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Application Effect Analysis of Image Fusion Methods for Extraction of Shoreline in Coastal Zone Using Landsat ETM+

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Abstract: Extraction of shoreline incoastal zone is important for coast protection and management. This paper presents extractingthe shoreline with fusion images, which are obtained using various image fusion methods such as IHStransform, Brovey Transform, Multiplicative, Principle Component, Wavelet Resolution Merge. Artificial constructions (e.g. coastalembankments), islands, lakes, tidal mudflats and estuaries have been selected as evaluation objects, shorelines of which are extracted and analyzed. The result indicates that shoreline extraction effect by the Principle Component method is bestamong other methods.

Keywords: Image Fusion, Shoreline, Landsat ETM+

1. Introduction

The extractionof shoreline, boundary between sea and land, is important to study the coastal zone from satellite images. When shoreline is determined correctly, the seashore changes can be detected and data that are necessaryfor reclamation or use of tidal mudflat can be provided.

The factthat area of the seashore is wide and change is serious makesit very difficult todetermine the shoreline by special field survey and observation. Therefore, the methods of shoreline detection by Remote Sensing have been studied widely [6-10, 13].

García-Rubio et al. [7] extracted shoreline from SPOT images using an unsupervised classification (ISODATA).

Because Landsat TM image has comparatively high spatial resolution and spectrum resolution and it has a lot of information it is used as basic data for research on resources of the earth and environment widely all over the world.

Some successes were achieved in studyingshoreline detection using TM image.

Ghoneim et al. [8] used a segmentation technique to extract shoreline from the mid-infrared channel of MSS, TM/ETM+.

Kong et al. [10] applied an interactive interpretationtechnique combining an automatic boundary detection algorithmwith human supervision to detect the shorelinein MSS, TM/ETM+ images.

Kloiber, et al. [9] extracted the shoreline by using unsupervised classification after combining TM image with aerial image.

Frazier et al. [6] studied a method of detecting water bodyand mapping from TM image and McFeeters [13] enhanced information related to waterfrom satellite images using Normalized Difference Water Index (NDWI).

Due to limitation of spatial resolution of TM imagethe shoreline detection could not be made further accurate. Therefore, shoreline detection accuracy can be advanced by using high space-spectral resolution image by fusing TM images and satellite images with high spatial resolution. Some researchers have suggested effective methods of image fusion [15].

Generally, there isRGB-IHStransform, Brovey Transform, Multiplicative, Principle Component, Wavelet Resolution Mergein image fusion methods.

The RGB-IHStransform method transforms every pixel in the RGB space to the IHS space, then matches the component I with histogram of the High resolution Pan image. And this makes the RGB fusion image by inversing histogram-matched Pan image with components H, S separated [1, 2, 5, 16].

In the Principle Componentmethod [14, 16], the first component image is obtained by the Principle Component analysis for multi-spectral bands image at first. Next, it matches the mean and standard deviationvalues of the high resolution image to the first component image, stretching high resolution image to be fused. Then it replaces the first component image with the high resolution image, and the higher spatial resolution multi-spectral image is obtained by Inverse Principle Component [2].

The Multiplicativemethod fuses two images that have different spatial resolutions by using multiplicationcalculation [3, 4].

$$(DN_{i\_m})(DN_h) = DN_{i\_new}$$

Where, i is the number of bands, DN_{i_new} is a value of i bands after fusion, DN_{i_m} is a value of i bands of various band images and DN_h is brightness value of high resolution image.

The Brovey Transformmakes fusion between images that have three bands and high resolution image by using the following equation [12].

$$\begin{cases} R' = \dfrac{R}{R+G+B} Pan \\ G' = \dfrac{G}{R+G+B} Pan \\ B' = \dfrac{B}{R+G+B} Pan \end{cases}$$

Where, R , G , B are pixel brightness values of red, green, blue bands respectively, pan is brightness value of high resolution image and R' , G' , B' are pixel brightness values of red, green, blue bands respectively after fusion in various band images.

The Wavelet fusion methodis based onthe Wavelet transform [17].

The Wavelet transform makes analysis of signal information easy by operation thatdisjoints complex signalsto blocks of different criteria.

Wavelettransform is similar to Fourier transform. In the Fourier transform, long continuous (sine and cosine) waves are used as the basis. The wavelet transform uses irregular, asymmetric “wavelets” as basic functions and analyzes images in different scales. So, it overcame weakness of local analysis ability of Fourier transform which has not high local analysis ability [9].

Through the wavelet transform, the image is presented feature parameters of original image by decomposing to each of the waveforms [11]. Therefore, the image fusion based on the wavelet transformcan usedifferent fusion methods for different feature parameters sothat the better fusion effect can be obtained.

These fusion methods have advantages and disadvantages. In this study, these fusion methods are applied to shoreline detection and the results are compared and analyzed.

2. Study Area

The coastal zone includescoastalembankments, tidal mudflats, dunes and the big and small mouths of rivers.

A coastalembankment can be considered to be the constant shoreline. New tidal mudflat can be formed outside coastalembankments.

In tidal mudflat area, the boundary between sea and land cannot be indicated clearly because of reflection features ofbottom material and low regions of mudflat affect the shoreline detection because water existsthere at ebb tide.

The suspended materials such as suspended sand make it difficult to extract the shoreline in the mouths of rivers.

The effects of noise exclusion and shoreline detection of fusion methods are compared by selecting regions that have various topographic objects in this paper.

The coastal zone that includesthe rivers, islands, lakesortidal mudflatsis selected for the study area (Figure 1).

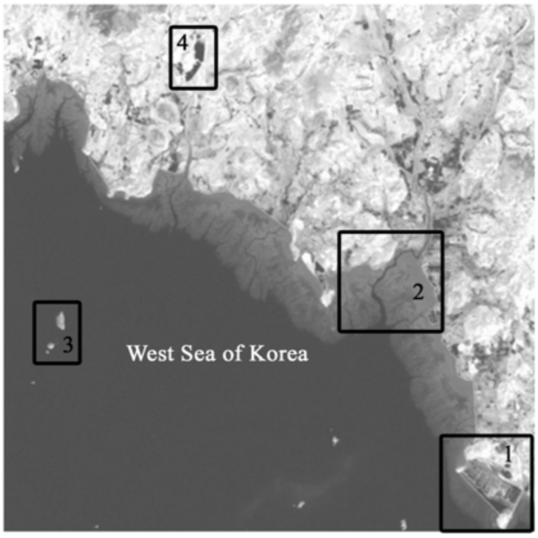


Figure 1. *The study areas.*

(Area 1 indicates the coastalembankment zone, Area 2 indicates the estuary zone, Area 3 indicates the island zone, Area4 indicates the lake zone)

3. Methods and Results

Reflectance of seawater is not higher thanreflectance of other objects in visible bands (480-580μm). Most radiation entered in seawater is absorbed over 740μm. Thus, many researchesinto water have been performedinvisible bands generally. As water has strong absorptionfeature in infrared bands (740-2500μm), this range of band is used a lot for shoreline detection.

The Normalized Difference Water Index (NDWI) has been used a lot up until now in shoreline detection [13]. The Modified Normalized Difference Water Index (MNDWI) defined below is used to overcomeNDWI’s limitation and to get the shorelinemore correctly.

$$MNDWI = \frac{Green - SIR}{Green + SIR}$$

Where, $Green$ is the green band reflectance and SIR is the short infrared band reflectance. These arerespectivelyequivalent to 2 and 5 bands in LANDSAT TMimages.

Effectiveness analysis of fusion methods has been doneas follows.

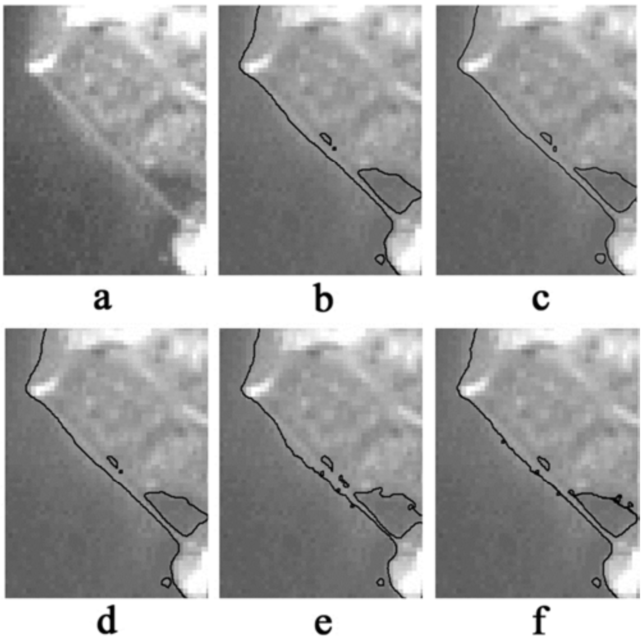
First, the atmospheric correction and the sun height correction are made for satellite images.

Second, fusion between Pan Band's image and other band images of Landsat ETM+ are completed by each fusion method. Thus, whenfusing satellite images from different sources, the geometric correction between images is not required.7, 5, 2 bands are used to calculate MNDWI in cases ofthe IHS Transform and the Brovey Transform.

Third, the shoreline is extracted bycalculating MNDWI indexin obtained fusion images.

Fourth, the detection effects of islands, lakes, tidal mudflats, estuaries and artificial construction boundaries are compared.

The extraction results of coastalembankments are as follows (Figure 2).

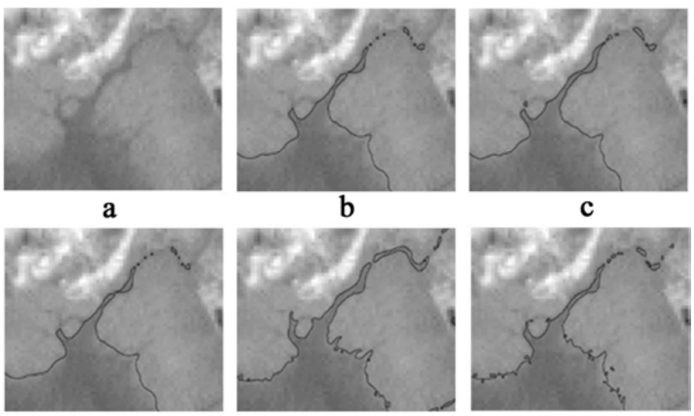


a) Source, b) Brovey, c) IHS, d) Multiplicative, e) PC, f) Wavelet

Figure 2. *The result of coastal embankmentextraction.*

As shown in figure 2, all methods detected boundary of a coastalembankmentnearly similarly. Relatively, the Principle Component method and the Wavelet Resolution Mergeshow more clearly details of area where water exists in interior coastal embankment than other methods. The detection results of theIHS transform, Brovey Transform, Multiplicativeare very similar.

Figure 3 shows the extraction result of shoreline in the estuary.

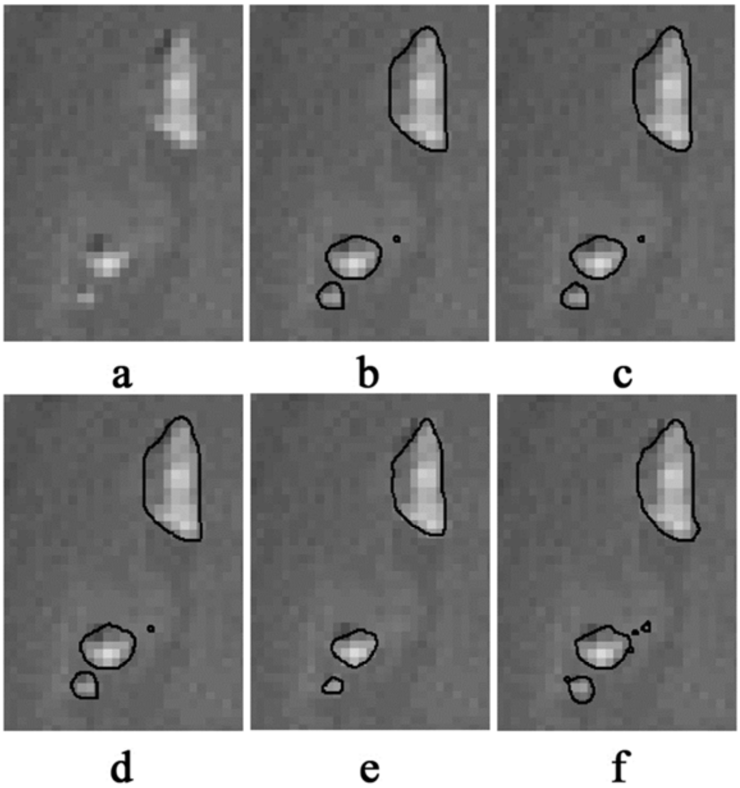


a) Source, b) Brovey, c) IHS, d) Multiplicative, e) PC, f) Wavelet

Figure 3. *Shoreline extraction result in the estuary.*

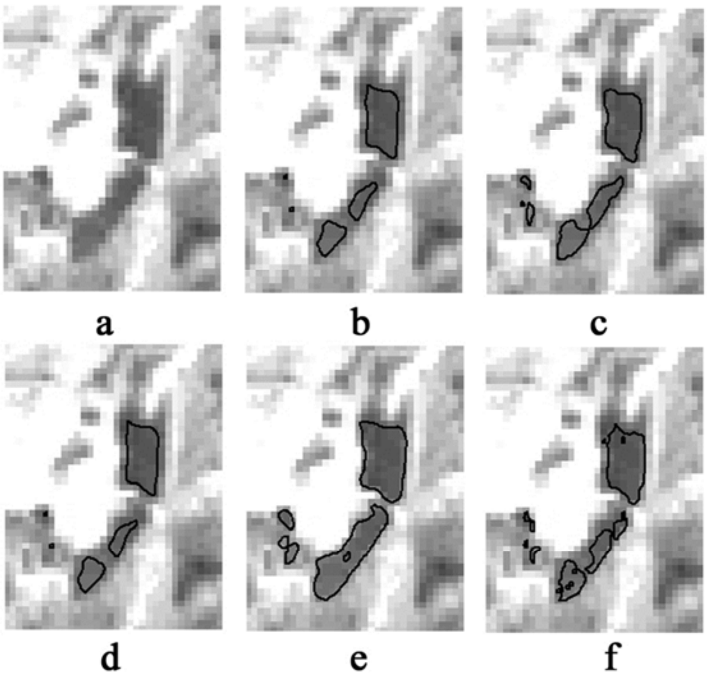
As figure3 shows, thePrinciple Component and the Wavelet Resolution Merge exhibit details of topography better in the estuary.

Figure 4 and 5 show resultsofthe extracted boundaries of theisland and the lake.



a) Source, b) Brovey, c) IHS, d) Multiplicative, e) PC, f) Wavelet

Figure 4. *Extraction results of island boundary.*



a) Source, b) Brovey, c) IHS, d) Multiplicative, e) PC, f) Wavelet

Figure 5. *Extraction results of lake boundary.*

To compare accuracy of every method, the boundaries of islands, lakes, estuary and coastalembankmentsare extracted in high resolution images and used them as a standard.

The relative errors betweenthe shoreline extracted from the high resolution image and the shorelines extracted from fused images are shown in Table 1.

Table 1. *Comparison of relative errors for shoreline extraction by image fusion methods.*

Fusion Method	Lake area/%	Island area/%	Tidal mudflat area before the coastalembankment/%	Detail Description
IHS	0.37	0.16	0.08	medium
Brovey	0.51	0.17	0.08	medium
Multiplicative	0.53	0.17	0.08	medium
PC	0.1	0.1	0.03	high
Wavelet	0.36	0.13	0.05	high

As shown in Table 1, the shoreline extracted from fused images by the Principle Component method has a smaller error than all the other methods, the relative error of the estimated result is 0.1%for the area of lakesor islands, and it is 0.03%for the tidal mudflat area before the coastal embankment.

Except for the Principle Component method, the relative error of the Wavelet Resolution Merge is smaller than all the others.

The relative errors of IHS transform, Brovey transform and Multiplicative are almost the same and their accuracy is relatively lower than that of PC and Wavelet.

4. Conclusion

In this paper, the detection accuracy of shoreline can be lower than studying individual objects because shoreline is detected on the enormous seashore.

However, thearea of study area issetwidely andthe fusion methods are applied because the shoreline detection in satellite image didnot treat the limited regions or the individual objects.

Result shows that fusion methodby the Principle Component analysis makes relativelysmallerrors andexhibits details of topography better than all the other methods. Also, the error of the Wavelet Resolution Mergeis smaller than other methods. However, the calculation of the Wavelet Resolution Merge is more complicatedthan the Principle Component and it is not comfortable to use it because of the more conditions for implementation of the Wavelet Resolution Merge than the Principle Component method. There are some errors in the results of this paper because shoreline was detected by MNDWI. Butthe problem of evaluating which methodis more effective fordetection of shoreline will remain unaffected.

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