A RAPID METHOD FOR WATER TARGET EXTRACTION IN SAR IMAGE

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ABSTRACT:

For the inherent speckles in SAR imagery, the processing of object extraction becomes more difficult. Using the traditional target extraction arithmetic for optical imagery, we can not get ideal result on SAR imagery. Water object in SAR imagery represents as some continuous region with low lightness and strong speckle noise. The traditional method to extract low lightness object can be implement by segment the imagery to binary imagery using a specify threshold. As the strong effect of the inherent speckle, how to gain an appropriate threshold is difficult. In this paper, the authors propose a sequential nonlinear filtering-based method to extract the water object in SAR imagery automatically. The experimental results using real SAR imagery show that our method can extract water objects in SAR imagery rapidly and accurately.

1. INTRODUCTION

Synthetic Aperture Radar (SAR) can generate images of the ground in all weather conditions including rain and fog at any time of day or night. It is a kind of important equipment for modern electric reconnaissance, widely used in civil and military. In recent years, SAR imaging has been rapidly gaining prominence in applications such as remote sensing, surface surveillance, and automatic target recognition. In the navigation application of military, extracting the airport, water region, road, etc. in SAR imagery is important to produce the reference imagery for matching with the real-time imagery.

Different from some other remote sensing data, the SAR image do not obey the rule of projection but the rule of time of flight, and the SAR image data is most sensible on the geometric character of the surveyed object, not only on the macroscopical level, but also on the microscopical level. Both the natural character and the status of the object are important parameters of SAR image. In the application of SAR image automatic target recognition, it can seldom get good effect by using the traditional object extraction region segmentation operators, which are frequently used in optical images. A number of algorithms for SAR image segmentation and target extraction have been proposed. In the case of low contrast and strong interference, BI did the detection processing to extract some target with specific shape in the remote sensing images on the method based on the mathematical morphology theory (BI, 2005). In order to extract airport objects in real aperture radar image, CHEN employed radon transform technique to detect the runway and match the result with SAR imagery (CHEN, 2006). XIA proposed a method for object extraction and classification in SAR imagery using the threshold segmentation and character extraction techniques (XIA, 2005).

In this paper, the authors proposed an algorithm based on grey morphology and sequential nonlinear filtering to extract the water objects in SAR imagery.

2. WATER OBJECTS EXTRACTION BASED ON GREY MORPHOLOGY AND SEQUENTIAL NONLINEAR FILTERING

In the SAR imagery, water area represents as the region which has low lightness. Now, using threshold segmentation method to transform the original image to binary image is mostly adopted to extract low lightness object. Affected by the intense inherent noise, choosing an appropriate threshold automatically is an important and sophisticated theme. Using the method based on hypothesis testing, after interaction many times, the threshold can be obtained.

In this paper, based on the lightness of the water object and the spatial distribution characteristic of it, the method based on image segmentation threshold algorithm is not used. Employed the grey morphology and nonlinear filtering techniques, the author proposes a method to extract the water region in SAR image rapidly and effectively.

From the basic gray-scale morphology operator, we can build up a sequential nonlinear filtering model to extract water objects in SAR imagery.

Gray-scale dilation of f by b, denoted $f \oplus b$, is defined as

$$(f \oplus b)(s,t) = \max\{f(s-x,t-y)+b(x,y) \mid (s-x),(t-y) \in D_f; (x,y) \in D_b\} \quad (2.1)$$

Gray-scale erosion of f by b, denoted $f \Theta b$, is defined as

$$(f\Theta b)(s,t) = \min\{f(s+x,t+y)-b(x,y) \mid (s+x),(t+y) \in D_f;\ (x,y) \in D_b\} \tag{2.2}$$

In Equations (2.1) and (2.2), D_f and D_b are the domains of f and b, respectively. For digital image processing, function f is input image, function b is structuring element, itself a subimage function. At each position of the structuring element the values of dilation and erosion at that point are the maximum value of ($f+b$) and minimum value of ($f-b$) in the interval spanned by b.

Gray-scale dilation and erosion are duals with respect to function complementation and reflection. The general effect of performing dilation on a gray-scale image is twofold:

(1) if all the values of the structuring element are positive, the output image tends to be brighter than the input;

(2) dark details either are deduced or eliminated, depending on how their values and shapes relate to the structuring element.

And for erosion operator, the effect is also dual:

(1) if all the elements of structuring element are positive, the output image tends to be darker than the input image;

(2) the effect of bright details in the input image that are smaller in area than the structuring element is reduced, with the degree of reduction being determined by the gray-level values surrounding the bright detail by the shape and amplitude values of the structuring element itself.

As the water objects in SAR image represents as some consecutive regions consist of pixels with low lightness, we can combine the gray-level dilation and erosion to perform gray-level closing operator. First perform gray dilation to eliminate inconsecutive dark pixels and the water objects were reduced as well; and then perform gray erosion to restore the water objects without reintroducing the details removed by dilation (Easanuruk, 2005; Shih, 1998).

As the inherent strong speckle noise in SAR imagery, we also introduced the order-statistics filters to improve the method (Pitas, 1996). Order-statistics filters are nonlinear spatial filters whose response is based on ordering (ranking) the pixels contained in the image area encompassed by the filter, and then replacing the value of the center pixel with the value determined by the ranking result. Median filter, as the most used order-statistics filter, replaces the value of a pixel by the median of the gray levels in the neighbourhood of that pixel (the original value of the pixel is included in the computation of the median). For certain types of random noise and particularly the pulse noise, they provide excellent noise-reduction capabilities, with considerably less blurring than linear smoothing filters. The speckle in SAR imagery is multiplicative noise, and can be reduced by median filter. The max filter and min filter are also order-statistics filters. The max filter using the 100th percentile results and is useful for finding the brightest points in an image. The min filter is the 0th percentile and is useful to find the darkest points in an image. They are also applicable for water object extraction in SAR imagery.

In this paper, we combine the gray-level morphology and nonlinear order-statistics filter to make the object extraction processing more effectively. We define a specific structuring element, and transform the gray-level morphology operator to nonlinear filter processing. After this, we can employ the sequential nonlinear filter to extract water objects in SAR imagery. Based on equations (2.1) and (2.2), define D_b as the N x N neighborhood, and function b as zero function, that is its values in domain D_b always are zero. So the equations (2.1) and (2.2) can transform to equations (2.3) and (2.4) respectively.

$$(f \oplus b)(s,t) = \max\{f(s-x,t-y) \mid (s-x),(t-y) \in D_f;\ (x,y) \in D_b\} \tag{2.3}$$

$$(f\Theta b)(s,t) = \min\{f(s+x,t+y) \mid (s+x),(t+y) \in D_f;\ (x,y) \in D_b\} \tag{2.4}$$

So we can transform the gray-level dilation processing to max filter operator, and gray-level erosion to min filter. In this paper, we combine the nonlinear filters to build up a sequential nonlinear filter model. First we use max filter to eliminate inconsecutive dark pixels in SAR image, and the water object with consecutive distribution also be reduced as well. Second, we employed the median filter to reduce the speckle noise. Finally we use the min filter to restore the water objects which were reduced in the first step. In this paper, the size of neighbourhood is 3x3. We can also perform the max filter several times in series, and perform min filter the same times as well. After these steps, we can get water objects in SAR imagery and remove almost all the non-water objects.
Employed this sequential nonlinear filter algorithm, we can extract low lightness pixels region effectively, and most of these region are water objects. But it also contains some non-water objects, such as airport, roads, etc. So we need the advanced processing to select the water objects from the filter results automatically.

3. WATER REGION MODEL AND WATER OBJECT AUTOMATIC SELECTION

After the processing of sequential nonlinear filter, we can get the low lightness targets in SAR imagery. It is necessary to mark the targets regions and select the water objects from the filter results automatically. As the lightness of pixels in water region is very low, first we can set the pixels which lightness over some specific level (in this paper we select the middle level 128) to background lightness 255; and then employ the region grow algorithm to mark all the regions in the result image.

For automatic selecting the water targets, we need calculate some characteristic of the marked regions. In this paper, we calculate the area value, average gray level and the histogram of every marked region. And based on the characteristic of SAR image and knowledge of water object, we build up the water objects model with the following rules:

(1) Area rule: regard the region which area less than some specific value as non-water region.

(2) Lightness rule: regard the region which average lightness or the lightness of the peak of histogram over some specific value as non-water region.

(3) Histogram distribution rule: as the water region consist of most low lightness pixels and some noise pixels, its histogram should has a single peak in the left side. Therefore, we build the histogram distribution rule regarding the region can not accord with all the following conditions as non-water region: (a) gray level of the histogram peak less than the average gray of region; (b)the number of pixels with gray level of the histogram peak more than 10 percent of total pixels in the region; (c) the number of pixels with gray level ranging from the histogram peak to the peak level plus 5 more than 60 percent of total pixels in the region (d) the number of pixels darker than the histogram peak level less than 1 percent of total pixels in the region.

Based on these rules and the characteristic of regions, we can select the water objects automatically. The Figure 1 is the flowchart of the approach proposed in this paper.

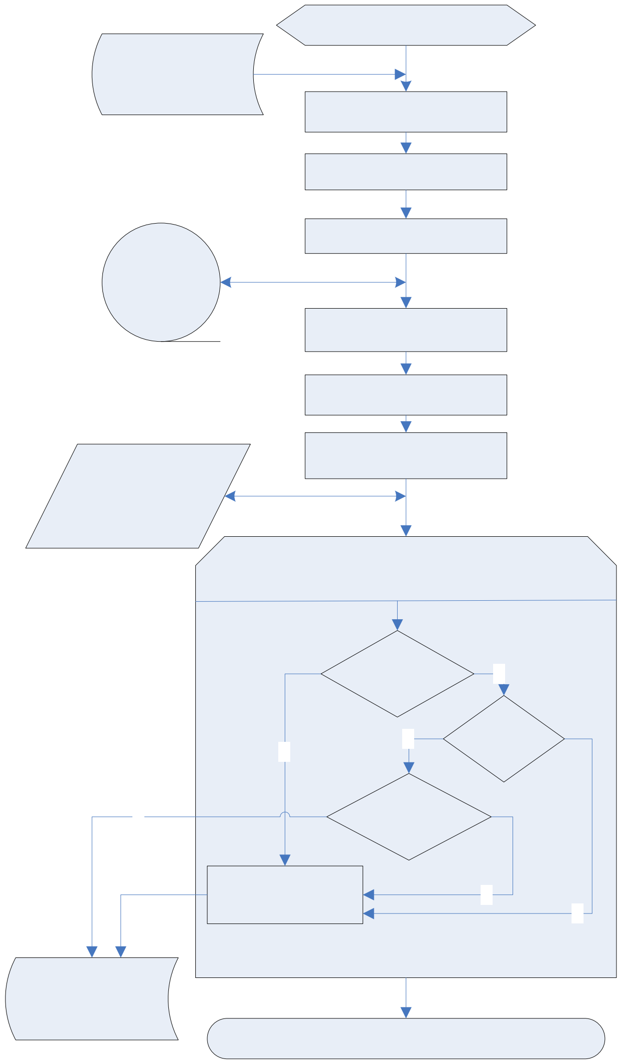

Figure 1. Flowchart of the proposed approach

4. EXPERIMENTAL RESULTS

We do experiments using the Wujiang SAR image which has water region, airport region and mountains. The result proved that the method proposed in this paper is feasible and valid, and the water object in the SAR image can be extracted rapidly and efficiently. Figure 2 is the original SAR imagery region (512 x 512). Figure 3 is the result image after the sequential nonlinear filtering. Figure 4 is the result after water object selection automatically. Figure 5 is the water objects extract by algorithm proposed in this paper.

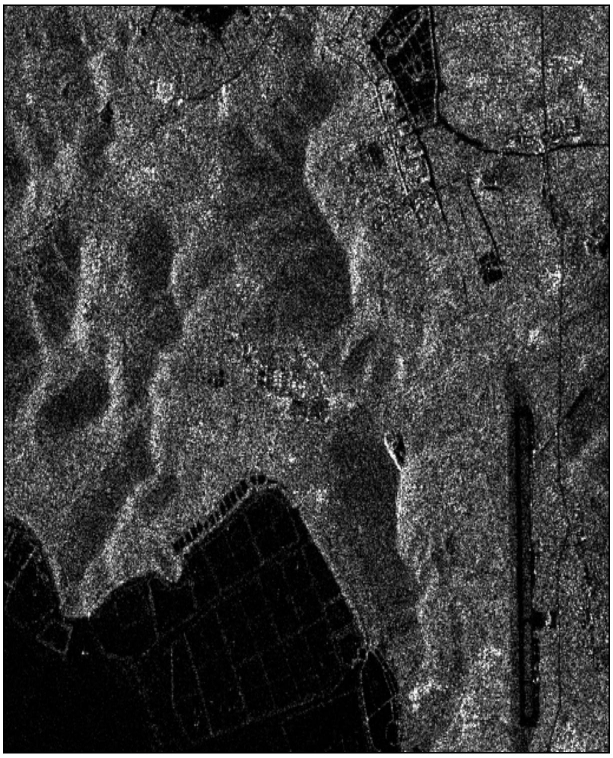

Figure 2. Original SAR imagery

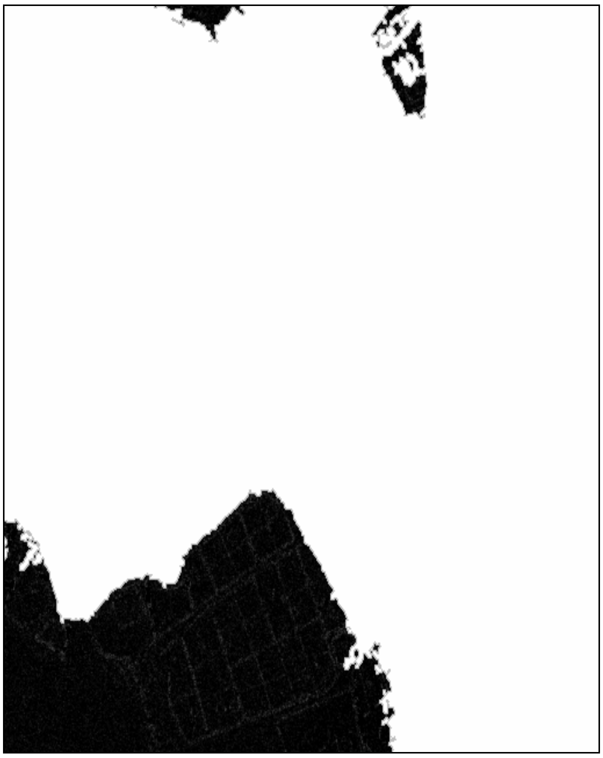

Figure 4. Result imagery after water object selection

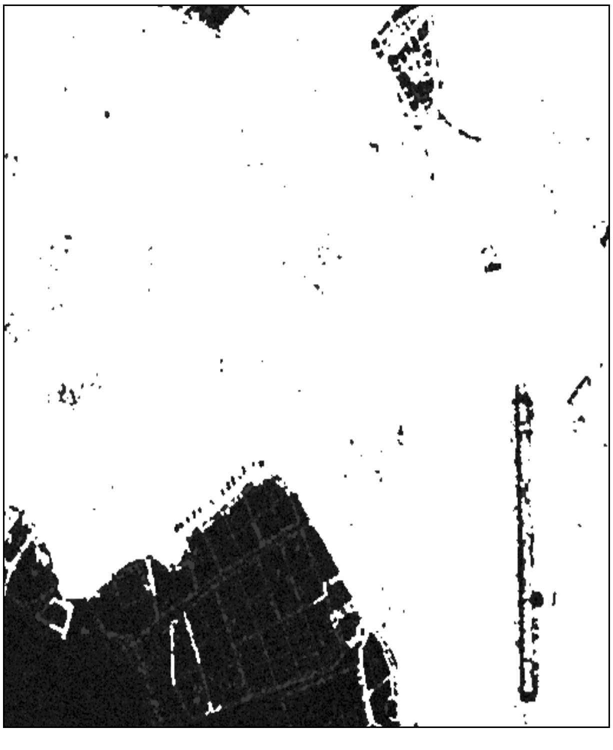

Figure 3. Result imagery after sequential nonlinear filtering

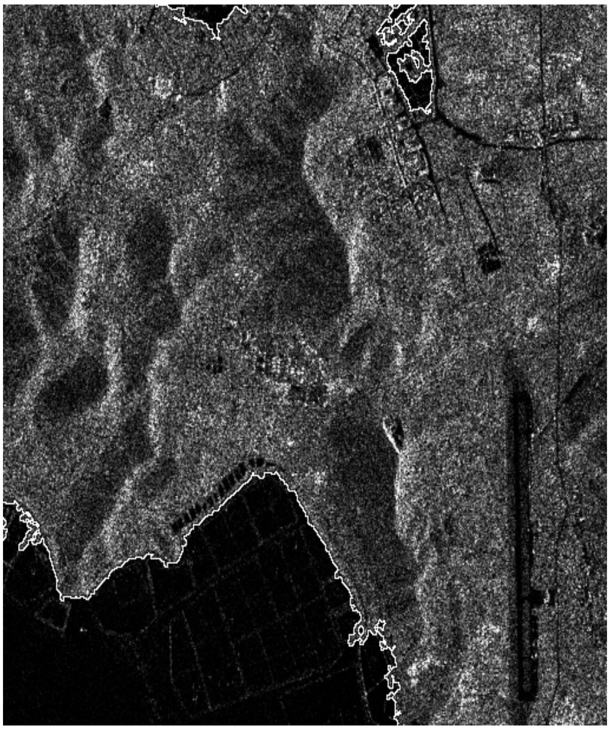

Figure 5. Water objects in SAR imagery

5. CONCLUSIONS

Based on the characteristic of water target, we proposed a method employing sequential nonlinear filter technique to extract water objects in SAR imagery, and make experiments using real SAR imagery. The results show that this approach can extract water objects in SAR imagery effectively and rapidly. For further research, we can calculate more characteristic parameters of region, and apply this algorithm to other low lightness objects extraction in SAR imagery.

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