Coastal video monitoring: the Nazaré system.

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Abstract: The use of video systems for coastal monitoring purposes experienced a significant development over the last years in response to the increasing need of acquiring a comprehensive understanding of the coastal environment. The main aim of this work is to describe a video monitoring system (COSMOS – cosmos.fc.ul.pt) installed at Nazaré lighthouse, in operation since 2009. The COSMOS acquires snapshot images of Praia do Norte beach at 1 Hz supporting the generation of Timex (10 min. average) images from which the coastline position is extracted using supervised image classification algorithms. Presently the system is being complemented with additional cameras, targeting the nearshore and the Nazaré beach, in order to support the characterization of the wave deformation over the Nazaré Canyon head and to enable an integrated analysis of the shoreline evolution in at a wide range of time-scales (hours to years).

Key words: Video monitoring, Nazaré, COSMOS

1. INTRODUCTION

Understanding shoreline change is an essential element to support coastal planning and management. A major challenge in this task is to recognize and comprehend coastal behavior in a wide range of spatial and temporal scales.

In this context, over the past 20 years, video systems have emerged as a powerful tool (Holman and Stanley, 2007), enabling the acquisition of data related to a large range of coastal phenomena including beach morphology (Plant and Holman, 1997), swash processes (Holland et al., 2001), nearshore bar morphology (Holman et al., 1993), longshore currents (Cohen et al, 2004) and surf zone bathymetry (Stockdon and Holman, 2000).

This work aims to describe the implementation and application of a COaStal video MOnitoring System (COSMOS) in the understanding of beach morphodynamics in the vicinity of the Nazaré headland.

2. SYSTEM DESCRIPTION

The coastal video monitoring system (COSMOS) is being developed at the University of Lisbon since 2007 (Silva et al., 2009). This lightweight system targets several key characteristics including portability, low-cost, robustness and easy installation. The system is based on the principle of terrestrial photogrammetry in which the position of the objects in the field can be related with their projection on the image, allowing the acquisition of quantitative field information from remote images.

The system is composed of three main modules: image acquisition, image processing and feature extraction and geometric correction (Fig.1).

2.1 Image acquisition

In the present system, image acquisition is performed using an internet protocol (IP) Mobotix video camera, with 3.1 megapixel resolution which allows the capture of high frequency, high resolution, JPG snapshot images. The camera has a non-metric lens with a 43 mm equivalent (35mm) focal distance and a horizontal image angle of 45º and vertical of 34º. Images are recorded on-site to a high capacity hard disk.

2.2 Image processing and feature extraction

One of the most useful outcomes of a video monitoring system are TIMEX and SIGMA images (Holland et al., 1997). The former are built from averaging a collection of snapshots acquired from a stationary field of view, while the latter correspond to the standard deviation of grayscale pixel intensities. These procedures have been implemented in a tool named COSMOS IPT (image pre-processing routines), a windows program developed in C#.

Feature extraction can be related to a plethora of beach and oceanographic indicators such as shoreline position, intertidal beach topography and swash line recognition. In COSMOS these tasks are performed using standard image analysis algorithms available either from commercial and open-source software.

2.3 Geometric correction

The geometric correction is the core of any coastal video monitoring system, particularly those based on non-metric cameras such as COSMOS. The transformation of image coordinates into world coordinates involves three main steps: i) camera calibration, where the internal camera parameters are determined in the laboratory, this procedure is essential and even crucial if video systems are built...
upon standard non-metric cameras; ii) the development of image correction subroutines, which aimed to correct the relatively large image distortions induced by camera optics; iii) the development of image rectification subroutines to transform oblique images into vertically equivalent images; this transformation is based on external camera orientation parameters obtained in the field through the surveying of ground control points.

In the COSMOS geometric correction tasks were accomplished using the Rectify Extreme program, a tool developed in the scope of the present work in Windows using C# and MATLAB® programming languages and which is freely available at system website (http://cosmos.fc.ul.pt).

After the completion of the rectification processes, the application automatically writes a Tiff World File (a six-parameter plain text file used in the affine transformation from image coordinates into map coordinates), so the rectified georeferenced images can be directly imported by standard GIS applications (either commercial or open-source).

3. NAZARÉ MONITORING SITE

Nazaré is located in the west coast of Portugal, at the southward end of the littoral cell that extends from Douro river mouth to the Nazaré Canyon head (Fig. 2). This coastal stretch is fully exposed to the North East Atlantic wave regime characterized by a NW predominant swell superimposed with a less energetic local wind sea with a wider directional spread. The Nazaré canyon, cuts the full width of the continental shelf and slope, with an approximate E-W orientation, and has been reported in the literature as the major active sediment conduit to the abyssal plain. Canyon morphology strongly disturbs the wave propagation pattern over the nearshore area and is responsible for interrupting the net southward longshore sediment transport.

This peculiar situation makes this coastal stretch particularly interesting and a case study in what concerns the understanding of the processes related to the injection of coastal sediments into the canyon head (see Duarte et al., this volume). In order to understand these processes it was decided to install a video monitoring system at Nazaré.

The first camera (Camera 1) was installed on December the 29th, 2008 at the Nazaré lighthouse facility (Forte de São Miguel) located at the Nazaré headland (Fig. 3). The camera was installed on a metallic pole on the roof of the building, approximately 50 m above mean sea level, and connected to a PC through an Ethernet cable. Prior to installation, the camera was carefully calibrated in the laboratory using the methodology described in Vision Caltech (2009). Image acquisition takes
place, at selected hours during daylight, with a 1 Hz frequency and images are recorded in an on-site hard disk. The system was setup to monitor the Norte beach, along a coastal stretch that extends for more than 1 km alongshore. Due to operation constrains, mainly related to power failures, the system only became fully operational since October 15th, 2009. Camera external orientation was estimated using a set of ground control points (GCPs); the relation between undistorted image coordinates and ground coordinates was performed manually in the Georref tool, a component of the Rectify Extreme software.

On January 30, 2012 a second camera (Camera 2) was installed at the Nazaré lighthouse facility, in a place close to the first camera but looking directly to the ocean (Fig. 3). The aim of this camera is to acquire data on the incident wave regime, specifically targeting the characterization of the wave deformation over the Nazaré Canyon head, which is responsible for the generation of unusual high waves. Image acquisition was programmed to 1 Hz frequency in one hour bursts starting at 9h30, 12h30 and 15h30.

On April 12, 2012 a third camera (Camera 3) was installed at the Sítio da Nazaré, at the support room of the sanitary facilities located at N.ª Sr.ª da Nazaré square (Fig. 3). The camera is oriented southward, with an excellent overview over the Nazaré beach. Image acquisition was programmed to 1 Hz frequency in one hour bursts starting at 9h30, 12h30 and 15h30.

As both cameras 2 and 3 are still in the test phase, data exploitation is presently limited to camera 1.

4. RESULTS

An example of the results obtained with camera 1 during 2010 is displayed in Fig. 4. In the images is possible to see that the beach experienced a huge cross-shore variation (more than 100 meters), related with the seasonal variation in the wave forcing. Particularly interesting is the observation made in August, where the northerly wave sea induces a high southward longshore drift, which exceeds the retention capacity of the Nazaré headland. The understanding and quantification of this behavior will give valuable information concerning longshore sand transport magnitude updrift of Nazaré headland and simultaneously on the magnitude and frequency of littoral sand injection into the canyon head.

An illustration of image rectification and pixel footprint is displayed in Fig. 5. Pixel footprint, which represent the dimension of each pixel in the geographic space, shows the typical contrast between alongshore and cross-shore components: the alongshore footprint is more sensitive to the distance from the camera and ranges from a few decimetres to more than 10 m when the distance exceeds 1 km; on the other hand, the cross-shore component is generally lower than 2 m throughout the target area. As pixel footprint affects the accuracy of the extracted beach features, it is expected that the positional accuracy will decrease when the distance from the camera increases.
Results from automatic image classification are displayed in Fig. 6. This classification, which targeted the extraction of coastline position, was performed using supervised image classification algorithms.

5. CONCLUSIONS

This work describes a coastal video monitoring system (COSMOS) which aims to provide new coastal data, complementing the existing video systems, with the advantage of being portable, flexible and low-cost. This coastal video monitoring system has been in operation at Nazaré since 2009 and has demonstrated great potential to the understanding of the coastal morphodynamics in the vicinity of the Nazaré canyon head. Presently, the system is extended with two additional cameras, targeting the nearshore and the Nazaré beach, in order to support the characterization of the wave deformation over the Nazaré Canyon head and to enable an integrated analysis of the shoreline evolution over the coastal sketch that extend from Norte beach to the Nazaré bay.

All data and software is freely available to the scientific community and end-users so that the system can be exploited to its full potential and be used in support of coastal zone management.

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