COASTLINE DETECTION USING COHERENCE MAP OF ERS TANDEM DATA

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ABSTRACT: A coastline is the boundary between land and ocean masses. Knowledge of coastline is essential for autonomous navigation, geographical exploration, coastal erosion monitoring and modelling, water line change, etc. Many methods have been researched to extract coastlines from the synthetic aperture radar (SAR) and optic images. Most methods were based on the intensity contrast between land and sea regions. However, in these methods, a coastline detection task was very difficult because of insufficient intensity contrast and the ambiguity in distinguishing coastline from other object line. In this paper, we propose an efficient method for the delineation of coastline using interferometric coherence values estimated from ERS tandem pair. The proposed method uses the facts that a tandem pair of ERS is acquired from a time interval of an accurate day and that the coherent and incoherent values in coherence map are land and water, respectively. The coherence map was generated from ERS tandem pair, filtered by MAP filter, and divided into land and water by the determination of threshold value that is based on the bimodality of the histogram. Finally, a coastline was detected by delineating the boundary pixels. There was a good visual match between the detected coastline and the manually contoured line. The interferometric coherence map will be helpful to identify land and water regions easily, and can be used to many applications that are related with a coastline.

KEY WORDS: coastline detection, interferometric coherence, coherence map, ERS tandem

1. INTRODUCTION

A coastline is the boundary between land and ocean masses. Knowledge of coastline is the basis for measuring and characterizing land and water resources, such as the area of the land, and the perimeter of coastline. Information about coastline position, orientation and geometric shape is also essential for autonomous navigation, geographical exploration, coastal erosion monitoring and modelling, and coastal resource inventory and management.

Automated coastline extraction from digital image data belongs to the boundary detection problem in the field of computer vision and image processing, in which edge detection and image segmentation are two conventional approaches to the boundary detection. Technically, edge detection methods emphasize the first property and locate the meaningful intensity discontinuity by using spatial differentiation or edge template operations. Segmentation is conceptually based on the second property. Commonly used segmentation algorithms include thresholding, region growing, and region splitting and merging. Edge detection is relatively simpler to implement than segmentation.

Segmentation methods require more post segmentation processing steps to delineate the boundary pixels, and face difficulties of determining a reliable threshold in thresholding algorithms and formulating homogeneous criteria in region growing, and region splitting and merging algorithms. Because of the frequent lack of consistent, sufficient intensity contrast between land and water regions and the complexity in distinguishing coastline edges from other object edges, most general-purpose edge detection and image segmentation techniques are inadequate for a coastline extraction task. It is recognized that a comprehensive procedure is required to automate the coastline extraction process (Lee and Jurkevich, 1990; Liu and Jezek, 2004; Yu and Action, 2004).

Mason and Davenport (1996) employed an edge detection method with a coarse–fine resolution processing strategy and applied their approach to several full scene ERS-1 SAR images. A contrast ratio edge detector (Touzi et al. 1988, Mason and Davenport 1996) was used to determine shoreline pixels that have strong edge strength. The edge gaps along the coastline are filled with the use of an interpolation procedure based on active contour models. Due to the difficulty in setting a global contrast ratio threshold to define coastline edge segments, and the limitations in the active contour modelling to fill the edge gaps, the delineation accuracy of their method is also limited.

Whereas it is a quite simple task with optical data such as Landsat TM, the SAR data inherent properties (e.g. speckle statistics, complexity of the backscatter mechanisms) impede a straight-forward solution of the problem using only the pure amplitude information of the data. Apart from the presence of speckle a lack of contrast between land and sea often is observed in case of wind-roughened or wave-modulated water surfaces. SAR image illustrates the difficulty of shoreline detection in SAR magnitude images.

In this paper, an efficient technique is proposed to overcome the problem of missing contrast in the SAR magnitude. As will be demonstrated, the use of the interferometric coherence as a measure of the stability of the scatterers between two SAR acquisitions may serve as a criterion to distinguish between the land and sea surfaces. Coherence information has already been exploited successfully in land use applications or for the purpose of forest/non-forest-discrimination. Forested areas, similar to water, mainly appear decorrelated in repeat-pass interferograms whereas agricultural and urban areas are characterized by medium to high correlation. It is generated the coherence map using ERS-1/2 tandem pair images. The histogram indicating the backscattering characteristic of the coherence map value was analyzed. Analyzing histogram, it could be divided the boundary between of land and sea by bimodal shape of the histogram. Therefore the boundary curve is become to the vector line which was used for the coastline extraction.

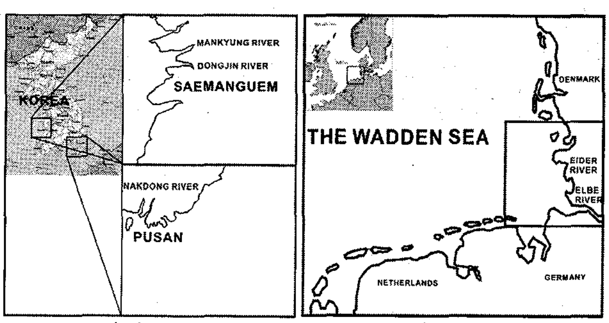
2. STUDY AREA & DATA

Three sites for this study were chosen: 1) Saemanguem tidal flat area is located at the estuary of Mankyung and Dongjin rivers discharging fresh water in the west coast of Korean Peninsula, 2) Pusan area is located at the estuary of Nakdong river in the South sea of Korea and 3) Wadden sea area where is developed huge tidal flat is located in Germany (Figure 1).

The Saemanguem tidal flat and the Wadden sea area were selected to validate the performance of coastline extraction in tidal flat.

In three test sites, seven ERS tandem pairs were used for coastal extraction in this study (Table 1).

All of ERS data were provided RAW data format by ESA, and fourteen SLC images were generated from them using APP processor. Seven coherence maps produced by EV-InSAR software were used to extract coastline. Figure 2 represents SLC images and coherence map in Wadden sea area.



(a) (b)

Figure 1. The study area in (a) Saemanguem tidal flat and Pusan are in Korea (b)Wadden sea in Germany.

Table 1. SAR data images

Area	Satellite	Date and time
Saemanguem	ERS-1	96/03/16 02:13
	ERS-2	96/03/17 02:13
Pusan	ERS-1	95/12/27 13:41
	ERS-2	95/12/28 13:41
Wadden sea	ERS-1	95/06/30 21:27
	ERS-2	95/07/01 21:27
	ERS-1	96/02/23 10:22
	ERS-2	96/02/24 10:22
	ERS-1	96/04/05 21:27
	ERS-2	96/04/06 21:27
	ERS-1	96/06/07 10:22
	ERS-2	96/06/08 10:22
	ERS-1	99/04/07 10:25
	ERS-2	99/04/08 10:25

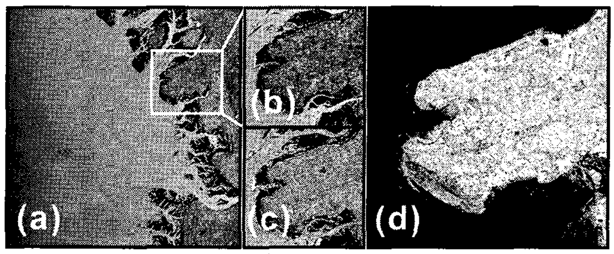


Figure 2. (a) SAR image (b), (c) ERS-1/2 tandem pairs (d) coherence map

3. METHODOLOGY

The detailed processing flow of the proposed method for coastline extraction is summarized in Figure 3. The coherence map is generated from ERS tandem pair first, and a binary image is produced from it using bimodal histogram of it. After noise, river and lake are removed from the binary image using filtering and manual task, coastline is extracted by vectorizing the corrected binary image.

3.1 Coherence Map Generation

The coherence is a measure of the phase consistency in radar return between two images, and defined by (Zebker and Villasenor, 1992)

$$\gamma = \frac{\left|\sum_{i=1}^{N} c_1^{(i)} \cdot c_2^{(i)*}\right|}{\sqrt{\sum_{i=1}^{N}\left|c_1^{(i)}\right|^2 \cdot \sum_{i=1}^{N}\left|c_2^{(i)}\right|^2}} \qquad (1)$$

where c_1 and c_2 are complex values in image 1 and image 2, and c_1^* denotes the conjugate of c_1. The coherence value is a value between 0 and 1.

To generate coherence map, careful interferometric processing was applied including the following processes:

1) Coarse and fine co-registration
2) Band-pass filtering in azimuth direction

3) Spectral shift filtering in range direction
4) Over sampling of the complex data by a factor of 2

In this paper, the coherence is estimated by window size of 20 by 5 to reduce the speckle noise.

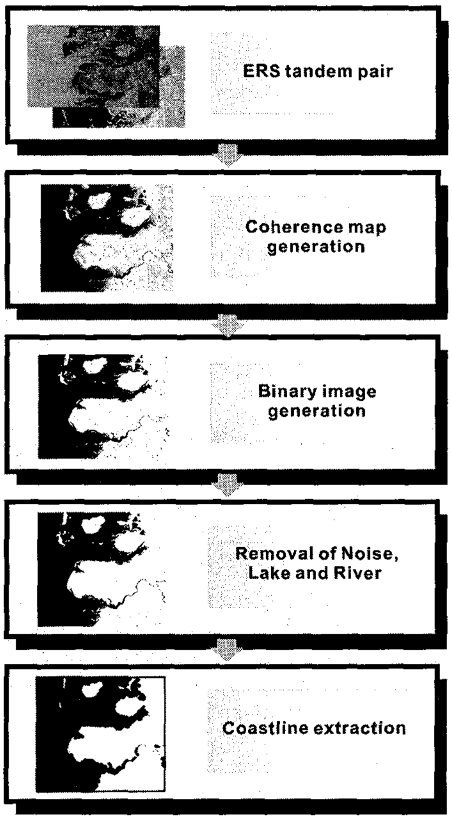


Figure 3. The proposed processing flow for coastline extraction

3.2 Binary Image Generation

In coherence map, the coherent and incoherent values indicate land and water, respectively. If a region consists solely of the land or the water pixels, the probability distribution of the coherence values will be unimodal. However, if the region contains a coastline, coherence values of land pixels and water pixels will be grouped into two dominant modes with relatively distinct mean values in the histogram of the coherence map. The two component distributions commonly overlap each other because of speckle noise. As shown in Figure 4(c), the histogram for this region has two peaks and one valley, namely, a bimodal shape. For this reason, the problem of extracting the coastline depends on the decision of optimal threshold value corresponding to the histogram valley point. Given the optimal threshold value, the pixels in coherence map can be reliably classified into land and ocean pixels. In this study, an optimal threshold value was determined by the Lenvenberg-Margardt method that are proposed by Press et al. (1992) and reviewed by Liu and Jezek (2004).

Using the determined optimal threshold value, the coherence map is converted to the binary image. Figure 4 shows an example for the conversion of coherence map into the binary image in Wadden Sea area.

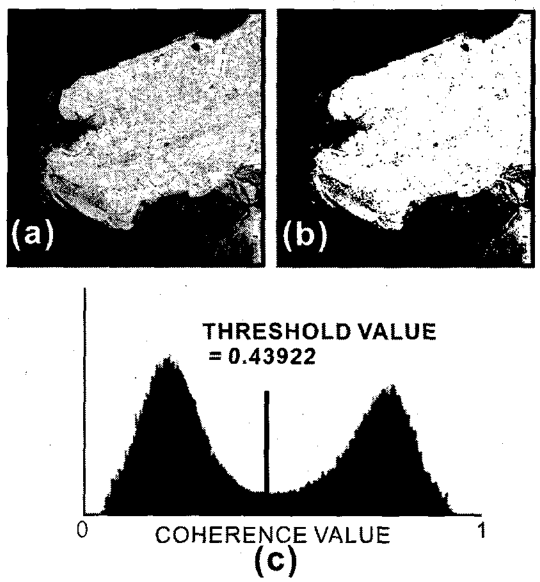


Figure 4. An example for the conversion of coherence map into the binary image in Wadden Sea area: (a) coherence map, (b) binary image and (c) histogram of the coherence map.

3.3 Removal of Noise, Lake and River

The binary image has noises, and lake and river in land. Noises are reduced by using blunder removal filter, but lake and river are removed from manual task. Figure 5 represents an example of the binary image and the binary image after noise, river and lake are removed.

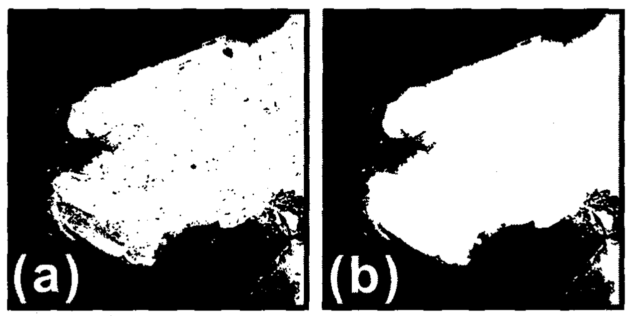


Figure 5. (a) The binary image. (b) The binary image after noise, river and lake are removed

3.4 Coastline Extraction

The coastline is automatically extracted from the corrected binary image. Figure 6 shows the extracted coastline.

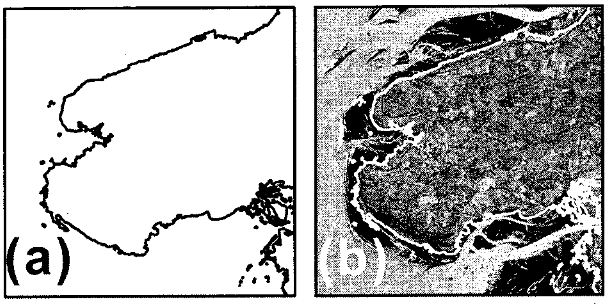


Figure 6. (a) The extracted coastline. (b) The extracted coastline superimposed on SAR amplitude image

4. RESULT AND DISCUSSION

The coherence map was generated with ERS-tandem pair images. The boundary between land and more is divided to white and black color by bimodal histogram of the coherence map. The median filter is applied to the white & black map, and noises in region except the land were directly removed. Vector-lines were extracted through the adjusted the white & black image at boundary. Figure 7 shows to match ERS SAR images and vector lines.

5. CONCLUSION

A semiautomatic method of extracting the coastline in ERS tandem coherence map was proposed. The proposed method uses the facts that ERS tandem pair is acquired from a time interval of one day and that the coherent and incoherent values in coherence map of ERS tandem pair indicate land and water, respectively. The coherence maps were generated from 7 ERS tandem pairs and filtered by MAP filter. After an optimal threshold value for each coherence map was determined by the Lenvenberg-Margardt method, seven binary images were generated. After noise, river and lake were removed from the binary images using filtering and manual task, the coastlines for 7 ERS tandem pair were extracted by vectorizing the corrected binary image.

The proposed method was efficient in the tidal flat.

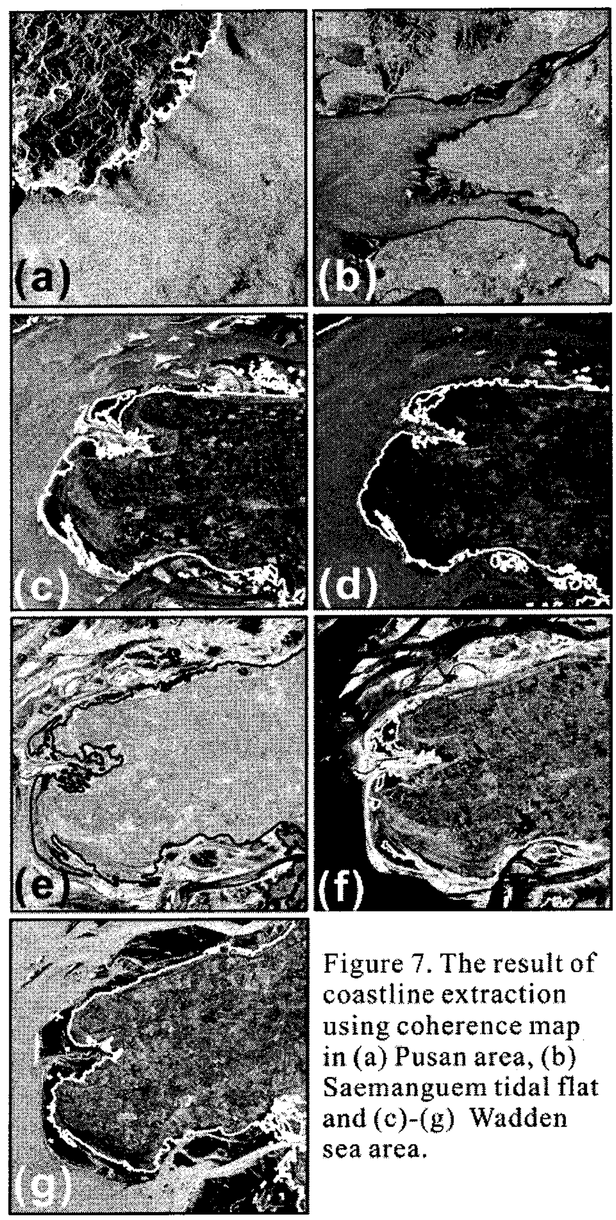


Figure 7. The result of coastline extraction using coherence map in (a) Pusan area, (b) Saemanguem tidal flat and (c)-(g) Wadden sea area.

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