The Measurement of Coastlines Using SPOT-5 High Resolution Satellite Images

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Abstract: Taiwan, an island nation, has an area of 36,000 square km and coastlines of about 1,600 km. Because the human activities, industrial production, and economic development have mostly taken place on the coastal plains, Taiwan is facing overpopulated and overdeveloped problems on the coastal areas. A project to establish a fully GIS-based system to manage coastlines is presented in this paper. Firstly, the project converts all maps associated with the coastlines to the digital form and integrates into a GIS system. Secondly, the system which contains a variety of functions of the image processing and spatial analysis is designed to measure the length of the coastlines from a series of SPOT satellite images and aerial photos. Consequently, the associated statistics of the coastline data is analyzed and presented to the related government organizations.
Keywords: Coastlines, Remotely sensed image, GIS-based system.

1. Introduction

Taiwan, an island nation, has an area of 36,000 square km and coastlines of about 1,600 km. Most of Taiwan is composed mainly of mountains and hills. The eastern part consists of mostly rugged mountains and contains steep rocky coast and cramped continental shelf. There are gently rolling plains in the west, where the coastal plains and basins are relatively flat. In general, Taiwan is composed of both rugged and fairly straight coastlines. Because most of the human activities, industrial production, and economic development take place on the coastal plains, Taiwan is facing overpopulated and overdeveloped problems on the coastal areas [1]. In addition, because of the intensive interaction of the natural processes and man-made developments, the coastlines of Taiwan have undergone rapid shifts and severe changes in position and shape [2]. Recently, the government is strongly advised to take an urgent action to fully investigate the coastal areas. Among them, the comprehensive measurement of the coastlines is given priority. In Taiwan, the measurement and investigation of the coastlines are typically conducted by the labor-intensive ground survey, which is unable to obtain the updated data island-widely and yearly. Consequently, a project is jointly conducted by the National Central University and Construction and Planning Agency, Ministry of Interior. The main mission of the project is to develop an efficient and reliable method to provide the length data of the coastlines to the government on a completed and consistent basis. Many studies have been conducted to use satellite images for the investigation and measurement of the coastlines [3][4][5]. In this project, SPOT-5 high resolution satellite images (2.5 m) are used as the basic sources and a man-computer interactive system is developed to measure and analyze SPOT-5 images. The extraction of the coastlines is manually digitized through the interactive system which contains the related GIS data to aid the digitizing process. The study recently has completed the digitization of the whole Taiwan Island. The results demonstrate that the system is able to extract the graphic information and related attribute data of coastlines from the satellite images. Furthermore, the associated statistics of the coastline data is analyzed and presented to the related government organizations. The detailed system description will be depicted in section 2. The results and discussions can be found in section 3. Finally, the conclusion remarks are given in section 4.

2. System Descripton

Firstly, the data layers contained the associated information of the coastlines are transformed to the digital form from a variety of data sources. These data are listed as follows.

(1) Basic data of seaports
(2) Data of sea walls
(3) Related attribute data
(4) Aerial photos
(5) SPOT satellite images

The system is implemented with a GIS developing software “ArcView”, a product of ESRI (Environmental Systems Research Institute). The software has a built-in macro language “Avenue”, which enables user to develop a customized application for specific purpose. We use this software to integrate the GIS layers mentioned above and design interfaces for users to access those data conveniently. The system environment is illustrated in Figure 1. With the system, the users not only query satellite images easily, but also overlay the images with related GIS layers for further analysis. Moreover, an image analysis module, which contains the functions of image digitizing and attribute editing, is developed to digitize the coastlines and add attributes from both SPOT-5 high resolution satellite images and aerial photos. Because the attributes of the coastlines are required to classified into natural (i.e. sandy beach, reef rock, and natural fishing port) and artificial (i.e. liquefied natural gas receiving terminal, industrial park, and coastal road) classes, an external module written in C language is customized in the system to implement the classification of coastlines. Figure 2 shows the user interface for editing the attributes of the coastlines from both SPOT images and aerial photos. Figure 3 illustrates the coastlines digitized from SPOT image and the attributes depicted for the coastlines.

3. Result and Discussion

The study recently has completed the coastlines digitization of the whole Taiwan Island and the Pescadore Islands. A ground survey employing a GPS equipment with 1m accuracy is performed to measure a portion of coastlines. The coordinates of twenty-one control points are measured from SPOT image and recorded from GPS. The comparison of both measurements shows a 4m discrepancy on average. The results and the related statistics of the coastlines digitization can be found in Table 1. A close look at Table 1 will reveal that Taiwan Island itself has about half the coastlines are classified as artificial class. This striking finding indicates a truth that the coastlines of Taiwan have long been occupied by artificial cultivated fishery, jetties, and the coastal roads. Nevertheless, the Pescadore Islands, a series of 64 islands located off the west coast of Taiwan, has about 73% of island’s coastlines are classified as natural class. The result shows that the Pescadore Islands as a popular tour spot has escaped from the disturbance of human activities, industrial production, and economic development. A further statistical analysis also indicates that most of western part of Taiwan has a relatively higher percentage of artificial coastlines than eastern part. The discovery can be verified by the fact that the western Taiwan is the most overpopulated and overdeveloped areas.

4. Conclusion

In order to aid the investigation and measurement of the coastlines, this study presents a GIS-based system developed to digitize the coastlines from SPOT-5 high resolution satellite images. The system is designed and customized to store the related GIS and satellite images and to perform the digitization. A project is conducted to complete the coastline digitization of the whole Taiwan Island and the Pescadore Islands. The results and the related statistics reveal that Taiwan Island itself has about half the coastlines are classified as artificial class. The finding demonstrates a tragic fact that this island nation is giving away the natural beach to the “cement coast”. Based on this study a further evaluation will be conducted to take the necessary measures to protect this island’s coast.

Acknowledgement

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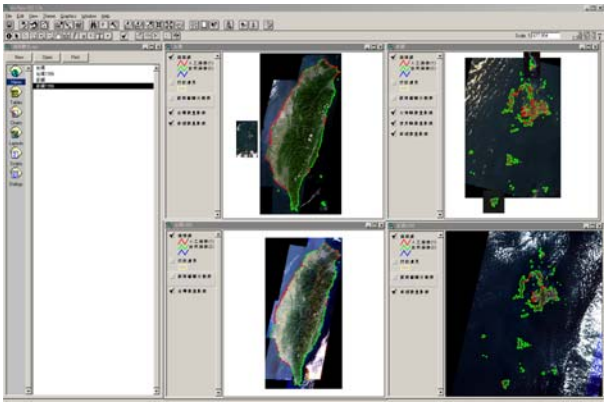

Fig. 1: System Environment

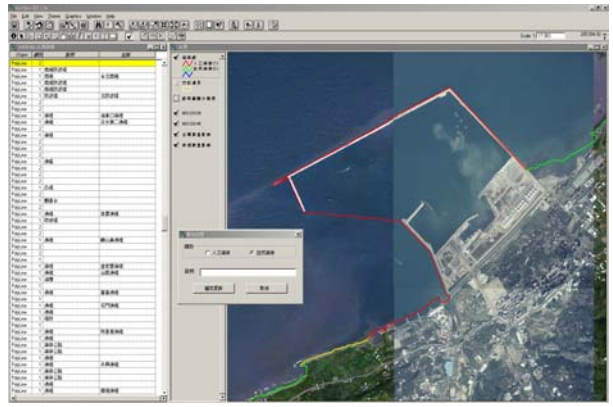

Fig. 2: The User Interface for Editing the Attributes of Coastlines from SPOT Images and Aerial Photos

Coastlines	Category	Image
Natural Coastlines	Sandy beach	
	Reef rock	
	Natural fishing port	

Coastlines	Category	Image
Artificial Coastlines	Liquefied natural gas receiving terminal	
	Industrial park in off-shore island	
	Coastal roads	

Fig. 3 The Digitizing Results and the Attributes of Coastlines

Table. 1 The Statistics of Coastlines of Taiwan

	Natural Coastlines (m)	Artificial Coastlines (m)	Natural Coastlines (% of the total)	Artificial Coastlines (%of the total)
Taiwan Island	668,503	687,019	49%	51%
Pescadore Islands	272,302	101,788	73%	27%
Taiwan and Pescadore Islands	940,805	788,807	54%	46%