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Remote sensing monitoring of coastline change in Pearl River estuary

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ABSTRACT: The study focused on applying remote sensing technology to monitor the rapid varying of coastal lines on Pearl River delta, Hong Kong and Macau. Which are pretty difficult to be measured timely and quantitatively. The "Neural Network classifier" is used upon multi-temporal remote sensing images to classify the changes of coastline in different periods. Digital coastline is overlay with the remote sensing image to show and verify the location of true shorelines. Land reclamation and new airports, together with their related constructions, in Hong Kong and Macau are the most important factors.

1. INTRODUCTION

Pearl River Delta, including Hong Kong and Macau, is an important region in South China. The Pearl River estuary has experienced tremendous environmental evolution due to the fast social and economic development in this area, especially in recent decades. The enormous developing speed makes it difficult to be detected fully and in time by traditional measurement.

This study aims at detecting the fast changes of coastal line of Pearl River Delta by using state-of-the-art remote sensing technology to produce the information timely for management and supervision.

The research range includes Pearl River Estuary, Hong Kong and Macau, between 112°48'E ~ 114°10'E and 23°10'N ~ 21°55'N.

2. RS FOR MONITORING OF COASTLINE CHANGES

There are many successful studies to monitor shoreline changes or urban expansion by using multi-temporal satellite images (L.C. Chen and J. Y. Rau, 1998. X. Li, A.G. Yeh, 1998. etc.). The major variation of shorelines in the area was caused by human-made land-making and embankments along Pearl River estuary but did not change much with the influence of sea tide.

Landsat satellite data obtained separately in early 1970s (MSS data on Dec. 25, 1973, perhaps the earliest satellite remote sensing data in this area), TM data on Jan. 20, 1992, and end of 20th century (Dec. 22, 1998) are used to analyze the historical changes as well as the latest development of coastal lines. These images are all obtained on the clear days in winter but time gap of 25 years should be noticed.

Band 4 of Landsat data are in near infrared spectral range (MSS4: 800nm~1100nm, TM4: 760nm~900nm) suitable for measuring outlines of water bodies. They are selected to detect the boundary of land and water.

Two historical Landsat data are matched with new Landsat data of 1998 (pixel size: 60m by 60m, 1/2 sampled from original TM data), and the three band 4 data with the similar spectrum band but different recording times are color

combined as blue (1973), green (1992) and red (1998) to show the coastline evolution directly.
Digital coastal lines from the map, published in 1993, overlay with the remote sensing image to display the location of true shorelines at that time. Meanwhile, it can show and check the affection of sea tide and tidal range along Pearl Rive estuary coast zone.

3. NEURAL NETWORK CLASSIFICATION

Accurate classification is a well-known difficulty in image processing technology. In the high turbid and shoal coastal zone, such as the research area, waters mixed with various of materials including suspended particles, sediments and phytoplankton etc, can often being classified as "land" in many supervised or unsupervised classify algorithms. It is very difficult to classify correctly the new land growth, shorefront with shoal waters.
The back-propagation neural network (Wang Wei, 1995. Sun Dan-Feng, et al., 1999) classifier (PCI Production, 1999) is used to supervised classify the pseudo color three-temporal remote sensing image, as three inputs. Four classes are selected in the pseudo color multi-temporal remote sensing image as: old land (land without change since 1970s), water, new land 1992 (land increased from 1970s to 1992), new land 1998 (land growth from 1992 to 1998). The satisfied result is obtained by adjusting the training areas and number of hidden layers and units.
The areas of increased lands are calibrated according to computer automatic statistics based on the classified image (Pixel Size is 60m by 60m) after post classification processing – sieve filter. The result images are geometric corrected and overlay with digital map coastlines to show and check the location of true shorelines.
Figure 1 gives the program diagram.

4. IMPORTANT CHANGES

Figure 2 exhibits images showing the changes of coastal lines in Pearl River estuary. There are 4 parts in figure 2. Part (a) is of the whole researching area and other parts are pictures of sub-areas. Every part contains two pictures. The left ones are the color combination of three Landsat band 4 data by using the data of 1998 as red, 1992 as green and 1973 as blue. The right ones are the results of the neural network classifier after post classification processing.
The new lands formed in different periods are very clear in both pictures, with white color meaning the land in 1970s, yellow and green color representing the variation shape of shorelines from 1970s to 1992, and the red color displaying the new coastal lines since 1992 to 1998. The digital map coastlines, colored in green or light blue on images of figure 2 (a), match with 1992 shorelines in most parts. As the spatial resolution of the multi-temporal remote sensing image is 60m, in the study, the affection of sea tides can be displayed only when the tidal zone is wider than 60m. So, only those clear miss-marching zones on west bank of Pearl River estuary are caused mainly by tidal influence.
Three parts in Pearl River estuary show the distinct changes of coastal lines, not caused by tidal influence as they are much wider than tidal zone. They are Hong Kong and Shekou area, Macau and Modao Men area as well as Hengmen Island and Xinken area.

4.1 Hong Kong and Shekou Area:

The new Chek Lap Kok Airport of Hong Kong is the most outstanding change in the research region. Part (b) of figure 2 gives sub-images of this area. Both of two pictures display the remarkable human-made lands after 1992 with red color. The related constructions such as ports, railway, embankment, even the bridges across the sea are shown clearly.
Shekou peninsula of Shenzhen has quite a bit of reclaimed new land on north bank of Deep Bay.
In this area, the changes of coastal line from 1970s to 1992 are much smaller than from 1992 to 1998.

4.2 Macau and Modao Men Area

Part (c) of figure 2 displays images of this sub-area.
The changes of coastal lines on Macau and nearby islands occurred mainly during 1992 ~ 1998 period. Macau new airport and connected highways as well as nearby islands, east bank of Modao Men, formed remarkable new lands. The north and west banks of Modao Men, north of Sanzao Island, have a quite large area of reclamation ground during 1970s ~ 1992 period, and has connected Sanzao Island with mainland which altered the island to a peninsula. The varying of coastlines along Huangmaohai Sea took place in this period.

4.3 Xinken and Hengmen Island Area

Part (d) of figure 2 shows three pictures of this sub-area.
The region located in the Lingding Yang has experienced fast reclamation during a long time. The change of shorelines in Xinken and Hengmen Island are especially remarkable, and varied Hongqi Men waters into a narrow channel.
Comparing the pictures in part (d), the accuracy of classifier can be observed. There is still some miss-classification in the middle picture, especially in the high turbid and shoal waters from Hengmen Island to Qi'ao Island. The boundaries between such waters and reclamation lands are difficult to be classified. This sub-area is classified specially by the neural network classifier again, and the new result is shown as right picture. Meanwhile, several algorithms of supervised classification are tried, such as Maximum likelihood, Minimum distance and Parallelepiped, but only the result of neural network classifier is acceptable.

5. PRECISION ANALYSIS

The precision of the method depends on follow constituents:
First: the spatial and spectral resolutions of remote sensing data.
In this example, the Landsat MSS4 and TM4 data are used because of the limit of data resources. There is only Landsat MSS data ready for application in the monitoring area in early 1970s.
Actually, Landsat TM5 data, in the spectrum range of short-wave infrared 1550nm ~ 1750nm, will be more suitable for monitoring the change of shorelines in high turbid coast zone such as Pearl River estuary because of its spectral feature of very sensitive to water. Which will make the image classification, for growth land, shorefront and shoal and turbid waters, a little easier by using short-wave infrared or radar remote sensing image.
The cloud free image is the necessary condition in the study.

Second: the correctness of registering and matching multi-temporal remote sensing images, which is the most important factor and will influence greatly the result of whole research, as it is the basis of following processing. In the example, the maximum error, occurred on matching MSS image to TM image, is 1.97 pixels. Pixel size is 79m by 79m.

Third: the accuracy of classified results, which is the key point in the method, and will determine later the accuracy of area statistics for growth lands caused by changes of shorelines. Neural network classification gets acceptable results and the precision is 90%, statistics from a random sample on the classified image. Although the accuracy is not very good but it better than results from other classification methods in present study.

Fourth: the precision of image geometric correction and the accuracy of digital coastline vector. Which are related to the scale of map utilized and errors occurred in image processing and map coastline digitization. In the example, the error of image geometric correction is = 1.91pixel (RMS: x=0.56 y=1.47) and pixel size is 60m by 60m (1/2 sampled from original TM data). The small scale of map, 1:300,000, is used in the work due to actual restriction.

6. CONCLUSION

The present study suggests the way of long-term shoreline environment monitoring by remote sensing technology. Neural net classification is used to classify multi-temporal remote sensing image. Areas of the new ground grown in different periods of time are calculated quantitatively according to computer statistics based on the results of classification. Digital map coastlines overlay with the multi-temporal satellite image and classified picture to show and check the location of true shorelines at that time. Such study methods are economical and efficacious for monitoring coast zones on which shorelines change quickly and caused mainly by human-made factors, such as Pearl River Estuary.

Land reclamation and new airports in Hong Kong and Macau as well as related constructions such as highways, railways, ports and embankment are the most significant shoreline changes.

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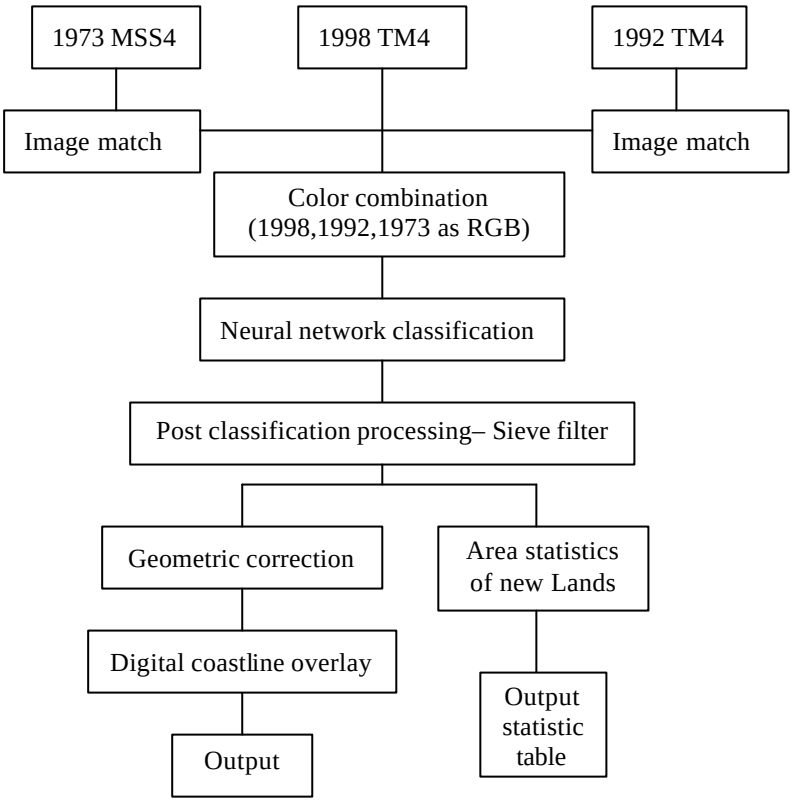

Figure 1. Program Diagram

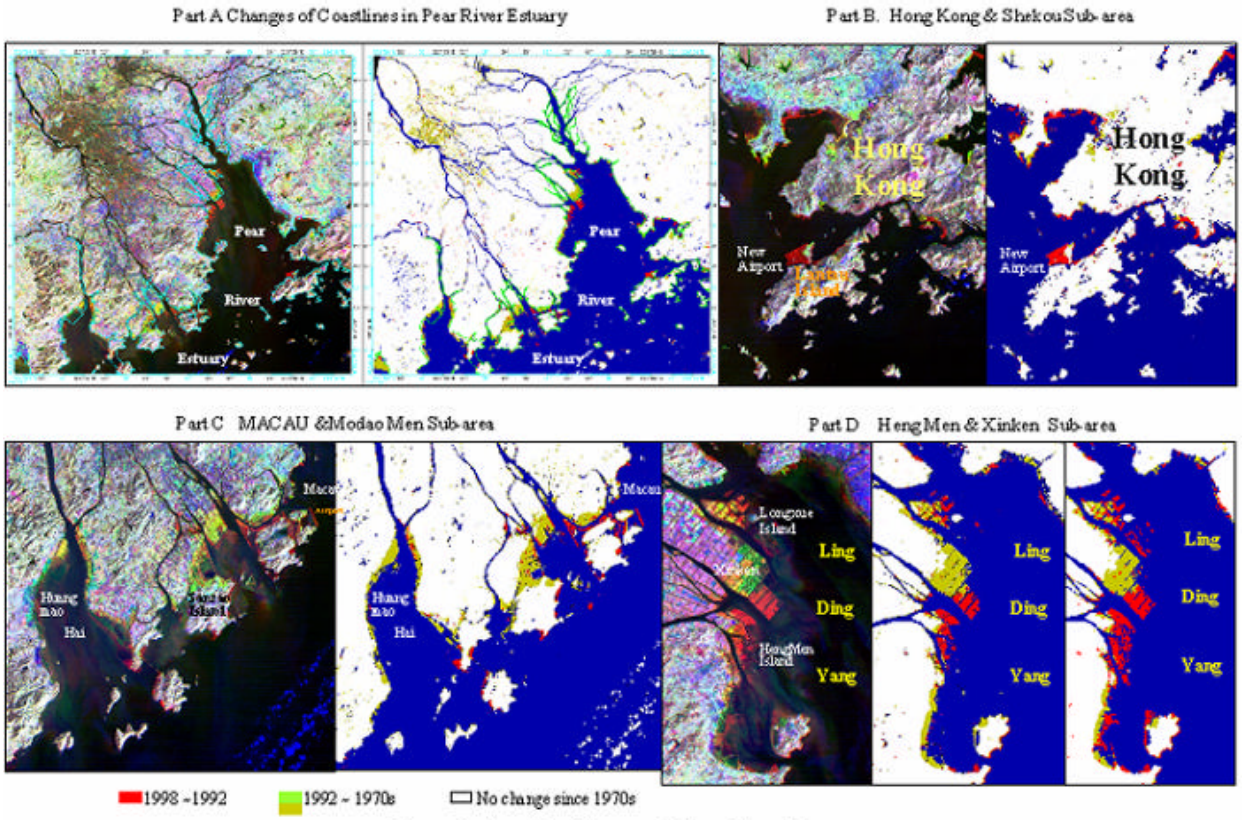

Figure 2. Coastline Changes in Pearl River Estuary