Application of satellite remote sensing to coastal topography generation – A study case in Northern Taiwan

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Abstract

The aim of this study is to construct the coastal topography of Taiwan island by using image processing techniques with SPOT data. In western Taiwan, the tidal flats are generally large. Because of the tidal currents and wave action, the topography of tidal flats is highly dynamic and change rapidly. Moreover, these areas are temporarily flooded, shallow, and very wide spread, it is thus difficult to conduct a survey either from the ship or by terrestrial methods. Satellite imagery provides a good alternative for detecting the coastline changes because of its general availability, large ground coverage, sufficient information contents, and the trend of higher spatial resolution. We apply the "waterline method" to obtain a digital elevation model of inter-tidal zone. The waterline method is a useful approach by using the near infrared content (NIR) to extract the surface information of the tidal flat environment. First, we used the near infrared band image of the SPOT to delineate coastline. Since the transparent capability of NIR in water is very low, the reflectional intensity of this band could help us to distinguish whether a pixel observed in the image is above or below water and where the coastline is. Second, we stacked the extracted coastlines from a set of satellite images acquired at different time with different tidal levels, then superimposed the heights relative to mean sea level on the corresponding positions. After building up a set of heighted coastlines within the inter-tidal zone, the regional gridded digital elevation model can be interpolated. Our preliminary results show that with suitable images and tidal level records, the optical image processing is a useful high-resolution and efficient tool for coastal topography generation.

Introduction

Our investigation has two main components. The first is to extract the entire coastline of Taiwan island, and the other is to construct the regional tidal flat digital elevation model (DEM).

Automatic generation of a tidal flat digital elevation model (DEM) is an important issue because of its diverse utilities. The SPOT data has the capability to generate digital elevation models with a height accuracy in an order of magnitude of meters. In this study the remote sensing techniques and water line method are used to improve the morphologic information. The 'water line' method (Cracknell *et al*., 1987；Koopmans and Wang, 1995；Mason *et al.*, 1995；Ramsey, 1995) allows the construction of an inter-tidal DEM over large areas relatively rapidly as well as frequent subsequent monitoring of the DEM to detect changes. It involves determining the horizontal position of the coastline from a remotely sensed image processing techniques, then superimposing the results on this boundary the heights relative to tidal level records. From multiple images it is possible to obtain multiple waterline with various tide elevations, a set of heighted coastlines within the inter-tidal zone can be constructed, and from this a raster DEM may be interpolated.

Coastline extraction

Coastline extraction is the first task in our study. The definition of the coastline must consider along-shore variation. We highlighted the semi-automated image-processing techniques, which offer our investigation to gain a better process-based understanding of the relationship between detected "coastline" features and the physical land-water boundary.

In general, NIR (Band3) is commonly used to delineate the waterline. For its high absorption in the water, the diffuse attenuation coefficient K_d of NIR reduces the apparent reflectance to 45% when the light deepened 20 cm under the clear water (Smith and Baker, 1981; Melsheimer and Chin, 2002).

Nonetheless, the coastal environments in Taiwan are extremely complexity, and water conditions change with different times and locations. To extract the coastline around the entire island we must adjust the attenuation ratio to extract the appropriate coastline (Figure 1a). In the Eastern coast of Taiwan, it is mostly composed of cliffs and rocky shores. Because of the lack of fine-grained sediment, it is possible to use a uniform attenuation ratio (45%) for coastline determination (Figure 1b). In contrast, the Western coast consists of softer formations, where the sea is often filled with clay material in suspension. In such an area, NIR penetration of the water diminish greatly as the a result of high water turbidity. For this purpose, raising the attenuation ratio is needed. (Figure 1c)

Tidal flat DEM construction

Xianshan Wetland is a vast tidal flat along the Hsinchu City coast, with dimension about 2~3 km in east-west direction and 15 km in north-south direction. The wetland is located between the mouth of Keya Stream to its north and to the northern boundary of Miaoli country to its south (Figure 2). We chose this area as our investigation area because this mud tidal flat is the largest in the Northern Taiwan, and also because the size variation of this area is appreciable during ebb and flood tide. In addition, it has tide gauge station in the vicinity.

A digital elevation model (DEM) of the inter-tidal areas on the western Taiwan is produced by the waterline method using SPOT5 images (Figure 3) and tidal level records. The concept of waterline method is finding the georegistered positions of the boundary between a water body and an exposed land mass from a remotely sensed image using image processing techniques, then superimposing the heights of the waterline relative to tidal level on the corresponding positions. From multiple images (Figure 4) obtained under different tidal conditions, it is possible to build up a set of heighted coastline within the inter-tidal zone, By interpotation, it may generate a gridded DEM.

Conclusion

From our preliminary results of coastline extraction and tidal flat DEM generation, we found that remotely sensed data can capture dynamic features at a certain time. Because of this, the spectral bands of optical scanner are suited for waterline determination. The coastline extraction techniques represented by NIR band shows a typical capability for obtaining DEM of relatively flat and mud terrain like the Xianshan Wetland area.

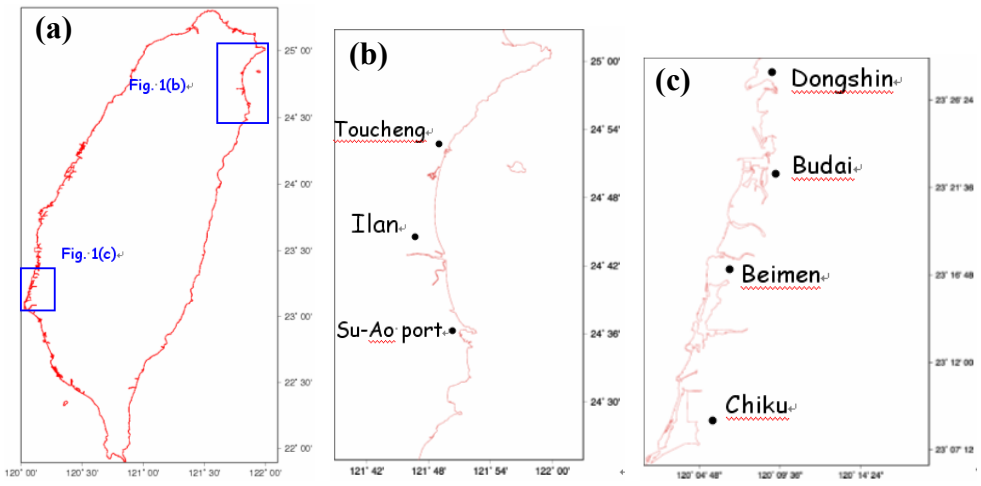
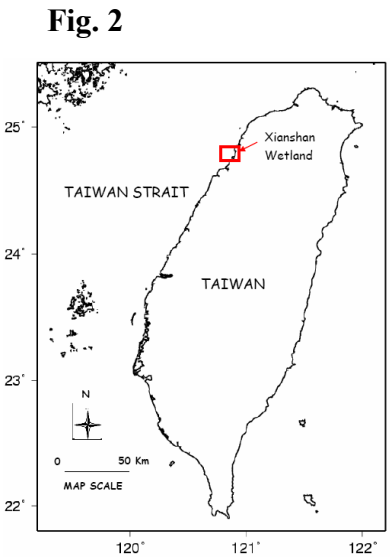


Figure. 1(a) Taiwan coastline with 10 m resolution extracted from ten SPOT5 images

of 2005. Detail feature in small square areas are shown in Figures (b) and (c). **(b)**.Detail coastline of the Ilan area. **(c)** Detail coastline of the Budai area.



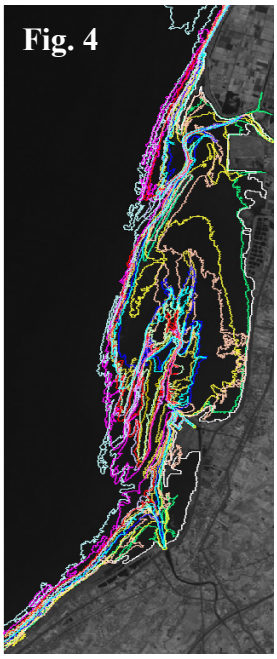


Figure. 2 Location of test area, the Xianshan Wetland.

Figure. 3 SPOT5 data of Xianshan Wetland.

Figure. 4 Multiple extracted waterlines from SPOT5 images of tidal flat.

References

Cracknell, A. P., Hayes, L. W. B., and Keltie, G. F., 1987, Remote sensing of the Tay Estuary using visible and near infra-red data：mapping of the inter-tidal zone. *Proceeding of the Royal Society of Edinburgh*, **92B**, 223-236.

Koopmans, B. N., and Wang, Y., 1995, Measurement of land-sea transition from ERS-1 SAR at different phases of tidal water. *ERSWAD Project Final Report.* Netherlands Remote Sensing Board (BCRS) report 95-20.

Mason, D. C., Davenport, I. J., Flather, R. A., McCartney, B. S., and Robinson, G. J., 1995, Construction of an inter-tidal digital elevation model by the 'water-line' method. *Geophysical Research Letters*, **22**, 3187-3190.

Ramsey, E. W., 1995, Monitoring flooding in coastal wetlands by using radar imagery and ground-based measurements. *International Journal of Remote Sensing*, **16**, 2 495-2 502.

Smith, R. C., and Barker, K. S., 1981, Optical properties of the clearest natural water (200-800nm), *Applied Optics*, **20**, 177-184.

Melsheimer, C., and Chin L. S., 2002, Extracting Bathymetry from Multi-temporal SPOT Images. *Asian Journal of Geoinformatics*, **3**, 37-42.