The validation analysis of the INSHORE system—a precise and efficient coastal survey system

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Abstract Government and environmental entities are becoming increasingly concerned with qualifying and quantifying the erosion effects that are observed in sandy shores. Correspondingly, survey methodologies that gather data for such erosion studies are increasingly being demanded. The responsible entities are continually broadening their areas of interest, are concerned in the establishment of regular monitoring programmes and are demanding high accuracy from the geospatial data that is collected. The budget available for such monitoring activities, however, does not parallel the trend in the increasing demand for quality specifications. Survey methodologies need improvement to meet these requirements. We have developed a new land-based survey system—the INSHORE system—that is ideal for low cost, highly efficient and highly precise coastal surveys. The INSHORE system uses hi-tech hardware that is based on high-grade global positioning system (GPS) receivers and a laser distance sensor combined with advanced software algorithms. This system enables the determination of the ground coordinates of the surveyed areas with a precision of 1 to 2 cm, without having a sensor in contact with the ground surface. The absence of physical contact with the ground makes this system suitable for high-efficiency surveys. The accuracy of the positioning, which is based on advanced differential GPS processing, is enhanced by considering the estimated attitude of the GPS receiver holding structure and eliminates undesirable offsets. This paper describes the INSHORE survey system and presents the results of validation tests that were performed in a sandy shore environment.

Keywords Topography · DGPS · Survey system · Attitude · Accuracy

Introduction

An awareness of climatic changes and their consequences has led the responsible authorities of several governments with sandy shore borders to create and implement coastal management plans that will avoid drastic and sudden erosion effects.
In countries such as Portugal, where about half of the political border is constituted by sandy shores, special attention must be paid to the temporal changes of these littoral features. To perform an accurate assessment of sandy shores, the subaerial monitoring methodologies employed at the beach must meet strict specifications, including the following: (1) low operation costs; (2) highly efficient surveying; (3) high accuracy in the determination of the geo-spatial morphological elements of the terrain and the associated physical parameters, such as beach volumes and (4) the ability to perform frequent monitoring campaigns (at time scales ranging from days to weeks, or months) over stretches of beach tens of kilometres long. These specifications are demanding on the survey methodology.

The main geo-spatial information that is required for sandy shore analysis is the volumetric quantity of sediments within a specified study area. The seasonal variation in this data provides information on the beach dynamics. Shoreline evolution, measured in the form of the frontal dune baseline or other shoreline indicators, is also important as it provides information on the retreat or advancement of the shore. Therefore, it seems reasonable that dedicated survey procedures would be able to determine the three-dimensional coordinates of ground points with an altimetric accuracy below 3 cm for standard monitoring scales. The requirement of high altimetric accuracy is due to the rising offsets in the calculation of sediment volume (because this calculation is performed with the mathematical operation of integration). The local vertical component must be accurate and must not contain a systematic offset (i.e., its error must be randomly distributed around zero). After integration, such an offset would lead to a significant offset in the calculation of the volume. The offset could also be misleading in the analysis of volumetric variation between consecutive monitoring events.

Since the 1960s, many different survey methodologies and techniques have been developed and published. The following is a brief description of some of the techniques that are specific to volumetric quantification and shoreline delineation. Traditionally, sandy shore survey were made through cross-shore profiles carried out with theodolites and total stations. These applications require at least two operators; one for the total station and the other holding the target steadily at every point that is to be coordinated (Emery 1961; Komar 1976). This method, although accurate (in terms of coordinate determination), is not suited for the frequent monitoring of long coastal stretches due to its inefficiency (Dornbusch et al. 2008).

Another technology that has been used successfully in several applications is image processing (digital or analog). It is possible to generate digital elevation models (DEM) that map the coastal surface based on airborne photogrammetry with sequential and overlapping high-resolution photos (Fletcher et al. 2002; Anders and Byrnes 1991). However, to achieve accuracy of a few centimetres it is necessary to have the coordinates of about six ground points per photo (the so-called ground control points, or the GCPs). These are the points that are determined through static mode differential global positioning system (GPS) surveying. Though this method has good accuracy, it is expensive due to the equipment required for each survey, and it is not efficient as the survey of the GCPs is time consuming. Airborne photogrammetry requires meteorological conditions that are not always compatible with post-storm beach surveys. Moreover, on sandy surfaces it is not easy to identify good candidates for GCPs because these sites must be easily identified on the photo and must be well dispersed in each photo; the homogeneity of the sandy surface makes this a difficult task. An alternative to airborne photogrammetry is the airborne laser scanning technique, which is efficient and provides reasonable accuracy (Huising and Gomes Pereira 1998; Shrestha et al. 2005). However, the requirement of an aircraft and the expensive laser scanner makes this solution unattractive from the perspective of the operation costs. A different approach to image-based coastal monitoring is the use of fixed high-resolution digital cameras installed along the coastal stretch (Lippmann and Holman 1989; Holman et al. 1993). With cameras mounted on the top of high poles, information regarding shore dynamics can be determined through the analysis of images captured at different points in time. However, the precision obtained with this method...