Application of a Pan/Tilt Controlled Camera in Coastal Image Research at Hsi-tzu-wan Bay

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ABSTRACT

The purpose of this study is to develop an image analysis system for coastal observation based on a pan/tilt controlled camera. The system substitutes for multi-directional camera system in large-scale coastal observation. Each image in different pan/tilt angle is considered an independent camera image for subsequent image processing techniques. The system is based on the Direct Linear Transformation algorithm (DLT) to calibrate the intrinsic and extrinsic camera model. In terms of the geometrical relationships relating image and world coordinates, images pixels are transformed to the world coordinates. All of images are integrated in the same coordinates to obtain a composite coastal view. A generalized gradient vector flow active contours model (GGVF snake) is then used to track the coastlines. The database of coastal images obtained can be used to analyze intertidal bathymetry and foreshore topography in short-term and long-term variations. A coastal observation system is installed atop a building roof overlooking the whole bay area of Hsi-tzu-wan in order to study the nearshore morphology variation after a beach restoration program was conducted since April 2008. During the period of observation, several typhoons raid on the bay and scour the beach drastically. In summary, this paper provides new application of a pan/tilt controlled camera setup to replace multi-camera system of coastal observation. The combination of existing techniques, direct linear transformation algorithm and the active contour model, enables us to estimate the nearshore morphology variation during and after the coastal works.

KEY WORDS: coastal observation; coordinate transformation; DLT.

INTRODUCTION

Hsi-tzu-wan is located near Kaohsiung city at the southwestern coast of Taiwan. It is adjacent to Kaohsiung First Harbor and is a popular scenic spot in Taiwan. The morphology of nearshore zone of Hsi-tzu-wan varies drastically during typhoon season in the summer, which is demonstrated by quick change of eroding shorelines and submerged sandbars. The process of accreting shorelines and sandbars is more slowly during the swell seasons. A beach restoration program contains two artificial headlands and beach nourishment was conducted during April 2008 to July 2008. The subsequent change of the shorelines and sandbars are important information for future planning.

Adequate measurement of the beach response to waves is vital for various coastal problems and video-based photography provides a low expense way of measurements. Holman and Lippmann (1987) used snapshots and ten-minute time averages from camera mounted on a tripod to study the nearshore bar system. These optical remote sensing techniques have been evolved into a network of video-based photography system called Argus. The history and technical capabilities of Argus system is provided in a recent paper of Holman and Stanley (2007). The image data collected from camera include snapshots (showing wave activity), ten-minute time average images (showing wave dissipation patterns and revealing submerged sand bars and rip channels), and variance images (separating dynamic from steady areas of the image). At most sites, multiple cameras with different orientations take images that are later merged together to increase spatial coverage.

Parallel to the development of Argus system, an image processing technique called active contour model (or snake) has been developed and refined by researchers. It was first introduced by Kass et al. (1988) and has been traditionally applied in various visual problems such as edge detection, shape modeling, segmentation, and motion tracking.

In this paper, a pan/tilt controlled camera is used to observe widely-spaced nearshore area. A snake model is then used to track the coastlines in each composite image obtained from the camera. The database of coastal images obtained can be used to analyze intertidal bathymetry and foreshore topography in short-term and long-term variations.

DIRECT LINEAR TRANSFORMATION

The fundamental principle of Argus video techniques can be found in Holland et al. (1997). Direct linear transformation (DLT) method developed by Abdel-Aziz and Karara (1971) is used in Argus system to transform measurements from image data into rectified world coordinates. This section provides the key elements on how to effectively transform the image coordinate system to world coordinate system.

Using the coefficients defined in Fig. 1, the relationship between image and world coordinates can be derived in terms of the collinearity equation as: