Coastline detection in SAR images using discriminant cuts segmentation

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Abstract. The discriminant cut algorithm is used to detect coastlines in synthetic aperture radar (SAR) images. The proposed approach is a region-based one, which is able to capture and utilize spatial information in the image. The real SAR images, e.g. ALOS-1 PALSAR and COSMO-SkyMed SAR images, together with in-situ GPS data were collected and used to validate the performance of the proposed approach for coastline detection in SAR images. The accuracy is better than 4 times the image resolution. The efficiency is also tested.

1. Introduction

Coastline detection is important for land/water resources management, safe navigation, coastal erosion monitoring, among others. In recent years, coastline detection from spaceborne synthetic aperture radar (SAR) images is a fast growing development field due to SAR’s wide spatial coverage, high resolution, and all-day/all-weather imaging capabilities. Automatic coastline extraction from a SAR image is not a trivial task due to both the presence of the speckle noise and the non-uniform characteristics of the sea surface roughness caused by different mechanisms including wind, wave, and their interactions [1].

Many studies have devoted to develop semi-automatic or automatic algorithms for coastline detection in SAR images. Among them, many researches [2-4] on coastline detection in SAR images are pixel-based. Therefore they are not able to capture and utilize spatial information in the image data. In this study, we proposed a new region-based approach for coastline detection in SAR images, which is based on discriminant cuts segmentation [5]. To validate this approach, the ALOS-1 PALSAR and COSMO-SkyMed (CSK) SAR images, together with in-situ GPS data were collected. The experimental results show that the proposed approach is effective and efficient in coastline detection in SAR images.

2. Methodology

Discriminant cut is a graph-based spectral cluster algorithm. It emphasizes the general criterion of the cluster algorithms: maximizing the within-cluster similarities while minimizing between-cluster associations [5]. We introduce the discriminant cut algorithm to detect coastlines in SAR images.

The proposed approach includes three image processing steps: pre-processing, land-sea segmentation, and post-processing. In the pre-processing step, speckle reduction, geometric correction and anisotropic diffusion filtering [6-7] are performed. In the land/sea segmentation step, the divide-
and-combine approach and discriminant cuts segmentation are combined to derive the land/sea boundary of SAR images. For divide-and-combine approach, the image is first divided into many regular sub-blocks (a few tens of pixels by a few tens of pixels) for further processing. By doing so, local characteristics in the image may have due care or attention; and the processing speed may be enhanced due to smaller size of sub-blocks. And then each block is partitioned into regions using discriminant cuts segmentation. After that, all the regions are combined. Lastly, a threshold calculated automatically (e.g., Otsu’s method [8]) is applied to partition the combined image into land and sea classification, with a binary image output. In the post-processing step, some objects whose boundaries are not the coastline are removed by filtering out isolated targets that consist of less than a predefined T pixels from the binary image. And then the exterior boundaries of land are traced automatically. Finally, the detected boundaries are converted to a vector coastline file.

3. Experimental results

Two experiments are undertaken. The first experiment is on the application of the proposed approach in Japanese ALOS-1 PALSAR images. The second experiment is on the application of the proposed approach in Italian COSMO-SkyMed SAR images.

3.1. Experiment I

Two Japanese ALOS-1 PALSAR FBS images covered the coast of Shanghai, China on January 15, 2010 were collected. Table 1 shows their relevant information. Their spatial resolution is 12.5 m.

| Sensor | Beam | Orbit | Date (dd/mm/yy) | Acquisition time (UT) |
|--------|------|-------|-----------------|-----------------------|
| PALSAR | FBS  | 21188 | 15012010        | 14:25:10              |
| PALSAR | FBS  | 21188 | 15012010        | 14:25:18              |

The ALOS-1 PALSAR images were first calibrated, re-projected (UTM), and resampled to 6.25 m pixel spacing. As the study area is covered by these two ALOS-1 PALSAR scenes: south and north, then they were mosaicked and the image of the study area was clipped. The clipped image size is 5112 × 3582 pixels. We detected the coastline in the clipped image by using the proposed approach. In the pre-processing step, the parameters in anisotropic diffusion filtering are set as follows: number of iterations is set as 15; integration constant is set as 1/7; the gradient modulus threshold that controls the conduction is set as 30. In the land/sea segmentation step, the size of sub-blocks is set as 50 pixels. Each block is partitioned into 5 regions using discriminant cuts segmentation. In the post-processing step, T is set as 5000. For comparison, we also detected the coastline in the clipped image by using global thresholding approach. The threshold value used in global thresholding approach is the same as that used in the proposed approach.

To evaluate the effectiveness of the proposed approach on coastline detection in ALOS-1 PALSAR images, we compared the detected coastlines by using the proposed approach with that by using global thresholding approach. The comparison result is shown in figure 1. The detected coastline by using the proposed approach is shown in green; that by using global thresholding approach is shown in red. To show more details, we enlarge some areas (indicated by small blue box) by 2.5 times (indicated by large blue box). From figure 1, the detected coastline in the ALOS-1 PALSAR image by using the proposed approach fits that by using global thresholding approach well in most areas. By visual inspection, we find the detected coastline by using the proposed approach differs from that by using global thresholding approach in some areas, e.g. area A ~ area D. In area A, both approaches fail to detect coastlines accurately due to low land/sea contrast ratio for this area is wet. In area B, the
proposed approach succeeds but global thresholding approach fails. The reason is that the proposed approach is able to capture and utilize spatial information while global thresholding approach is unable. In area C, both approaches work not well for this area is complex. In area D, both approaches work not well either due to interference from inland water. In summary, the proposed approach performs well under mid-high land/sea contrast ratio in coastline detection in the ALOS-1 PALSAR image. And it is able to capture and utilize spatial information in the ALOS-1 PALSAR image.

![Figure 1](image_url)

**Figure 1.** The detected coastlines in ALOS-1 PALSAR image on January 15, 2010. The detected coastline by using the proposed approach is shown in green; that by using global thresholding approach is shown in red. The large rectangle blue box is 2.5 times the length of the small rectangle blue box. Letters ‘A’, ‘B’, ‘C’, and ‘D’ represent the names of the small boxes.

### 3.2. Experiment II

An Italian CSK SAR Stripmap PingPong mode HH/VV polarized data covered the coast of Shanghai, China on December 3, 2012 was collected. Table 2 shows its relevant information. Its spatial resolution is 15 m. The tide level is middle in the acquisition time.

| Sensor          | Polarizations | Date (dd/mm/yy) | Acquisition time (UT) | Tide level (m) |
|-----------------|---------------|-----------------|-----------------------|----------------|
| COSMO-SkyMed    | HH/VV         | 03122012        | 02:18                 | 1.42 M*        |

*Note: ‘M’ indicates middle tide*

The HH channel image was used to test the proposed approach. It was first calibrated, re-projected (UTM), and resampled to 7.5 m pixel spacing. Then the image of the study area was clipped. The clipped image size is 2714 × 2985 pixels. We detected the coastline in the clipped image by using the proposed approach and by using global thresholding approach respectively. The parameters used in the proposed approach and global thresholding approach are the same as those in experiment I.
To evaluate the performance of the proposed approach on coastline detection in the COSMO-SkyMed SAR image, we compared the detected coastlines by using the proposed approach with that by using global thresholding approach. The comparison result is shown in figure 2. The detected coastline by using the proposed approach is shown in green; that by using global thresholding approach is shown in red. To show more details, we enlarge some areas (indicated by small blue box) by 2.5 times (indicated by large blue box). From figure 2, the detected coastline in the ALOS-1 PALSAR image by using the proposed approach fits that by using global thresholding approach well in most areas. By visual inspection, we find the detected coastline by using the proposed approach differs from that by using global thresholding approach in some areas, e.g. area A ~ area D. To quantitatively evaluate the accuracy of the proposed approach, we collected in situ GPS information along the coastline under middle tide condition on July 4, 2013 and July 16, 2013. The accuracy is 46 m. It is better than 4 times the image resolution. For more information on validation of coastline detection approach using SAR images, readers can refer to [9].

**Figure 2.** The detected coastlines in COSMO-SkyMed SAR image on December 3, 2012. The detected coastline by using the proposed approach is shown in green; that by using global thresholding approach is shown in red. The large rectangle blue box is 2.5 times the length of the small rectangle blue box. Letters ‘A’, ‘B’, ‘C’, and ‘D’ represent the names of the small boxes.

The efficiency is also tested. In experiment I, the run time is about 26 minutes on a personal workstation. In experiment II, the run time is about 16 minutes on the same personal workstation.
4. Conclusions
A novel approach of coastline detection in SAR images based on the discriminant cuts segmentation is proposed. The real ALOS-1 PALSAR and COSMO-SkyMed SAR images over the coast of Shanghai, China, together with in-situ GPS data were collected and used to validate the performance of the proposed approach. The experimental results show that the proposed approach is able to capture and utilize spatial information in SAR images and the accuracy of the proposed approach is better than 4 times the image resolution.

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