wet-dry line. The paper also illustrates the improved accuracy obtained by using survey grade GPS as opposed to USGS topographic maps to establish ground control.

Introduction

Coastal engineers are always seeking better tools to analyze shoreline changes. These changes include the result of long-term erosion or accretion and short-term impacts of severe storms. The two most frequently used methods to record shoreline change are directly from field surveys and remotely from aerial photographs. Both methods have advantages and disadvantages.

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Field surveys provide detailed information regarding the topography and bathymetry of the beach and shoreline. These surveys are relatively expensive. In addition, they can not be used to determine long-term change if no historical surveys have been conducted.

Alternatively, the interpretation of shoreline change from aerial photographs permits one to perform a historical analysis when such photographs are available. Unlike field surveys, traditional methods for analyzing shoreline change from aerial photographs do not generally furnish the three dimensional data provided by a field survey. Three dimensional data can be obtained from aerial photographs, however, if one utilizes photogrammetric techniques including the analysis of pairs of overlapping photographs.

Until recently, few coastal engineering projects have included the application of three dimensional photogrammetric techniques to analyze shoreline change, simply because traditional photogrammetry relies upon complex analytical stereoplotters. These devices do not lend themselves to routine use outside of the highly specialized photogrammetry laboratory.

The difficulties of using photogrammetry for shoreline change analysis have been significantly reduced by the introduction of the new computer based digital techniques. Digital photogrammetry replaces the analytical stereoplotter with a three dimensional image that has been generated by a computer coupled with a high resolution scanner. A pair of photographs is scanned, the two images merged and viewed on the terminal as a single three dimensional image with the use of special glasses worn by the operator. In addition to reducing the difficulty in generating a three dimensional image, the technique supplies an image in digital format. This greatly expands the opportunities for data manipulation and analysis.

This paper describes our experience with the application of digital photogrammetry to the analysis of shoreline change along the coast of North Carolina. While we are still learning, it is already clear that this technology has greatly expanded our abilities to make accurate measurements of erosion rates and the impacts of severe storms on the beach.

Project Study Area

The Holden Beach project described in the paper is located in Brunswick County, on the southernmost portion of the North Carolina coast, Figure 1. The study area is a typical barrier island separated from the mainland by a narrow estuary (the Intracoastal Waterway). Most of the beaches in Brunswick County are developed with low density single family houses as is typical for the mid-Atlantic coast. Long-term shore erosion is on the order of 2 to 4 ft/yr. The occasional severe storm, including both hurricanes and northeasters, coupled with the effects of long-term erosion has led to the loss of oceanfront houses and a general need to be able to make reasonable estimates for the future changes in shoreline position.

The analysis of the rates of shoreline change at Holden Beaeh is part of a larger study of the area being undertaken for the North Carolina Department of Emergency Management through a grant from the Federal Emergency Management Agency. The larger study is intended to develop new techniques for natural hazard identification through the use of digital photogrammetry.

Project Description

The analysis presented in this paper focuses on the measurement of the change in position of the shoreline. In this context the shoreline is defined as the interface between the wet and dry beach as seen from aerial photographs. This interface has been used by many investigators (e.g., Dolan, et al. 1978) as the shoreline, and is often referred to as the high water line in the literature. Strictly speaking it is not the high water line, but rather a time average of this line. This line is not fixed in spaee; it moves up and down the beach face depending upon the tide, beach slope, and to some extent the wave climate (Fisher and Overton, 1994).

Our laboratory utilizes both hardware and software developed by Intergraph Corporation. The photogrammetric grade scanner with a maximum scanning capability of 3386 dpi is a key feature of the system. It provides the digital resolution needed to achieve the accuracy desired in the data analysis. Figure 2 illustrates a typical digital photogrammetric project work flow. Two or more photographs are scanned (at a typical scanning resolution of 1693 dpi) and used to build a stereo image.

Standard photogrammetric procedures including interior and relative orientation correct for camera distortion and tilt.

One of the most important steps in this work flow is to establish an accurate set of ground control points. These points determine the absolute position of objects seen on the photographs. In order to maximize the ultimate accuracy of the project we have elected to use survey grade GPS equipment for this ground control.

Ideally the ground control should be established at the time of the aerial photographs. However, in many cases this is not possible, and we frequently have to establish ground control after the fact. For example, control points can be established from features that are visible in the photography and which can be surveyed accurately. Using photography from the last five years, this procedure has allowed us to establish control points with approximately 3 ft accuracy.

Once the control has been established, the computer can then generate a three dimension image of the beach. As noted above, the operator must be wearing a special set of glasses to view this image, much like one would do in a theater when viewing a 3-D movie.

The operator, using the stereo image, can next proceed to create a digital terrain model, or DTM. This model is developed by the operator "placing" the computer cursor on ground at multiple locations. This process requires a certain amount of training and experience, and therefore the quality of the DTM depends upon the skill of the photo analyst. Once the DTM has been created, a number of different digital products can be produced, depending upon the specific application and interest. Examples include orthophotos, triangulated irregular networks (TINs), grids, and draped images.

Shoreline Change Measurements

Figure 3 is a digital orthophoto for a portion of the study area for June 1992. A digital orthophoto is a computer generated 2-dimensional image which has been corrected for distortion. Accurate measurements can be made directly from this orthophoto. Because of the digital format it is possible to zoom in on a portion of the photo as shown by the inset in this figure. The shoreline (wet-dry line) has been identified by the operator as indicated by the line drawn on the beach. As noted above,

this shoreline is dependent upon the waves and tide at the site at the instant in time when the photograph was taken.

When analyzing shoreline change it is necessary to look at two dates. In addition to the 1992 date shown in Figure 3, we chose a set of photographs taken in 1955 as the second date. Figure 4 shows a pair of orthophotos at the same site for 1992 and 1955. The development that has taken place between these dates is clearly evident. In addition, the 1955 orthophoto was taken less than 12 months after Hurricane Hazel struck this coastline. Hazel (prior to Hurricane Fran in 1996) was the most severe storm to impact this shoreline in memory. The extremely wide overwash penetration shown on this photograph is due to that single storm. It is important to note that the absence on the 1955 photograph of most of the man-made features shown on the 1992 photograph makes it difficult to establish reasonable control for the earlier date.

Once we have identified the wet/dry line for the two different dates it is a relatively easy task to determine shoreline change. We use a technique developed by Dr. Robert Dolan (Dolan, et al. 1978). This technique uses an imaginary, shore parallel off-shore baseline as a reference line. The distance from this baseline to the shoreline is measured along an orthogonal drawn between the shoreline and the baseline. In our work we set these orthogonals at 150 ft intervals. Once the distance between the baseline and the shoreline is known for the two dates in question, it is a simple matter to compute the erosion/accretion rate.

Prior to our use of the digital orthophotos we used the more widely practiced techniques described by Dolan and others which depend upon less accurate corrections for the aerial photographs. In this prior method, ground control points for the photographs were identified using USGS topographic maps. Figure 5 illustrates the difference in erosion rates we found between these two methods at the study site. The difference is about 1 ft/yr. At this site, where the average erosion rate is about 3 ft/yr, this is a significant difference. Depending upon the site, this difference can be important when one attempts to use these data for shoreline management and construction permit programs.

The method to determine shoreline change described above is an essentially 2-dimensional technique. Since the digital image is stored in the computer as an 3-dimensional object, it is interesting to consider how one could determine shoreline change from this latter data. In this case

we work from a computer generated TIN. The TIN is a three dimensional wire diagram of the stereo image, as shown in Figure 6. The triangles connect points of known elevation.

From the TIN the software can generate cross-sections normal to the shoreline at any location. Figure 7 illustrates two such profiles, for 1955 and 1992. As an alternative to measuring the change in position in the wet/dry line, one can now measure the change in position of a specific elevation contour. For comparison, the wet/dry lines are also shown on this figure. Of course, the use of beach profiles to determine rates of shoreline change is not new. This is the normal procedure when working from field survey data. However, the ability to generate these profiles from digital historical aerial photographs is a relatively new procedure, and one worthy of future development.

Figure 8 illustrates the difference in erosion rates determined by these two methods. For this site the change in position of the wet/dry line between 1955 and 1992 yields a higher erosion rate than the method which is based upon the change in position for the 3 ft contour for these same dates. Note that the general trend in the data is consistent between the two methods. All things being equal, we feel that the erosion rate based upon the contour is preferable because it reduces the influence of the waves and tides on the data.

We are continuing to explore the pros and cons of the two methods to measure shoreline change. A rigorous test with field survey data is needed prior to making any conclusions regarding the preference of one over the other.

Draped Images

The discussion above has focused on the use of digital photogrammetry for measuring shoreline change. Another important use for this technology is the ability to generate realistic looking computer images of the beach. One way to generate such an image is to "drape" the orthophoto over the TIN, as shown in Figure 9. This image (shown here with a 5x vertical distortion) enables us to visualize the topography and see clearly the dunes, roads, houses, and vegetation. Such pictures are valuable both to the analyst as well as the general public. In the latter case these images can be used to help explain a problem, proposed solution, or probable impact. Again, since this is a digital image, it is

possible to easily change the scale, angle of viewing, and distortion as needed. We are currently working with these draped images to prepare a report which identifies areas most vulnerable to damage from severe storms.

Conclusions

While the application of digital photogrammetry to coastal engineering is new, it is already clear that this technology will provide important improvements to the field. In particular, the ability to generate orthophotos from historical aerial photographs will allow us to make more accurate determinations of rates of shoreline change. In addition, the computer generated images will create new tools for both shoreline managers as well as the general public to understand the nature of shoreline change.

Acknowledgments

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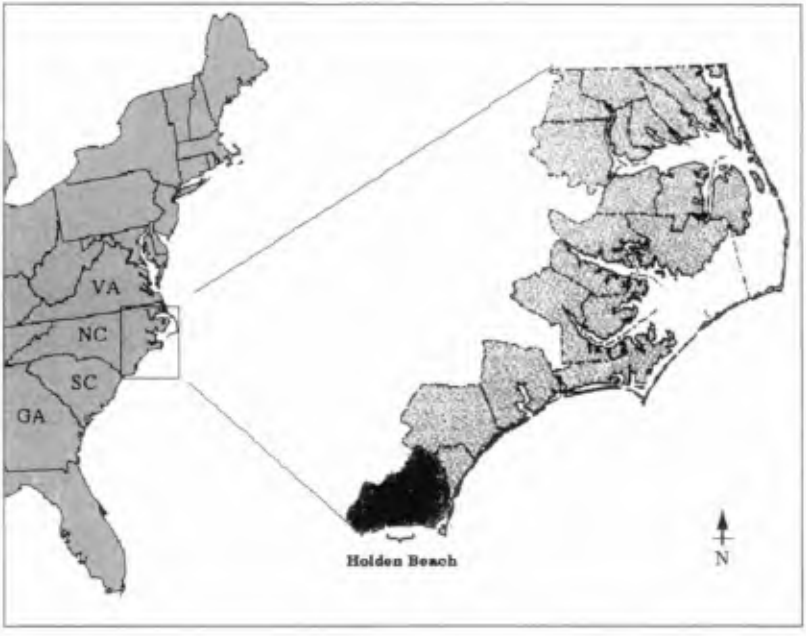

Figure 1. Project Study Area

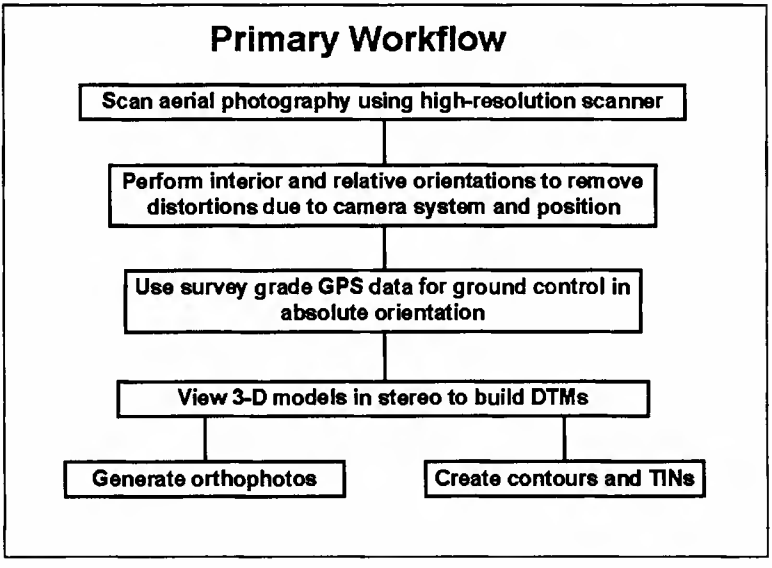

Figure 2. Project Workflow

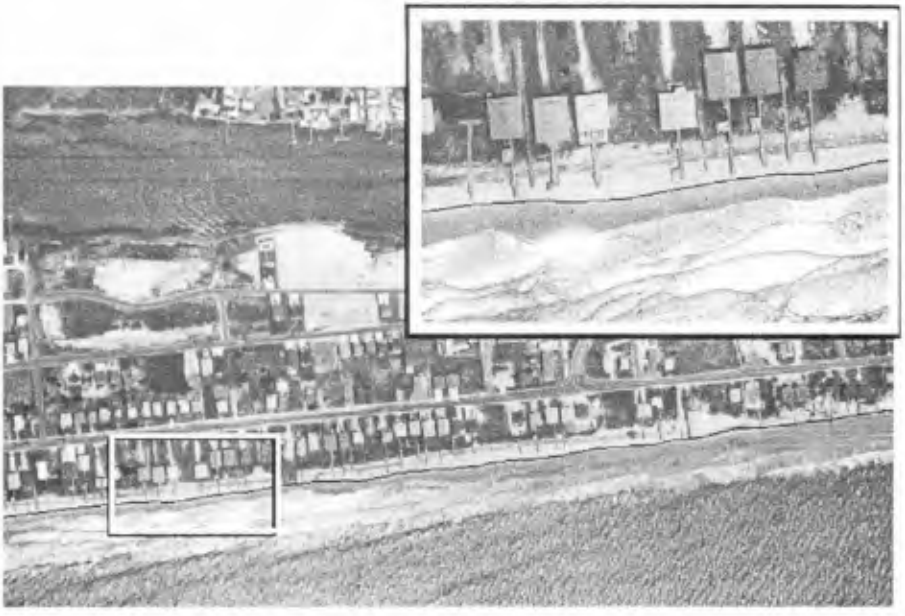

Figure 3. Holden Beach Orthophoto

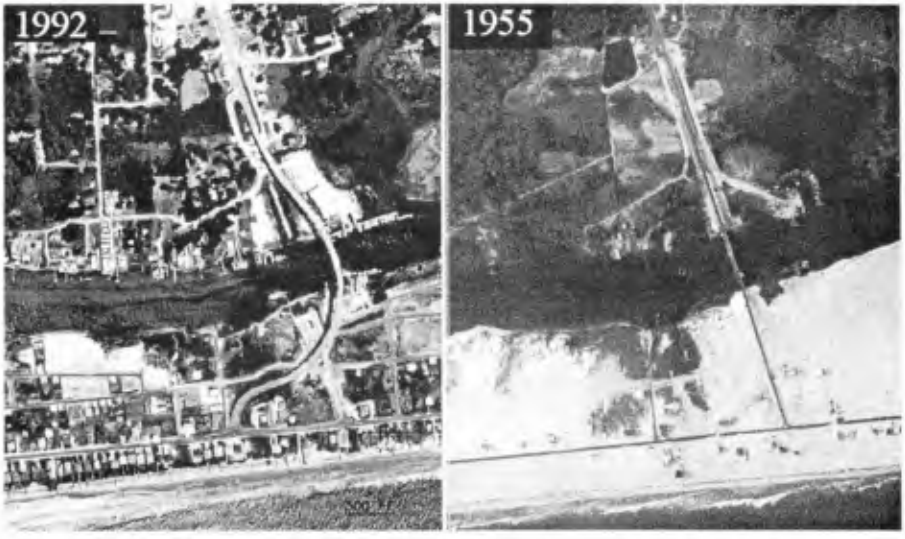

Figure 4. Holden Beach Orthophotos for 1992 and 1955

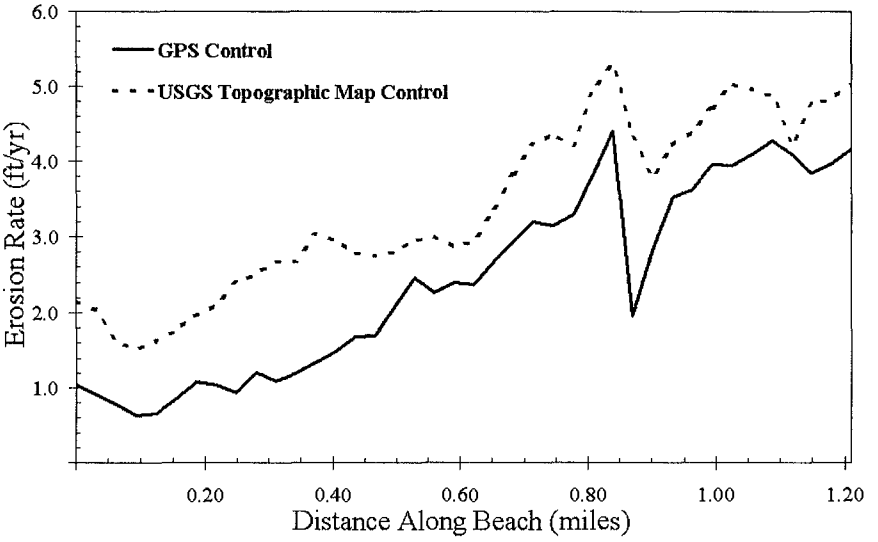

Figure 5. Comparison of Erosion Rates: Mapping Error

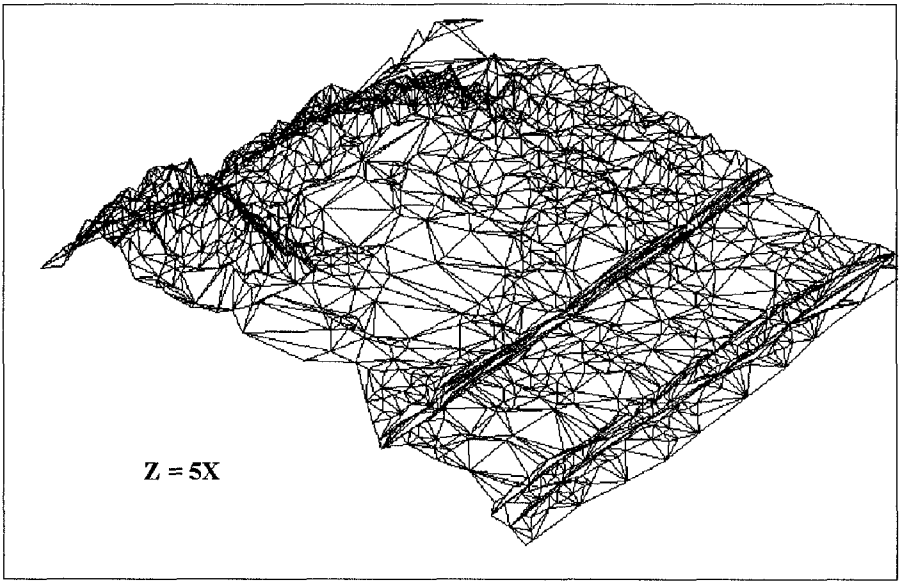

Figure 6. 1955 TIN for Study Site

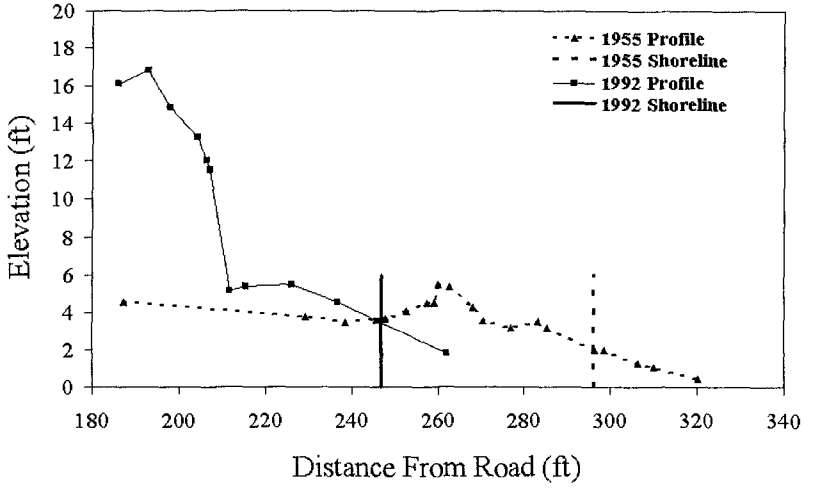

Figure 7. Computer Generated Shoreline Profiles

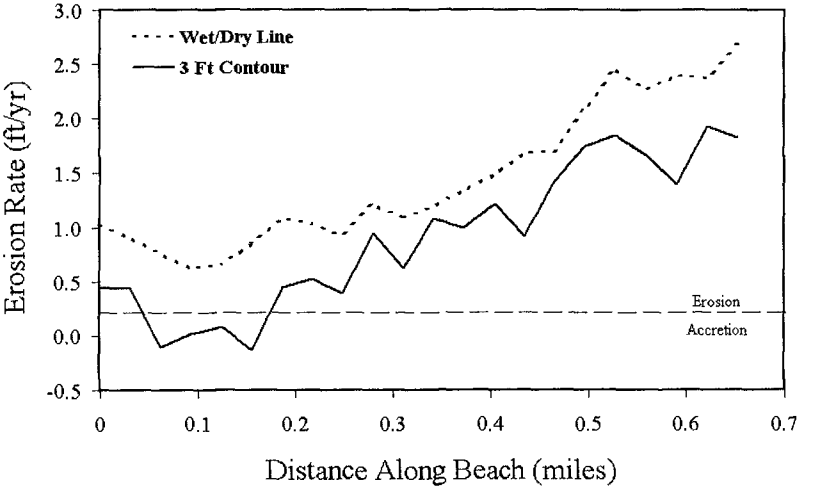

Figure 8. Comparison of Methods for Determining Erosion Rate

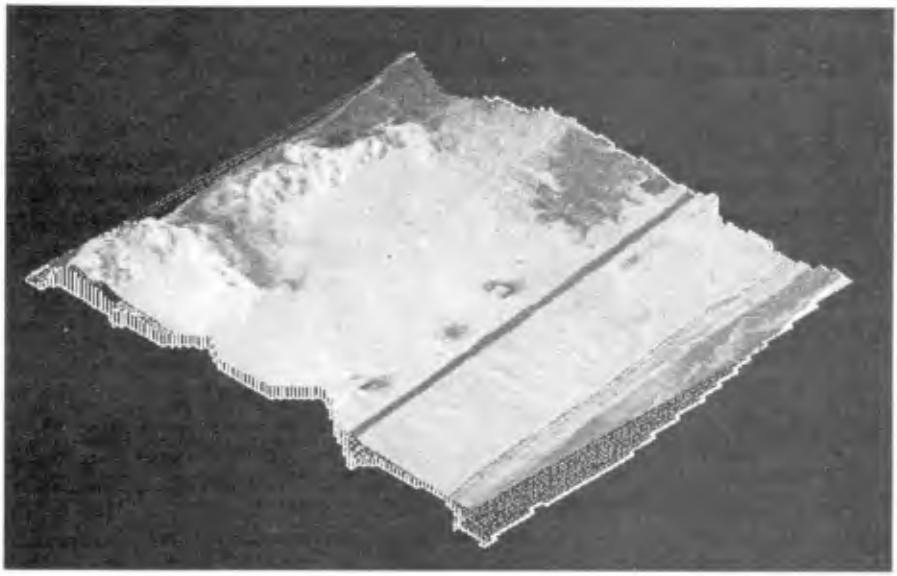

Figure 9. 1955 Orthophoto Draped Over Computer Generated Grid