ROAD EXTRACTION FROM SAR IMAGE USING AN IMPROVED STATISTICAL ALGORITHM

M. Cheng[a, *], Q. Ye[a,b]

[a] Department of Surveying and Geo-informatics, Tongji University, Shanghai, 200092, China - cmyxl@163.com
[b] The Center of R&S and Spatial Information Technical Research, Tongji University, Shanghai, 200092, China – yeqin@mail.tongji.edu.cn

Commission Ⅲ, WG Ⅲ/5

KEY WORDS: Road extraction, Feature extraction, SAR image, Speckle statistics, Phase grouping

ABSTRACT:

An efficient statistical algorithm of automatic extracting road from SAR images is devised in this paper. First, an feature detecting operator is used to find the road candidate. Then another smaller operator which calculating the homogenous statistic of locate region is applied to reduce the false alarm and smooth the road edge. Finally, the road linear features are extracted by fusing the results of these two operators, and a phase grouping method is used to combine the road linear features. We apply this algorithm to a RadarSat image to illustrate the accuracy and efficiency, and the performance is satisfied.

1. INTRODUCTION

The technique of extracting road from SAR images is widely applied in many fields, such as road positioning and transportation planning. The road detection requires an algorithm with high accuracy and efficiency. The traditional artificial recognition method has been limited to its very low efficiency, although the road network can be extracted with high accuracy. Automatic or semi-automatic extraction has been a research subject these years, many efficient approaches have been proposed to deal with the road detection from SAR images.

Generally speaking, these road detecting methods can be divided into two steps: Firstly, using the edge-detecting operators such as difference operator, Canny operator etc to calculating the intensity of the neighborhood area of the target pixel. Secondly, a global method about the prior knowledge of the large range structure is introduced to build up a large span linear structure with the linear segments calculated by the first step(Chen, 2003). However, the disadvantages such as false alarm and linear fractions appear after the extraction due to the presence of speckle and the non-stationarity of the image data.

In this paper, an almost automatic algorithm including two operators based on the statistical character of the road area is devised to detecting the road linear features. The contrast and homogeneity of the road area and the background are taken into consideration. The influence of the multiplicative speckle noise is effectively controlled and this algorithm can detect the road linear features with high accuracy and efficiency.

2. STATISTICAL PROPERTY

The road extraction from SAR image is subject to the multiplicative speckle noise because of the coherent nature of the radar. The speckle noise in SAR images complicates the character of the histogram and makes automatic road detecting by threshold segmentation difficult(Lee, 1989). Thus the statistical property of road area is usually been taken account into the extraction, and we shall discuss it next.

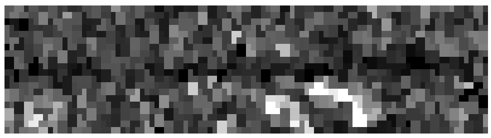


Figure 1. A image with a straight road in the center

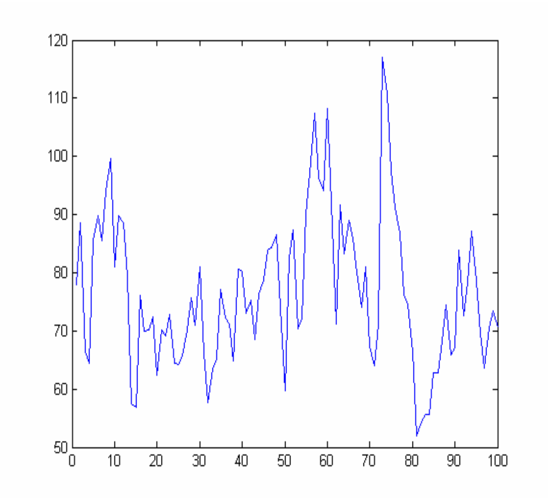
A small image including an almost straight road and its background area is intercepted from an integrated SAR image, and its width and height are 100 and 20, respectively. The road is located in the center of this image, parallel to the horizontal direction. Calculating the pixel gray value summation of every column, the relationship of abscissa and its corresponding summation is described in Figure 2(a). The relationship of ordinate and its corresponding summation is described in Figure 2(b).

In the horizontal direction which is parallel to the road direction, the summation is mainly distributed between 60 and 80. There exists some peaks and troughs as a result of the speckle noise effect. In the vertical direction which is perpendicular to the road direction, the summation of the center road area is lower than that of the around. Based on this two drawings, we can reach the conclusion that the pixel gray value of the road is lower than that of its two neighborhood. It indicates that the road is more black than the background.

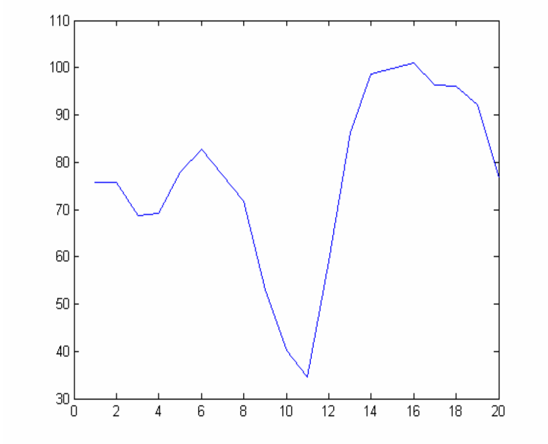
To investigate the differences between the road area and its background, five images whose size are 5×5 is intercepted from the area completely belonging to the road, and another five are from the background. The expectation and variance of each

* Cheng Mingyue. EMail:cmyxl@mail.tongji.edu.cn .Tel: 86-21-65981710

image are calculated and recorded in the Table 1. The expected of the road's gray value is much lower than that of the background in despite of the speckle noise effect, and it is always below 80. Meanwhile, the variance of the road is also much more lower than that of the background. Thus, another conclusion can be made that the road area is more homogenous than its background.



(a) Horizontal direction



(b) Vertical direction

Figure 2. Relation of the gray value sum and coordinate

Road	1	2	3	4	5
E	30.6	54.52	13.12	19.24	41.16
V	6.29	10.25	3.22	4.54	7.68
Non	1	2	3	4	5
E	173.84	134.96	195.24	107.72	154.12
V	32.77	24.94	35.88	20.29	28.73

Table 1. The expectation and variance of the road and non_road area(E: expectation, V: variance)

3. ROAD LINEAR FEATURE DETECTOR

In order to reduce the influence of the multiplicative speckle, the method proposed in this paper is based on the gray statistical property we discussed in the previous section . An almost automatic algorithm is devised with the assumptions that: 1) There is obvious contrast between road and its background; 2) The road itself is homogenous; 3) Road area is more homogenous than its neighborhood when taking the road candidate into account.

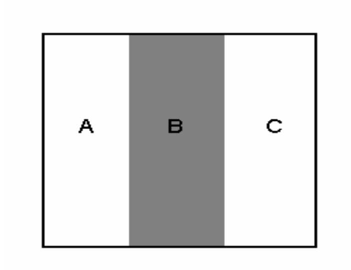


Figure 3. The edge detector

According to the first assumption, the local structure model of the road area is formed by three paralleling parts shown in figure 3 from which we can see that B represents the road area whose center is the target pixel while A and C represents the surrounding background area(Touzi, 1989; Geling, 1993). By computing the summation of the pixel gray value of each area and the average ratio of the road area to the background area according to formula (1)

$$R_1 = \frac{\sum_{i=1}^{n} B_i}{\sum_{i=1}^{m} A_i}, \quad R_2 = \frac{\sum_{i=1}^{n} B_i}{\sum_{i=1}^{m} C_i} \qquad (1)$$

we can get R_1 and R_2. If $R_1<1$ or $R_2<1$, then the central pixel of area B is a road candidate point. This operator can be used in 4 or 8 directions, the minimum value is chosen to be the best response. The first operator replaces the target pixel's own gray value with its neighborhood gray value and thus controls the speckle noise influence to the road extraction effectively.

While on the other hand, the replacement of target pixel's gray value by its neighborhood's will certainly lead to wrong detection, regarding the non-road pixel along the road edge as road candidate which also lead to the road fracture. In the previous part of this article, we discussed the statistical property of the road in SAR images, and concluded that the road area is homogenous in SAR images and is more homogenous than the background area in the meantime. In order to solve the previous problem, a statistic is introduced to describe the homogeneity of the imagery. Chose a 3×3 or 5×5 window with the target pixel at the center and calculate the variance(D) of this area, then we can get R3 by formula (2).

$$R_3 = \sqrt{\frac{1}{D}} \qquad (2)$$

As there are some homogenous areas in parts of the background, we take the pixel gray value(P) into consideration and get R4 by formula (3).

$$R_4 = 1 - \sqrt{\frac{P}{255}} \tag{3}$$

While traversing with the second operator, it should be noted whether the target pixel is a road candidate point. For candidate points and non-candidate points, different weights(λ) should be attached. Thus, we can get detector R for roads' linear characteristic extraction by formula (4).

$$R = R_1 \bullet R_2 \bullet R_3 \bullet R_4 \bullet \lambda \tag{4}$$

Whether a pixel point is a road point or not is decided by a threshold value T. if R>T, then it is a road point.

4. CONNECT THE LINEAR FEATURES

The road linear features are detected by the feature detector devised in the previous section. However, these linear features are always short and dispersed road segments. Effective method should be found to compose the segments to obtain significant road curves. The method in this paper mainly includes three steps(Xie, 2007): Firstly, mark every segment of the road. That is to mark the points which belong to the same road in a small area to obtain a structural body of this road. Secondly, do further connection with these segments on the basis of some particular rule. Finally, add constraint to look for the best connection method.

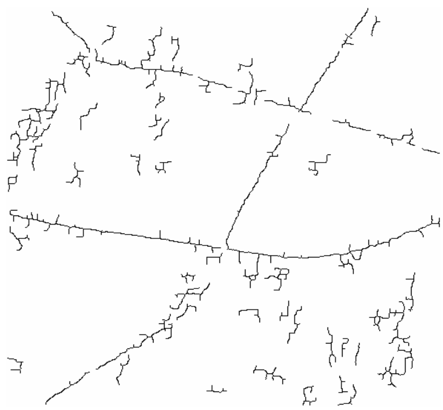
Generally speaking, slender segments are more likely to be a part of a road, while the isolated points and smallish segments are tend to be fake detection or other line-similar segments(Zhang, 2007). Also because the road are all continuous, near one segment there should be another segments which have the same direction with it. According to these two features above, applying two measures of the region area and the oblateness ($T_f = 4 \cdot \pi \cdot Area/(perimeter)^2$) to screen the road segments and keep only the reliable ones. Give the area thesholding value *Ta* and the oblateness thesholding value T_f. If the area of the road segment is smaller than *Ta* and the oblateness is bigger than T_f, and also there are no close segments in the same directions around it, then this segment should be recognised as non road segment.

Every segment obtained has its starting point and end point. It is defined that the starting point is the most left-superior or left-inferior one, while the end point is the most right-superior or right-inferior one. If the segment is vertical, then its starting point is the lower one and the end point is the upper one. It is a natural choice that to connect adjacent segments into a line. It improves the description of the linear character of detected segments, and simplifies the relationship between them. Therefore the straight line segments will be the foundation of the following organising work. All the line segments obtained in the linear feature detection have their own direction. If two adjacent segments have similar direction, then we consider these two segments to be on the same line. Thus we shall get the linear road by connecting two segments based on this phase grouping method.

5. EXPERIMENT

In this paper we experimentized a RadarSat image including road area taken in Tangshan, Hebei province, size of which is 512×512. Using the method putting out in this article to extract the road from SAR image, and then do erosion, expantion and thinning, we can get results shown in Figure 3(b).

(a) Original



(b) Result

Figure 3. Experiment images

Almost all the main roads are extracted form the SAR image using our method, especially the straight roads are extracted continuously and smoothly. However, there are some road fractions because of the lack of information. Based on the result, we can get that：

1) The method can effectively control the influence of the multiplicative speckle noise, especially when the background is unhomogeneous.

2) The extraction effect is better in the area in which the road is long and not very curving, as well as the linear fractions are less than the curving road.

3) Threshold has played an important role in the extraction. Especially to the first operator, the threshold should be large enough to reserve the most possible road candidate, however, it results in a higher probability of false alarm.

6. CONCLUSION

Compared to the traditional methods, our method has an advantage in detecting roads from SAR images with higher accuracy. The homogeneous factor of road and its background is introduced into the algorithm, as a result, the extraction of road edge becomes smoother. On the other hand, the extraction doesn't become computational complexity along with this introduction. Hence, the algorithm proposed in this paper is suit for the road extraction from SAR images.

REFERENCES

Chen, Y., 2003. *Digital Photogrammetry for Remote Sensing Image*. Tongji University, Shanghai, pp. 150-155.

Geling, G., 1993. An edge detection operator for SAR images. *Canadian Conference on Electrical and Computer Engineering* , 2, pp. 707-709.

Lee, J., 1989. Segmentation of SAR images. *IEEE Transaction on GeoScience and Remote Sensing*, 27(6), pp. 674-680.

Touzi, R., 1988. A statistical and geometrical edge detector for SAR images. *IEEE Transaction on GeoScience and Remote Sensing*, 26(6), pp. 764-773.

Xie, F., 2007. Road extraction from RS imagery based on wavelet and mathematical morphology. *Computer Engineering and Applications*, 43(22), pp. 241-243.

Zhang, S., 2007. Edge detection for SAR image based on Least Square Support Vector Machine. *Measurement & Control technology*, 26(11), pp. 61-63.