A MULTI-THRESHOLD BASED MORPHOLOGICAL APPROACH FOR EXTRACTING COASTAL LINE FEATURE IN REMOTE SENSED IMAGES

Qu Jishuang, Doctor Student, **Wang Chao**, Director

Institute of Remote Sensing Applications, Chinese Academy of Sciences, Beijing, China. 100101
milan09@vip.sina.com, cwang@public.bta.net.cn

ABSTRACT

While executing tasks such as sea surveilling, maritime searching and rescue, sea pollution monitoring utilizing remote sensed images, the coastal line feature should be determined at first. Thresholding methods is a type of simple but valid methods for image segmentation, likewise, they can be used to detect coastal line feature in remote sensed images. However, while conventional thresholding methods used to do it, they are always short of enough discriminating ability to objects' shadow, weak-scattering vegetations, dark artificial buildings, sea gulf blurred by noise along costal line. This paper proposes a multi-threshold based morphological approach, which divides the isolated regions by thresholding detecting into intra-continent, exterior-sea, and along-coastal isolated regions at first, and then utilizes two definitions and morphological operators to process along-coastal regions further so as to improve the detecting accuracy and decreasing false detecting, especially to enhance detecting accuracy for above objects' shadow, vegetations and dark artificial builds. Experiments are executed and the results exhibit the proposed approach possessing better performance than conventional thresholding approach.

1. INTRODUCTION

There are many advantages by utilizing remote sensed data to execute tasks such as sea monitoring, shipwreck rescue, sea pollution monitoring, et, including large area monitored, quickly responding time, much less cost, and so on, by which the efficiency of executing tasks can be improved prominently. Accordingly, optic and SAR data on-board have been used to monitor sea and ocean more and more.

While taking aforesaid application by remote sensed data, an important step to improve efficiency is to automatically extract coastal line feature by computer at first, then take accurate processing on targets in sea (http://www.wins.uva.nl/research/isis). To SAR data, thanks to the different scattering characteristics between water and solid material, intensity threshold method can be validly used to extract coastal line feature, but the result of extracting coastal line will be limited by the resolution and speckle. Optic data, because of its high resolution, even can be used to monitoring stowing away, smuggling besides aforesaid applications. In general, intensity threshold method can still be used to extract coastal line feature validly.

Thresholding method (Sahoo, 1988) is a type of simple but valid method for image analysis and image segmentation (Kohler, 1981), which has been used to process many types of image, including optic images, SAR images, multispectral images, etc. Simultaneously, it has propagated many detailed approaches (Kapur, 1985; Perez, 1987). Thresholding method can also be used to extract coastal feature in remote sensed images. However, if there are some dark regions like pseudo water areas, such as objects' shadow, weakly scattering vegetation, dim buildings along coastal region, some of them will probably be regarded as part of sea by traditional thresholding method, which will result in some false judgments. Nay, noise maybe makes some water area belonging to sea isolate, and result in false judgment.

In general, mathematical morphological operators (Heijmans, 1994) comprise $Erosion$, $Dilstion$, $Open$, $Close$, etc, and they are widely used to segment image, enhance image (Pesaresi, 2001). This paper proposes a multi-threshold based morphological approach to extract coastal line feature in optic remote sensed images. At first, we use conventional gray thresholding approach to extract the base coastal line feature, which is a binary image comprises many complex isolated regions. Then, by defining the region distance, the isolated regions are divided into intra-continent isolated regions A_{iso}^{Cont}, exterior-sea isolated regions A_{iso}^{Sea}, and along-coastal isolated regions A_{iso}^{Coast}. Afterwards, the along-coastal isolated regions A_{iso}^{Coast} are made a further process, that is, area thresholds based on prior knowledge are used to identify A_{iso}^{Coast}'s continent or sea area attribute. A further process by morphological operator $Erosion$ to the minimal-path is taken, which will connect the along-coastal isolated regions belonging to sea area with the main sea area. By it we can improve the accuracy of dividing sea area and continent area, and descend the false judgment rate. Finally, morphological operators $Open$ and $Close$ are used to fill the same attribute, continent or sea, areas, and acquire the accurate costal line feature in remote sensed images.

2. COASTAL LINE FEATURE EXTRACTING BY THRESHOLDING APPROACH

There are different characteristics for light scattering from all kinds of objects, which exhibit different color or intensity information in optic remote sensed images. Intensity threshold approach utilizes the water's dim intensity information to extract coastal line feature.

Assume intensity threshold to be $Thresh$, for optic remote sensed image I, $I(i, j)$ is any one of pixels, then we process $I(i, j)$ as following:

$$I(i, j) = \begin{cases} 255 & if\ I(i, j) >= Thresh, \\ 0 & if\ I(i, j) < Thresh. \end{cases} \quad (1)$$

Empirically, $Thresh$ selects image's mean intensity or its neighboring value, that is:

$$Thresh = mean(I) + \Delta \tag{2}$$

The Δ in equation (2) is $Thresh$'s tuning. The $Thresh$ can also be calculated by Otsu (Otsu, 1979) proposed approach.

By this procedure it's easy to divide the dim intensity main sea area, $main\ A^{Sea}$ and strongly scattering main land, $main\ A^{Cont}$. Of course, in the land area, there are also some dim intensity regions, such as lake, weakly scattering vegetation, and objects' shadow, which will result in some isolated false sea area after threshold processing. Simultaneously, some bays along the coastal line may be isolated as water area because of noise, and island or ships in the sea will form land as isolated points or regions. Similarly, image's noise maybe results in some isolated points or regions, too. So the result by threshold processing will be a binary value image containing main coastal line feature.

In order to extract coastal line accurately, these isolated points or regions must be processed using morphological operators ulteriorly. For the sake of convenient description, in following we will regard all isolated points and regions as isolated regions.

3. UTILIZE MORPHOLOGICAL OPERATORS TO INPROVE EXTRACTING COASTAL LINE FEATURE

Morphological Operators

Suppose structure element as SE. For any one of pixel p of image I, its value is $value(p)$. Assume $N_{SE}(p)$ to be the neighbor region formed by SE operating on pixel p, then the $Erosion$ operation SE acting on p is defined as:

$$Erosion_{SE}(p) = \{\wedge value(p^{'}) \mid p^{'} \in \{p\} \cup N_{SE}(p)\} \tag{3}$$

Similarly, the $Dilation$ operation SE acting on p is defined as:

$$Dilation_{SE}(p) = \{\vee value(p^{'}) \mid p^{'} \in \{p\} \cup N_{SE}(p)\} \tag{4}$$

Then the $Open$ and $Close$ operation by SE operating on pixel p can be defined as:

$$Open_{SE}(p) = Dilation_{SE} Erosion_{SE}(p) \tag{5}$$

$$Close_{SE}(p) = Erosion_{SE} Dilation_{SE}(p) \tag{6}$$

3.1 Judgment to Isolated Regions

Definition 1 *region distance*: Assume two regions A_1 and A_2, not connecting in 4-neighboring mode, P_1, P_2 are one of pixels in A_1, A_2 respectively, and $Conn$ is neighboring connecting mode between pixels, then the ***region distance*** between A_1 and A_2 is:

$$D(A_1, A_2) = \min_{P_1 \in A_1, P_2 \in A_2} (dist(P_1, P_2), Conn) \tag{7}$$

Points P_1^D, P_2^D in A_1 and A_2, the pixels corresponding to ***region distance*** are named ***distance pixels***.

Generally, the $Conn$ parameter in equation (3) selects 8 or 4 neighboring connection, and the *region distance* is zero if A_1 connects with A_2. Apparently, the *distance pixels* P_1^D, P_2^D in A_1, A_2 corresponding to *region distance* are not unique.

It must be confirmed to whom an isolated region A_{iso} belongs before it is erased. We divide these isolated regions as intra-continent isolated region A_{iso}^{Cont}, exterior-sea isolated region A_{iso}^{Sea}, and along-coastal isolated region A_{iso}^{Coast}.

Suppose thresholds of *region distance* as $Thresh_1^D$ and $Thresh_2^D$, then the isolated regions are divided by following formula:

$$A_{iso} \in \begin{cases} A_{iso}^{Cont} & \text{if } D(A_{iso}, main\ A^{Sea}) > Thresh_1^D, \\ A_{iso}^{Sea} & \text{if } D(A_{iso}, main\ A^{Cont}) > Thresh_2^D, \\ A_{iso}^{Coast} & \text{otherwise.} \end{cases} \tag{8}$$

In fact, to intra-continent isolated region and exterior-sea isolated regions, their continent or sea area attribute can be confirmed according to their intra-continent or exterior-sea attribute. However, to an along-coastal isolated region, it needs to confirm its continent or sea area attribute by further judgments. These judgments can be decided by its area characteristic. We regard the as sea area if its area follows a specific range.

3.2 Connecting Isolated Sea Regions

After confirming the intra-continent or exterior-sea attribute of an along-coastal isolated region, if a region belongs to sea area, there is still a work to connect it with the $main\ A^{Sea}$, making it become part of the sea area.

Definition 2 *minimal path*: Assume *distance pixels* P_1^D, P_2^D in regions A_1 and A_2, $Conn$ is the neighboring mode, then the ***minimal path*** is defined as:

$$Path_{\min} = \{Pixels \mid \min(dis(P_1^D, P_2^D, Conn))\} \tag{9}$$

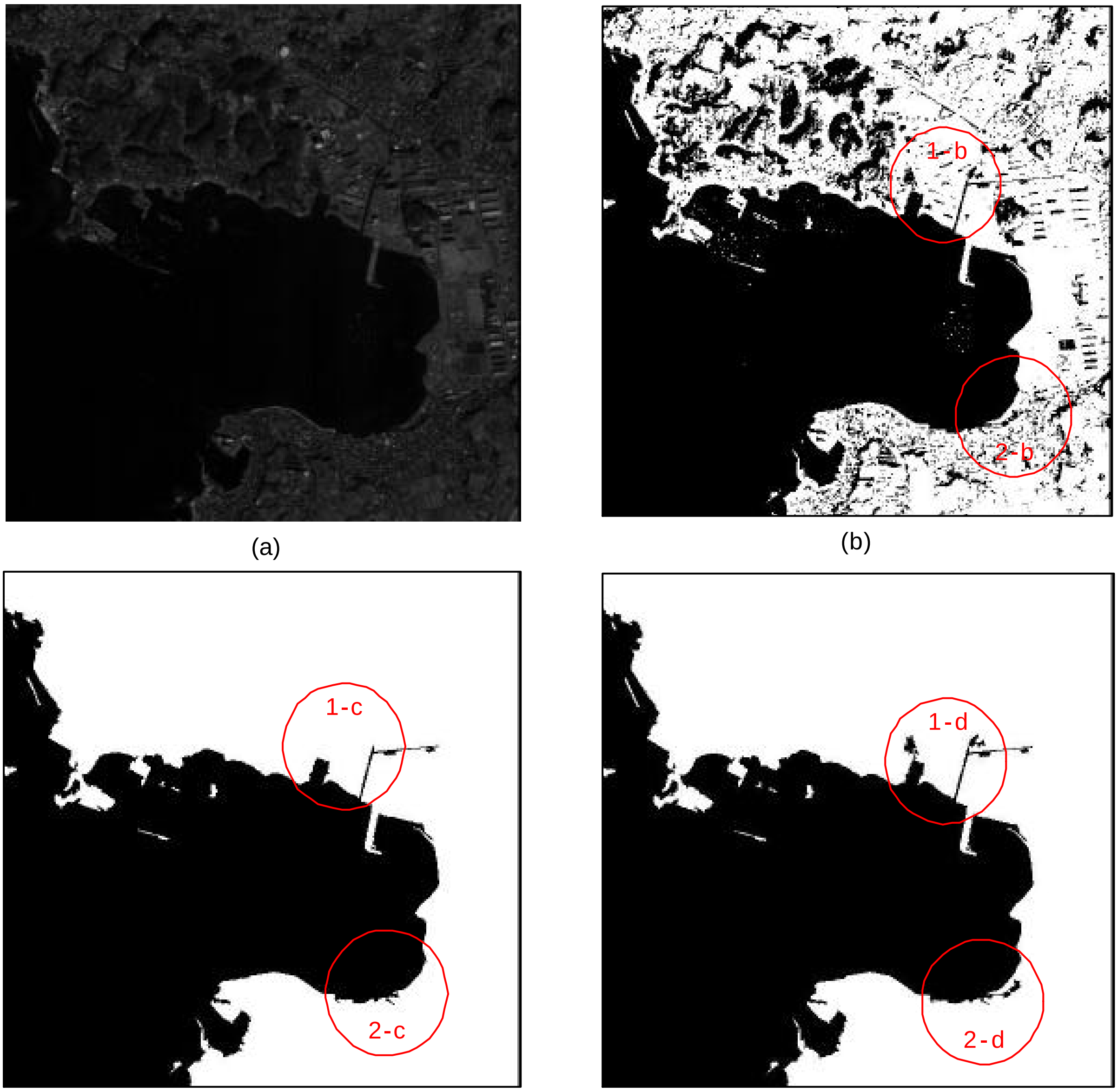

Figure 1 Experiment results for coastal line feature extraction. (a) Source remote sensed image, (b) Binary image after processed by gray threshold approach, (c) Coastal line feature extracted by conventional threshold approach, (d) Coastal line feature extracted by proposed approach.

Then, connecting an along-coastal isolated region belonging to the sea area with the $main\,A^{Sea}$ can be implemented by 'waterlizing' the *minimal path* between the region A_{iso}^{Coast} and region $main\,A^{Sea}$.

3.3 Eliminate Other Isolated Regions

After executing above processing, isolated regions belonging to the sea area have been connected with the main sea area and become a whole sea area. The remaining processing is to eliminate other isolated regions. We can use a region-erasing operator to eliminate them, and make them become part of continent or sea. Assume $Area(\cdot)$ an area operator for the same intensity and connecting region in a binary value image, to an isolated region A_{iso}, suppose its pixels' value is 1 then

$$I = \begin{cases} Open(A_{iso}) & \text{if } value(A_{iso}) = 1 \text{ and } Area(A_{iso}) < Thresh^{O} \\ Close(A_{iso}) & \text{if } value(A_{iso}) = 0 \text{ and } Area(A_{iso}) < Thresh^{C} \end{cases} \quad (10)$$

The $Thresh^{O}$ and $Thresh^{C}$ in equation (10) are area thresholds for $Open$ and $Close$ operation respectively.

After processed by foresaid steps, the coastal line feature in an optic remote sensed image will be extracted accurately.

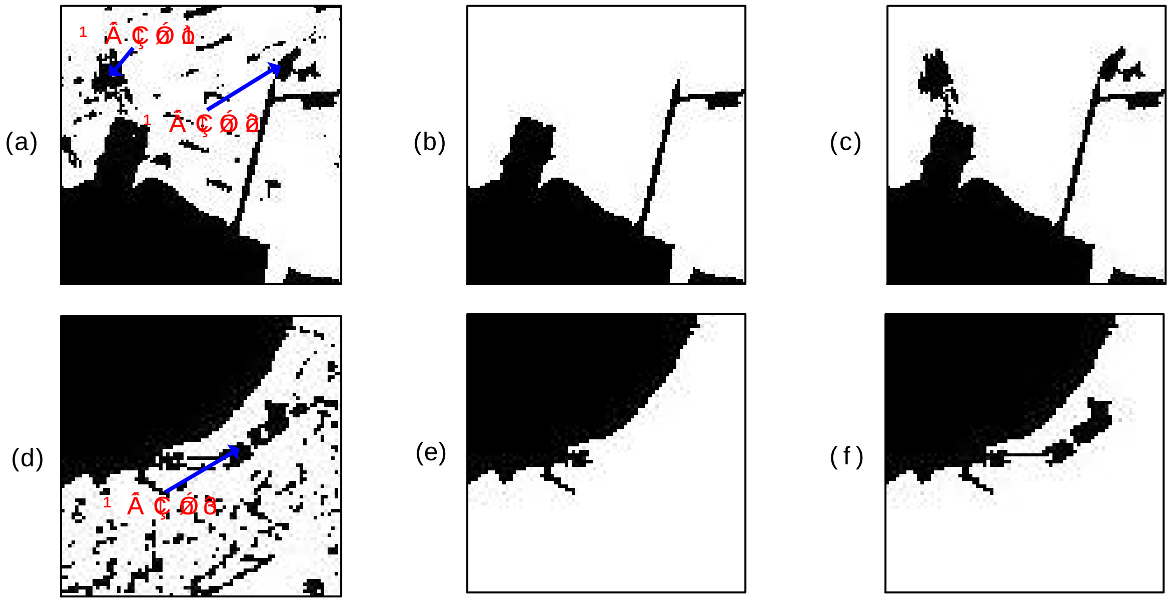

Figure 2 Enlarged results of 1 and 2 regions labeled in figure 1-(b), 1-(c) and 1-(d). (a) Enlarged region of 1-b, (b) Enlarged region of 1-c, (c) Enlarged region of 1-d, (d) Enlarged region of 2-b, (e) Enlarged region of 2-c, (f) Enlarged region of 2-d.

4. EXPERIMENTS AND RESULTS ANALYSIS

In order to validate the proposed approach, a experiment has been taken on a remote sensed image. Here we set A_{iso}^{Sea} and A_{iso}^{Cont} 's region distance $Thresh_1^D$, $Thresh_2^D$ to 2 pixels, the connection mode $Conn$ of region distance and minimal path to 4-connection. The $Open$ operation's area threshold is 16 pixels, and the $Close$ operation's area threshold is 50,000 pixels.

Figure 1 exhibits the experiment's source image and results. Figure 1-(a) is the source remote sensed image comprises continent and sea, and there are very complex regions along the coastal line. Figure 1-(b) is the binary image after processed by gray threshold approach, which shows a very complex binary image rather than a simple image just consisting of single continent and sea regions. Figure 1-(c) is a coastal line feature extracted by conventional threshold approach, while Figure 1-(d) is the coastal line feature extracted by proposed approach. In figure 1-(b), 1-(c) and 1-(d), there are two corresponding regions labeled 1-b, 2-b, 1-c, 2-c, and 1-d, 2d, which are two regions regarded as continent by conventional threshold approach, see 1-c and 1-d in figure 1-(c), however, are identified correctly by our proposed approach, see 1-d and 2-d in figure 1-(d).

Figure 2 shows the enlarged results of 1 and 2 regions labeled in figure 1-(b), 1-(c) and 1-(d). Figure 2-(a) is enlarged region of 1-b, figure 2-(b) is enlarged region of 1-c, figure 2-(c) is enlarged region of 1-d; Similarly, figure 2-(d) is enlarged region of 2-b, figure 2-(e) Enlarged region of 2-c, and figure 2-(f) is enlarged region of 2-d. From figure 2, the three isolated regions acquired by gray threshold approach are regarded as continent area falsely so that the coastal line feature's accuracy is crippled. The proposed approach in this paper identifies these false and corrects the results. Accordingly, a more accurate coastal line feature is extracted.

5. CONCLUSION AND FUTURE WORK

In this paper, a multi-threshold based morphological approach is addressed to extract coastal line feature from optic remote sensed images. Conventional thresholding approach is simple and valid for image segmentation. However, it will result in any false division to objects' shadow, weakly scattering vegetation, and dark buildings. By several morphological operators, simultaneously, proposing two definitions, region distance and minimal path, the proposed approach is proved to possess more accurate result than conventional threshold approach, which is validated by an experiment.

While multiple thresholds being used in the proposed approach, how to decide them adaptively is another important aspect needed to solve. Appropriate thresholds selection will provide optimized results (Nakagawa, 1979; Wang, 1984).

Thanks to the apparent comparison between water area and land in radar remote sensed image, data fusion methodology for optic images and SAR images can be used to extract coastal line feature, by which the advantages in every kind of data can be integrated and the result can be improved observably.

ACKNOWLEDGEMENTS

This work was completed by the help of Liu Zhi, Guo Ziqi, Gaoxing, Zhang Hong, Zhang Weiguo, Ge Jianjun, members of Radar Group, Remote Sensing Information Key Lab of Institute of Remote Sensing Applications, Chinese Academy of Sciences. Here the authors express thanks to them.

REFERENCES

Heijmans, H. J. A. M. (1994). *Morphological image operators*. Academic Press, Boston. http://www.wins.uva.nl/research/isis.

Kapur, J. N. Sahoo, P. K. and Wong, A. K. C. (1985). A new method for gray level picture thresholding using the entropy of histogram, *Comput. Vision Graphics Image Process*, vol. 29, pp. 273-285.

Kohler, R. (1981). A segmentation system based on thresholding, *Comput. Vision Graphics Image Process*, vol. 15, pp. 319-338.

Nakagawa, Y. and Rosenfeld, A. (1979). Some experiments on variable thresholding, *Pattern Recognition*, vol. 11, pp. 191-204.

Otsu, N. (1979). A threshold selection method from gray-level histograms, *IEEE Transactions on Systems, Man, and Cybernetics*, vol. 9, no. 1, pp. 62-66.

Perez, A. and Gonzalez, R. C. (1987). An iterative thresholding algorithm for image segmentation, *IEEE Pattern Analysis Machine Intelligence*, vol. 9, pp. 742-751.

Pesaresi, M. and Benediktsson, J. A. (2001). A new approach for the morphological segmentation of high- resolution satellite imagery, *IEEE Transactions on Geoscience and Remote Sensing*, vol. 39, no. 2, pp. 309-320.

Sahoo, P. K. Soltani, S. Wong, A. K. C. and Chen, Y. C. (1988). A survey of thresholding techniques, *Comput. Vision Graphics Image Process*, vol. 41, pp. 233-260.

Wang, S. and Haralick, R. M. (1984). Automatic multithreshold selection, *Comput. Vision Graphics Image Process*, vol. 25, pp. 46-67.