QUANTITATIVE ASSESSMENT OF SHORELINE CHANGES USING MULTI-TEMPORAL SATELLITE IMAGES

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Commission VII, Working Group 8

KEY WORDS: Multi-Temporal Satellite Images, Surface Reconstruction , Coast.

ABSTRACT:

We present here a new scheme that performs surface reconstruction and coastline change detection for tideland areas using multi-temporal satellite images and tidal measurements. The basic idea of this investigation is to reconstruct a reference DTM for a tideland area of interest from a set of multi-temporal SPOT images and tidal measurements first. Then, the coastlines on a historical target satellite images are extracted and compared to the one predicted from the reference DTM according to the associated tide elevations. The variations of shorelines between the reference image set and the historical images may thus be assessed quantitatively. A self-consistency check may also be performed to evaluated the quality for predicted shorelines. Experimental results indicate that the relative error is smaller than 5% as far as the area variation is concerned. The largest sand bar of Taiwan ,Wai-San-Ting, has lost its area about 37% during the last eight years.

1. INTRODUCTION

Detection of landcover changes for coastal areas is an important task in environmental monitoring [Hull ,1978]. The variations of shorelines have direct impacts on the economy development, land planning , and land management. Thus, The terrain changes of tideland have attracted world-wide interests.[Welch et al.,1992 ; Stokkom et al., 1993]

Carter[1978] investigated the applicability of satellite images in the data acquisition for wetlands. The spatial resolution of the satellite images i.e., Landsat MSS, is limited to 80M at the time. Frihy et al., [1994] identified the pattern of shoreline changes for Nile Delta. However, the tidal variation is not rigorously treated. In addition, three dimensional terrain analysis for shore areas is no considered.

The spatial, spectral , and temporal resolutions of satellite images have significantly improved in recent years. Hence, combining multi-temporal satellite images and tidal measurements , through image interpretation and analysis, make the detection of dynamic changes for shorelines possible. The basic idea of this investigation is to reconstruct a reference DTM for a tideland area of interest from a set of multi-temporal SPOT images and tidal measurements first. Then, the coastlines on a historical target satellite image are extracted and compared to the one traced from the reference DTM according to the associated tide elevations. The variations of shorelines may thus be assessed quantitatively.

The structure of this paper is as follows. In the next section ,we give a brief introduction to the techniques for the proposed scheme, Section 3 provides the experimental results. Finally, section 4 offers some conclusions.

2. THE PROPOSED SCHEME

The proposed scheme comprises two major components. The first is to derive a reference DTM for tideland areas from a set of reference satellite images incorporating different tide elevations. The second component predicts the shoreline for a given tide elevation from the reference DTM. Then a change detection for the shoreline may be performed with respect to a historical data set. The flow chart of the proposed scheme is shown in figure 1.

2.1 Generation of a Reference DTM

The procedure for derivation of a reference DTM includes:

(1)collecting a series of SPOT data as reference images which are associated with different tide elevations over a short period of time, when insignificant variations for a tideland area of interest are assumed,
(2)performing geometrical registrations among the reference images,[Chen & Lee,1992]
(3)Extracting shorelines from each of the reference images,
(4)assigning elevation for each point on the extracted shorelines according to tidal measurements,
(5)superimposing all layers of the extracted shorelines with different elevations,
(6)generating a reference grid DTM through an interpolation procedure. [Lee & Chen 1990]

2.2 Detection of Shoreline Changes

The procedure for detecting changes of shorelines includes:

(1)preparing a historical target image and acquiring the associated tidal measurements,
(2)performing geometrical registration for the target image with respect to the reference image set,
(3)extracting shorelines from the target image,
(4)tracing the corresponded shorelines from the reference DTM according to the tide elevation of the target image,[Lee & Chen,1990]
(5)overlaying the shorelines acquired from (3) and (4)
(6)the changes of shorelines between the historical target image and the reference image set are analyzed.

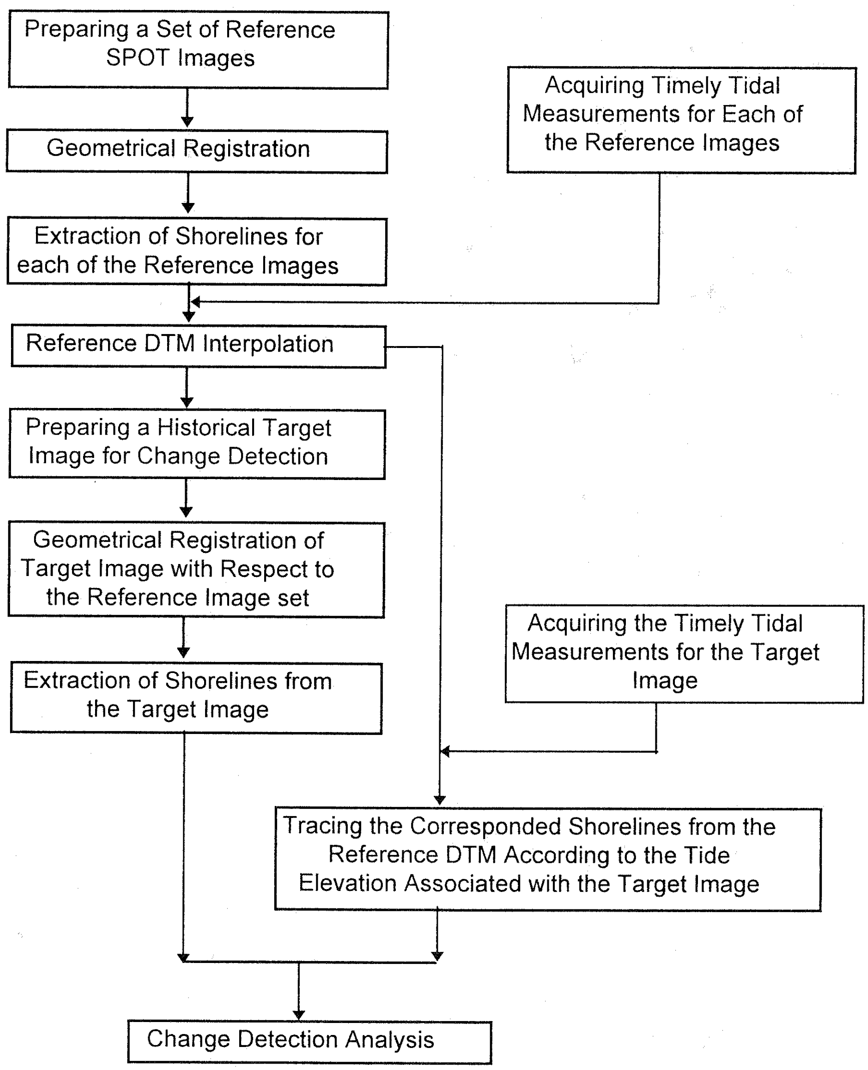

Figure 1. The Flow Chart of the Proposed Scheme

3. EXPERIMENTAL RESULTS

The experimental includes a real data test covering an offshore sand bar (Wai-San-Ting) to the west coast of Taiwan. The size of the sand bar is about 20km*20km. Five images were acquired in the first quarter of 1994 and are used as reference images.

Figure 2 to figure 6 show the five images respectively in which extracted coastlines are superimposed. A historical target image shown in figure 7 for change detection was acquired in 1986. The sampling time and the associated tide measurements are indicated in table1.

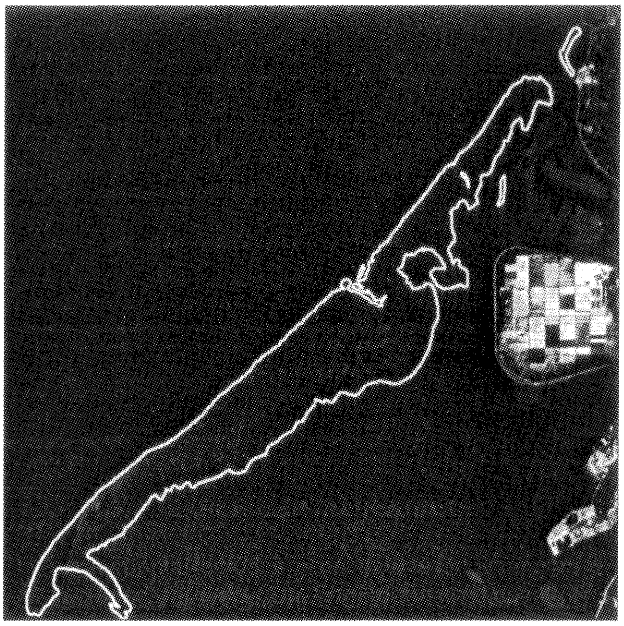

Figure 2. SPOT Image A,1994/01/03

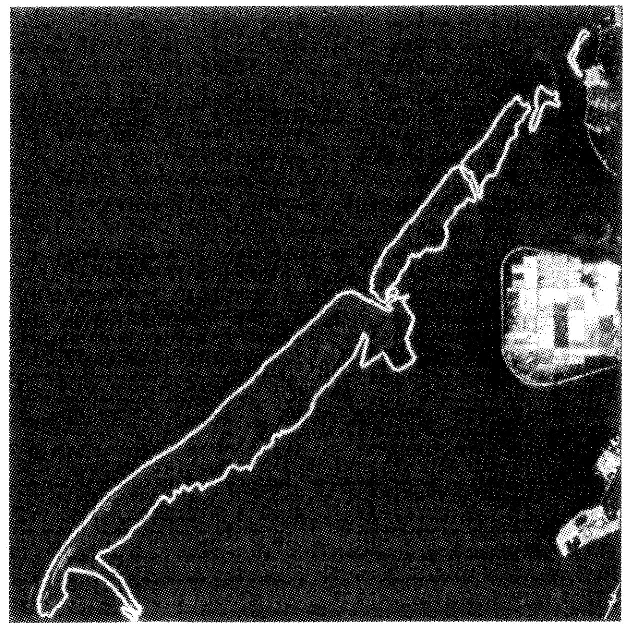

Figure 4. SPOT Image C,1994/02/06

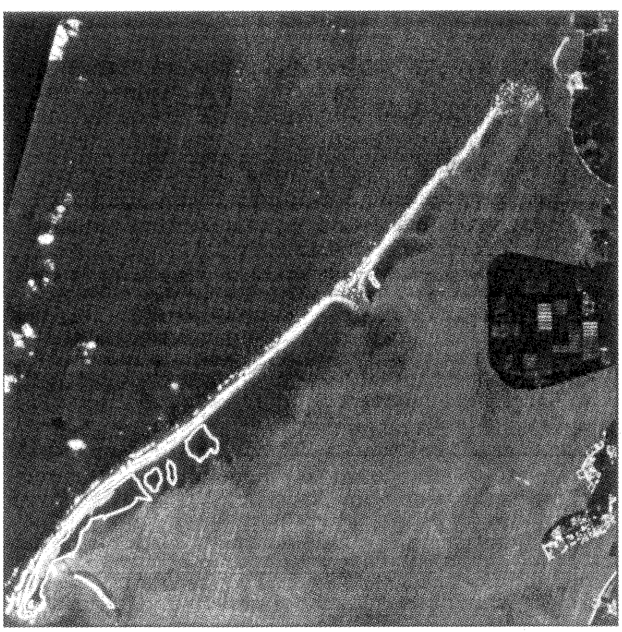

Figure 3. SPOT Image B, 1994/01/11

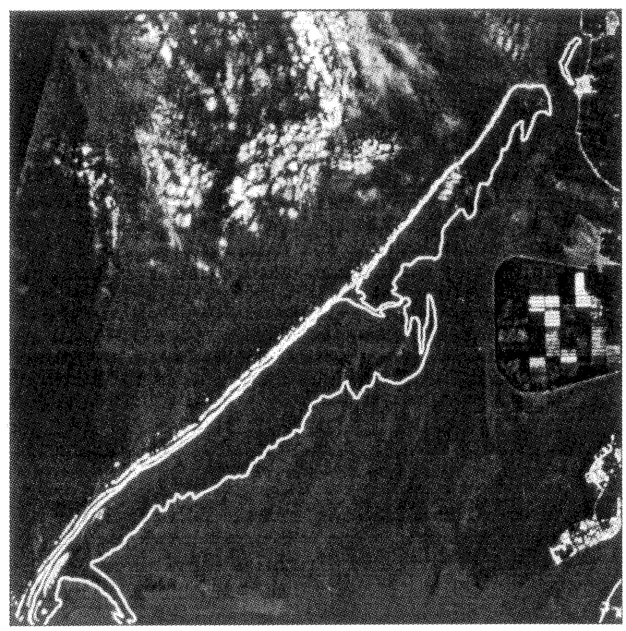

Figure 5. SPOT Image D,1994/03/04

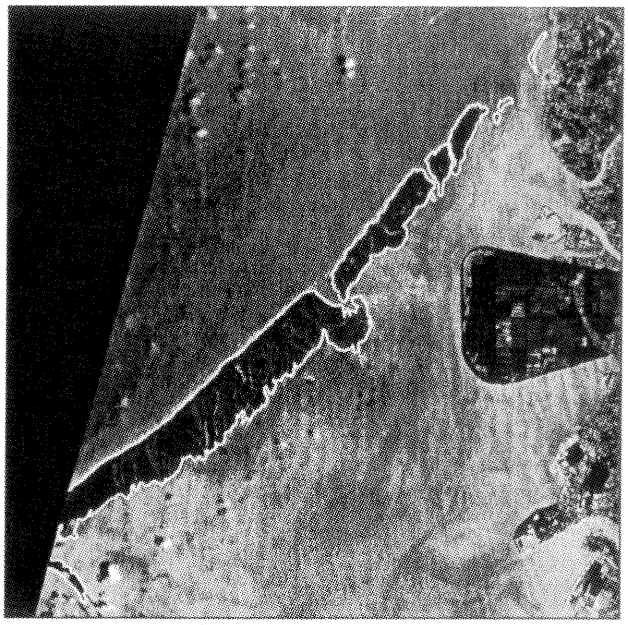

Figure 6. SPOT image E, 1994/04/17

Figure 7. Historical SPOT Image F,1986/09/28

Table 1. Sampling Time and Associated Tide Elevations

Sampling Time			Tide Elevation (M)
Reference Image			
ID	**Y-M-D**	**H-M-S**	
A	1994-01-03	10-55-53	-0.5340
B	1994-01-11	11-00-11	0.6519
C	1994-02-06	11-00-14	0.0156
D	1994-03-04	11-00-18	-0.2760
E	1994-04-17	10-56-00	0.0659
Historical Image			
F	1986-09-28	10-45-00	-0.5690

The reference image set is acquired in a short period, i.e., three months. Thus, the assumption of insignificant variations for the area of interest during the period is reasonable. The images are geocoded and resampled to 12.5m*12.5m pixel spacing. To assure the geometrical quality for the images, a registration check was automatically performed by matching feature points. The RMSE is smaller than 0.75 pixels, which corresponds a ground coverage of less than 10m.

The reconstructed reference DTM is shown in figure 8. For consistency check , the predicted shoreline from the reference DTM and the real shoreline from image are compared in figure 9. In which, the error of the area is 1.409 km^2 , i.e., 5% of the sand bar area. The solid line depicts the real coastline and the dash line illustrates the predicted coastline from the reference DTM.

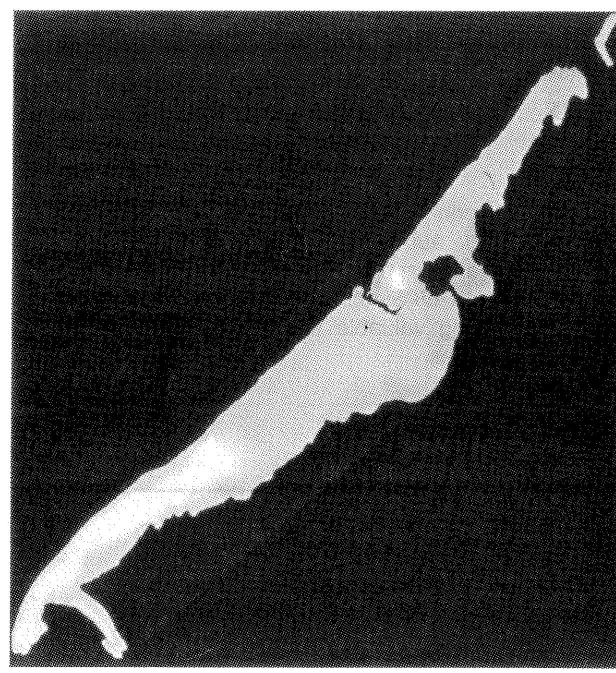

Figure 8. The Reconstructed Reference DTM

The predicted shoreline from the reference DTM according to the tide elevation associated with the historical satellite image i.e. image F is then compared with the real shoreline delineated from image F. Figure 10 illustrates the changes of Wai-San-Ting for the last eight years. In which, solid line depicts the real coastline from image D and the dash line illustrates the predicted coastline from the reference DTM. Quantitatively, the sand bar has lost its area of 37% during the last eight years.

4. CONCLUDING REMARKS

The coupling effect of two dynamic factors i.e. different tide elevations and terrain variations, complicates the terrain analysis for tideland areas. The proposed scheme is developed to cope with this complexity effectively. The relative error may reach 5% in terms of the area.

The features of the proposed scheme are threefold:

1. The tidal variation for shoreline change detection is considered.
2. The interrelated characteristics between image coastlines and the tidal variations are fully utilized.
3. Three dimensional analysis is possible. Which means that the volume change might be detected provided that the historical data set is sufficient.

The applicability of the proposed scheme relies on the temporal resolution of satellite images for constructing the reference DTM. As more and more resource satellites are scheduled to launch in the next decade, the applicability of the proposed scheme is getting promising.

ACKNOWLEDGEMENT

This investigation was supported by Sinotech Foundation. The authors are grateful for this support. Thanks also go to Dr. C.-S. Kung, Mr. B.-R. Yang, and Mr. C.-G. Shieh of Sinotech Engineers Consultants Inc. for providing valuable tidal measurements and detail explanations.

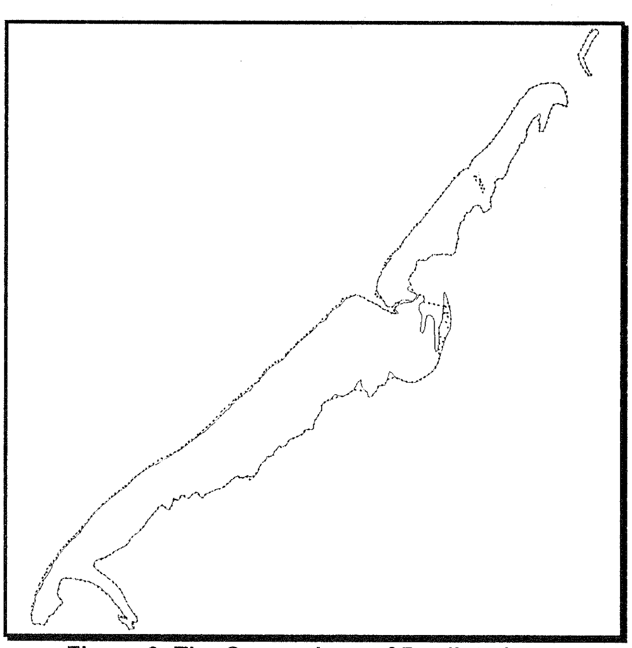

Figure 9. The Comparison of Predicted Shoreline(Dash Line) and Real Shoreline (Solid Line)

Figure 10. Shoreline Changes of Wai-San-Ting Predicted Shoreline(Dash Line) and Real Shoreline (Solid Line)

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