Exploring coastal morphodynamics of Ameland (the Netherlands) with remote sensing monitoring techniques and dynamic modelling in GIS

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CHAPTER 4

THE DERIVATION OF DIGITAL ELEVATION MODELS FROM AERIAL VIDEO DATA

ABSTRACT

Coastal morphological research benefits from digital elevation models. Videography, a cheap, simple and flexible airborne remote sensing technique, was used to construct such elevation models. A hand-held Hi 8 camera and a small airplane were used to collect video data of a 1300×320 m strip of beach and foredune area on Ameland. Simultaneously, the coordinates of the ground control points (GCPs) were measured with laser electronic distance measurement (EDM) equipment. A series of overlapping frames was grabbed, contrast-stretched and corrected for interlacing effects. The resulting images were processed with software that has some photogrammetric capabilities, R-WEL’s Desktop Mapping System (DMS). The images and the positions of the GCPs enabled computing of the camera orientation, and allowed for image rectification and stereo correlation. Stereo pairs form the basis for anaglyphs, which give a perception of height. In addition, the parallax in the stereo pairs allows derivation of quantitative height information. In this case, the information comprised semi-quantitative relative terrain heights; the absolute height values calculated by DMS are incorrect. This was due to inaccuracies in the camera technology and the use of photogrammetric software that was not designed principally to process video imagery.

1 INTRODUCTION

Videography has recently proven its use in coastal zone studies.

- Video cameras have been placed at fixed positions overlooking the beach. Under these conditions, video allows the study of time sequences of bar behaviour and run-up, and the measurement of intertidal bathymetry and foreshore topography (Lippmann & Holman, 1989; Holman et al., 1991; Walton-Jr, 1993; Holland et al., 1995; Holland & Holman, 1997; Plant & Holman, 1997).

- Aerial videography has been used mainly for monitoring development and decline of coastal vegetation (Everitt et al., 1991, 1996; Judd et al., 1997). Eleveld & Jungerius (1993) made some initial attempts in using videography for geomorphological mapping in a coastal dune area. Recent advances in video applications have been made through the creation of digital elevation models (DEMs) of coastal landscapes (Bakker et al., 1994).

- Finally, underwater videography from fixed positions and from movable platforms has been used for the registration of underwater life for several years (see for examples the Journal of Fish Biology and Fisheries Research).

Within the framework of this thesis, simple interpretations of video images have been made to test the usefulness of video data for geomorphological, ecological or engineering purposes. Classification of the grabbed 'raw' video data resulted in relevant classes that indicate landscape units and the geomorphological differentiation within these units; e.g. the differentiation between beach, dune and saltmarsh, and of creeks within the saltmarsh. Video data can also give an overview of the bar systems, an estimation of beach width, and an indication of erosion of the foredunes (Berkhout, 1995).

If this practical information is tabulated, then video imagery scores quite well in comparison with aerial photographs, and especially if compared with satellite imagery. An advantage is its high spatial resolution (compared to satellite imagery); disadvantages are the small coverage and the lack of height information (Chapter 2). From this study, it was recommended to generate overviews (with mosaic), and '3D vision', which facilitates the linking of geomorphological processes to their position in the terrain. An overview from mosaicked video imagery is presented in Chapter 9 (Fig. 8). A method for the derivation of height information will be described in this chapter. More research on the use of this relatively unknown sensor is necessary. An impression of height is required to describe coastal landscapes; absolute height is necessary to determine sediment volume changes (sediment budgets).

2 OBJECTIVES

This study aimed to:

- Explore the possibilities of video data for height impression,
- Investigate the use of aerial videography for 2.5D terrain mapping of beach and dune areas,
• Extract heights from CCD-video imagery as a first step towards volumetric change
detection.
To allow high accessibility of the technique, low budget optical instruments, computer
hardware and public domain software were used.

3 METHODS

3.1 The field campaign

A stretch along the North Sea coast of Ameland was selected as the test area. In this area, the
breaker zone, the beach and the foredunes are of interest because of their frequent
morphological changes. This study focuses on the beach and foredunes, since aerial
videography does not allow proper registration of underwater topography. The beach is a
fairly level terrain unit with an almost uniform reflectance. The foredunes are the main relief
features and show the highest contrast due to alternation of bare sand and vegetation.
The test site was selected between beach posts 14 and 16. The presence of a major relief
feature on this site improves the accuracy of height measurements by stretching the height
range; the highest dune top has an elevation of 17.8 m. Artificial structures, such as houses
and roads, facilitate orientation on the ground and in the air.

Electronic distance measurement (EDM) equipment was used to collect the local x, y and z
co-ordinates of the ground control points (GCPs). Twenty-seven markers of 3 × 2 m orange
and green plastic sheets were placed in the field at 150 m intervals along three parallel lines.
The distance between the lines was about 75 m. The sheets in the middle line were shifted
along the line by 75 m. The 27 markers covered a coastal stretch of about 1.3 km (Blok,
1996). Orientation in the field was based on aerial photographs and beach posts. To achieve
maximum contrast, the green markers were placed on bare sand on the seaward side of the
foredunes; the orange sheets were placed on the vegetated parts of the foredunes and stable
inner dunes.

Oblique video data were collected with a hand-held commercially available video camera, a
SONY TR750-E Hi8 CCD camera, in a light plane. The light top-wing aircraft was flown at
about 273 m (900 ft). The operator of the camera filmed sideways through an open window,
while pointing the camera at a downward angle of at least 45° from the horizontal.

3.2 Data processing

The EDM data were extracted from the electronic field book memory and processed with
SDRMAP (Sokkia, 1991; Eleveld & Van der Wal, 1993). This resulted in an ASCII file with
the RD (state plane) co-ordinates of the GCPs.

A series of frames with about 66% overlap was grabbed with Matra software, and contrast-
stretched. Each video frame consists of two independently recorded fields which are
interlaced. Considering the speed of the aircraft, a substantial displacement of the camera
occurred between the exposures for each of the two fields that make up one frame. The frames were corrected for interlacing effects; the extracted uneven fields were doubled, while the information in the even fields was discarded. The resulting images were processed in the Softcopy Photo Mapper (SPM) module of R-WEL's Desktop Mapping System (DMS) version 4.0 (R-WEL, 1995), which has some photogrammetric capabilities (Fig. 1).

First an ASCII image control point file with the image coordinates of the 'fiducial marks', i.e. the image coordinates of the points halfway along each edge of the image, was created. After enhancing the contrast with the ENHANCEGLOBAL procedure, the SPM procedure DIGITIZE IMAGE CPS was used to establish the image co-ordinates of the ground control points. Subsequently, the SPM procedure COMPUTE ORIENTATION was run. The resulting orientation parameters were used in the SPM procedure STEREO MODEL REGISTRATION. This module selects subsets from the left and right image, rectifies the subsets and registers them to each other so that a stereo pair can be obtained. One band has to be selected for the stereo correlation. The blue band proved to have the highest contrast in the sparsely vegetated areas and areas dominated by bare sand. Since these areas (e.g. the foredunes and nourished beaches) are the most interesting relief features within the area of interest, the blue band was used for further analysis.

The left and right images (originally one band, displayed as black and white) can be converted to monochrome images in such a way that their respective colours are complementary (e.g. red and cyan). The shift of cyan with respect to the red features (or vice versa) represents the parallax in the resulting anaglyphs. A '3-D' impression of the image results from viewing using glasses with a red and cyan (blue or green will usually suffice as well) coloured glass.

The SPM procedure AIR PHOTO STEREOCORRELATION extracts height information from stereo images by means of parallax. To establish parallax, DMS uses automatic correlation. Corresponding points are identified on the basis of the similarity of their respective environments (matrices of digital numbers (DNs)). The software derives height by comparing matrices with a maximum size of 17×17 pixels. In this case the matrix size was set to 15. A minimum and maximum anticipated elevation determines the maximum parallax that may occur and is used to reduce the matrix correlation search radius. The highest relief feature in the test area has an elevation of 17.8 m and the lowest point is a little above sea level. The minimum and maximum elevation were set to 0 m and 25 m, respectively, which was considered appropriate for the terrain type. The DEM post spacing (grid spacing) was set at 5 m. Spikes in the DEM were removed by using a median threshold filter (with the procedure ENHANCEFILTER); the smallest filter matrix of 3×3 was thought to be most appropriate. This resulted in several digital elevation models (DEMs). These could be north registered, and they could also be used for differential rectification of the image, giving georeferenced ortho-video images. (R-WEL, 1995, Blok, 1996). This was, however, outside the scope of this study.
**Figure 1. Data processing scheme (Blok, 1996).**
Figure 2. Derived relief. (a) Anaglyph. (b) Contour map. North oriented. RD-coordinates and elevation in m. (c) Digital elevation model.
4 RESULTS

The study produced:
- Anaglyphs, which make height perception possible (when they are studied with a pair of special glasses, one red and one green or blue), and
- Contour maps and DEMs, which show the extracted relative height values.

Figure 2a is an example of an anaglyph, Figure 2b is an example of a contour map, and Figure 2c shows an example of a DEM.

The series of images produced in this study provides an overview of the beach, foredunes and stable inner dunes. For the beach, the anaglyphs show a regularly sloping surface. The contour maps show a surface that seems a bit too high, and that is sloping to the left-hand and to the right-hand side of the image. The DEMs of the same area have an irregular surface; therefore, it is clear that stereo correlation produced erroneous results when applied to the beach.

For the foredunes and inner dunes, the anaglyphs show the large-scale undulations of the terrain. The contour maps and the DEMs give a fairly good representation of the relief in this area, though peaks do occur in areas with dense vegetation.

On the anaglyphs, the stereo vision deteriorates towards the horizon, i.e. towards the lower side of the image (as the images were rotated 180° during rectification and registration). There are two main technical reasons this deterioration:
- Towards the horizon, viewing angles decrease, causing the data density to decrease. Increasingly, objects viewed from the front will be projected onto the areas behind them. This caused loss of detail and produced a smearing effect in some anaglyphs.
- Towards the lower side of the image, the density of the vegetation increases. As a result, contrast is much less in this area. Using the blue band proved beneficial to contrast in areas with high reflectance, but the performance was slightly less in the more densely vegetated parts. Choosing other bands will, however, not improve this situation noticeably and will negatively affect the results for the areas of prime interest, the foredunes and nourished beaches.

Stereo vision also deteriorates towards the left-hand and right-hand sides of the images. This decrease in parallax is probably related to lens distortions and incomplete inner orientation of the CCD video camera.

In addition, some of the stereo pairs that form the basis for the anaglyphs were not aligned parallel to the line of flight. This was due to errors in the calculated camera orientation parameters. This imperfect alignment had a negative effect on the stereo correlation and stereo vision (Blok, 1996).

Most of the patterns that are visible in the anaglyphs can also be found in the elevation models. These include the smearing effect in the lower part of the images and the decreased parallax towards the left-hand and right-hand sides (Figs 2b & c).
From the contour maps, only major relief characteristics, such as the row of foredunes and major stable dunes, can be identified. The main reason for this is that the 5 m grid spacing causes a loss of resolution that prevents the recognition of smaller features. The wire frames give a better impression of the relief, but are less appreciable. The presence of obvious (i.e. large-scale) mis-correlations in most images implies that automatic identification of small features is not possible.

The absolute height values calculated by DMS are not correct. The entire DEM was fitted between the user defined maximum and minimum values, regardless of their value. For the DEM presented in this chapter these values were 0 m and 25 m, respectively. No relationship between the known elevation of each of the GCPs and their respective values as calculated by DMS could be established, preventing translation of the DEM to the correct elevation. This can be ascribed to parallax effects and to inaccurate correlation (Blok, 1996).

5 DISCUSSION

In this study, a number of limitations in the use of a commercially available camera for aerial videography were encountered. The relatively high resolution of video imagery could not be used optimally because of the poor image quality. A high quality image is needed for a good stereocorrelation of (parts of) the images. The dependence of the method on variation in reflection on a pixel scale limits its use to certain landscape units; heights in the dune area could be determined, but height determination on the beach was incorrect. A high quality image is also needed for the construction of a large-scale morphological overview of the strip; individual elevation models could not be coupled because of deviations towards the sides of the images. In an evaluation of various techniques for topographic measurement, Huising et al. (1996) also concluded that video is not suited for accurate topographic measurement, even though they used a technically more advanced camera.

However, the experiment has also shown that it is relatively easy to start a video recording campaign, and that it is a flexible and low-cost remote sensing technique. This survey did not explore all possibilities offered by videography. Especially the time component, i.e. the possibility of recordings over time, can be an important advantage of this technique (see Introduction). Mulder (1994) has argued that height derivation may be facilitated by using the vast series of snapshots that can be generated with videography. Preliminary results have been presented by Spreeuwers & Houkse (1996).

In some cases, the anaglyph gave better visual results than the DEM. The human eye and brain can evaluate the entire scene by adding the perception of shading, and object and pattern recognition to the perception of parallax. The automatic correlation identifies corresponding points on the basis of the similarity of their respective 'environments', which are matrices of DNs. For this reason, automatic stereo correlation is likely to produce unreliable results when dealing with areas with uniform reflectance, even though stereo vision is still possible.
In this study it was technically impossible to create reliable DEMs, because:

- The moderate spectral quality of the images and the use of fields instead of frames reduced the accuracy of stereo correlation,
- Lens distortion had a significant effect on the images and the DEMs,
- The DMS software could not produce DEMs with realistic absolute heights.

However, the use of a professional-quality camera would allow:

- Exposure to be adjusted manually and images to be recorded in the non-interlaced mode,
- The zoom lens to be replaced by a lens of fixed focal length.

The use of advanced photogrammetric software that can process a series of images simultaneously would speed up the processing phase considerably.

5.1 Future developments

- The use of airborne videography for accurate mapping and monitoring is still in its infancy. Further development of the technique requires expertise from various disciplines including photogrammetry and computer-vision science.
- Video is being used for visualisation, although some problems with absolute reflection of the data remain (Huising et al., 1996; Huising, 1996). The creation of overviews by automatic mosaicking is under investigation (Hartmann & Jordans, 1999).
- Automatic mosaicking would solve a practical problem inherent to the use of aerial CCD-video, namely the small area that is covered in one image. Even for our local survey, many GCPs were required. An alternative procedure for obtaining ground control or camera orientation, one that can be operated from the plane, needs to be developed.
- Because of its flexibility, video will be increasingly used for the registration of events for which its accuracy is of minor importance.

5.2 Further research on the Ameland case

The implication of the results of this study for the research on the Ameland case is that video will not be used to obtain absolute height information. For this area, direct elevation measurements are available, in the form of laser altimetry and JARKUS data (i.e. data from surveying, photogrammetry and loding). These data are used in the rest of the research.

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