# STUDY ON A MATCHING METHOD OF AIRBORNE SAR IMAGES

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**ABSTRACT:**

As an important step and technical nodus of synthetic aperture radar (SAR) image applications, image match is an important process in which the corresponding relations of pixel points between many SAR images can be got. Usually, the accuracy of image match directly affects the next operations of SAR images. Nowadays, image match methods can be mainly divided into two kinds: one is based on region and the other one on characteristic. The former usually uses normalization cross-correlation as a matching measure, so these methods aren't good enough to meet the requirements of SAR images or multisensor image match. And the latter mainly uses common characteristics from two images to make image match. Generally speaking, point characteristics are affected by noises much more. Given the coherent speckle noises of SAR images, it is better to make image match using edge or outline characteristics. Considering these problems, a new match method and flow of SAR image pairs based on edge detection and "virtual epipolar" are proposed and researched in this paper. First of all, a new edge detector, combined by Canny operator and Ratio operator, is used to generate edge information. In order to improve the matching speed and quantitatively analyze the results, some edge points with more obvious characteristics are obtained by Moravec operator which can be regarded as a base points set. Next, in order to find the corresponding points faster, a search strategy based on "virtual epipolar" is proposed and established. In the third step, using edge information combined with gray-level information of the image as the matching measure, the corresponding points are searched along the "virtual epipolar" line. To get rid of the wrong corresponding points, a quadratic polynomial method is used. At last, experiments have been conducted on airborne SAR image pairs with 1m resolution in Chengdu, China. As a result, the match method based on edge detection and "virtual epipolar" line studied in this paper is feasible, and the matching accuracy and velocity have improved much more than some other methods.

## 1. INTRODUCTION

Synthetic aperture radar (SAR) -commonly known, is an active microwave imaging system. Due to its working capability in all weather and all time, it is much more suitable for topographic mapping and targets detective in such areas with atrocious weather. In order to get more information from SAR images, a lot of SAR image processing methods have been developed. As an important step and technical nodus of SAR image applications, image match is a process in which the corresponding relations of pixel points between many SAR images can be got. The accuracy of image match directly affects the next operations of SAR images. Nowadays, image matching methods can be mainly divided into two kinds: one is based on the region and the other one on the characteristic[1]. Generally speaking, SAR image pairs are possibly captured in different time, with different angles of view and working bands, and even different carriers. Therefore, there are more speckle noises and bigger geometric distortions in SAR image pairs, for which the regional matching method is not suitable. However, the latter method that mainly uses common characteristics of images (for example: edge information, shape information, feature points and so on) to make image matching is much more suitable for SAR image pairs. Considering these problems, a new match method and flow of SAR image based on edge detection and "virtual epipolar" are proposed and researched in this paper. The main contents can be described as follows: (1) A new edge detector, combined by Canny operator and Ratio operator, is used to generate edge information; (2) In order to find the corresponding points faster, a search strategy based on "virtual epipolar" is proposed and established; (3) To get rid of the wrong corresponding points, a quadratic polynomial method is proposed.

## 2. EDGE DETECTION

Due to the particular imaging mechanism, there are more differences in SAR and optical image. Generally, in SAR image, the signal strength is larger which can induct more multiplicative noises. Even in the homogeneity areas (rice paddy, dry land, etc.), the reflecting signal intensity of same object in different position is usually different. Therefore, the classical edge detection operators, such as Roberts, Laplacian, Canny and so on, are not suitable for SAR image. Ratio operator, as the most typical edge detection algorithm of SAR image, which regard the regional gray average as the detecting character value, can availably avoid the disturbance of noises and get a higher precise, but the edge line is wider[2]. Therefore, in this paper, a combination of Ratio and Canny operator is made to improve the edge detector of SAR image.

### 2.1 Canny Detector

In 1986, Canny proposed three criterions to estimate the edge detector [3]: (1) low error rate, namely, should not leak edge pixel and also not obtain non-edge points; (2) high precise of detecting position, that is, the edge points detected should be in

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the actual centre as far as possible; (3) the points detected are relative with the actual edge points one by one, it is also to say that the width of edge should be a single pixel.

Canny detector uses the first order gauss differential coefficient to seek good balance between noise abatement and the edge detection, and its expression is similar to first derivative of gauss function. Suppose *G(x,y)* as the two-dimensional gauss function, and *f(x,y)* as the image, the edge intensity and direction of Canny detector can be obtained as follow expressions:

$$\text{Edge intensity}: C(x,y) = |\nabla G * f(x,y)| \quad (1)$$

$$\text{Edge direction}: n = \frac{\nabla G * f(x,y)}{|\nabla G * f(x,y)|} \quad (2)$$

However, there is no CFAR (constant false alarm rate) in SAR image for Canny detector, and the CFAR in high-brightness area is higher than low-brightness area. Therefore, Canny detector can't be used in SAR image edge detection directly [4].

## 2.2 Ratio Detector

Touzi and his partners proposed that there is a CFAR characteristic for Ratio operator in Gamma distribution coherent speckle[5],and using this algorithm to generate SAR image edge can get a higher precise. The main principle can be described as follows: in the glide detection window, getting the central pixel point as the detecting object, calculate the sample averages $u_1$ and $u_2$ in non-overlapping region of both sides along a certain line direction which passes this point (Note: suppose that the image data are 32 - bit intensity values; if the actual data are the 16 - bit range values, their mean square values should be used). Calculate the ratio(R) of two averages, and choose a smaller value larger than one from R and $R^{-1}$ as r. By the definition, we can know that if r tends to one, the average values of two regions are closer, and the objects of two areas are more likely same; Otherwise, if r tends to zero, the objects of two areas are more likely different, and the point to be detected maybe at the edge of two regions.

Given the edge different orientations, along four directions shown in Figure 1, each point should be detected, and reserve the smallest r value as the result. The neighborhood of Ratio operator shouldn't too big, because the bigger neighborhood can only detect the wide edge. As a rule, the neighborhood of Ratio operator is 5×5. The edge intensity and direction of Ratio detector can be obtained as follow expressions:

$$\text{Edge intensity}: \quad R_L = 1 / Min(r) \quad (3)$$

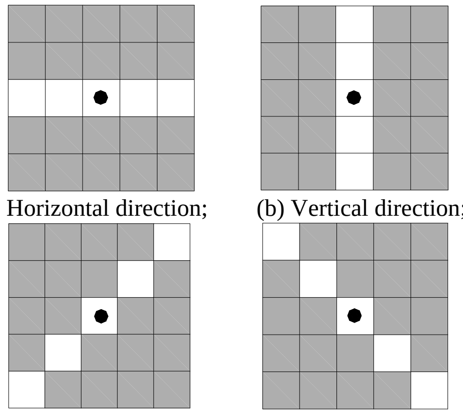
Edge direction: normal direction of corresponding straight line L

## 2.3 The Integrative Edge Detector

In order to make the edge detector with CFAR and a good direction, the edge direction can be calculated separately. Whether the edge operator with CFAR or not is determined by edge intensity. Therefore, the new detector using Ratio operator to calculate edge intensity and Canny operator to calculate edge intensity, which can be described as follows[4]:

$$\text{Edge intensity}: \quad R_L = 1 / Min(r) \quad (4)$$

$$\text{Edge direction}: n = \frac{\nabla G * f(x,y)}{|\nabla G * f(x,y)|} \quad (5)$$



(a) Horizontal direction; (b) Vertical direction;

(c) Right-leaning 45 degrees; (d) Left-leaning 45 degrees

Figure 1 Four different detecting directions of Ratio operator

## 3. ESTABLISHMENT OF "VIRTUAL EPIPOLAR" FUCTION

In computer vision field, epipolar is called "the polar line", and plays an important part in stereo process of remote sensing. However, due to the difference of imaging mechanism between SAR and optical image, it is difficult to understand when epipolar surface and epipolar line are established in SAR images. However, during making geometry rectification or generating DEM by SAR images, oblique distance projection can be transformed to central projection, and then "equivalent collinear equations" of SAR images can be established. In this condition, SAR images can build their own "equivalent epipolar equations" as the optical images to be used in image match. To distinguish the definition of "epipolar" in optical images, "virtual epipolar" line is called in this paper.

Many methods can be used to confirm the "epipolar ", and they are mainly divided into two kinds: one is based on the geometric correction of digital image; the other one on coplanar conditions[6]. If there are some ground control points, the equivalent elements of orientation can be got by collinear equation, and then the equivalent "epipolar equations" can be established. When it is difficult to get elements of interior orientation or only a part of the image should be dealt with, the RLT (relative orientation linear transformation) algorithm based on coplanar condition can be used to establish corresponding epipolar. Its expression can be described as follows [6]:

$$q = L_1^0 + L_2^0 x + L_3^0 y + L_4^0 x' + L_5^0 xx' + L_6^0 xy' + L_7^0 yx' + L_8^0 yy' \quad (6)$$

Where $L_1^0$ - $L_8^0$ are the equation parameters of "virtual epipolar"; ( $x$ , $y$ ),( $x'$ , $y'$ ) are the same name image coordinates; $q = y - y'$ .

Choose 8(or more than 8) same name control points, calculate the parameters of expression (6) by indirect adjustment method, and establish the "virtual epipolar" equations. If a certain point on the left image is ( $x_i$ , $y_i$ ) and its same name point is ( $x_i'$ , $y_i'$ ), using $x_i'$ to search the $y_i'$ along "virtual epipolar", $y_i'$ can be obtained by the following formula:

$$y_i' = \frac{(1 - L_3^0)y_i - L_1^0 - L_2^0 x_i - L_4^0 x_i' - L_5^0 x_i x_i' - L_7^0 y_i x_i'}{1 + L_6^0 x_i + L_8^0 y_i} \quad (7)$$

The region is also too big while doing search along the whole "virtual epipolar" for every base point, and this will take a long time. So, a dynamic demarcation method [7] can be used to ensure a search area. That is to say the search area of each point is confirmed by the last matching point, whose corresponding point has been got. Meanwhile, there are some errors while choose the control points, so it is necessary to get rid of the bad control points by calculating the residual errors. Furthermore, in order to assure a higher matching precise, the correlation coefficients should be calculated in a certain area around the corresponding point which is found by formula (7), and choose the true match point with the biggest value.

## 4. FILTER THE WRONG MATCHING POINTS

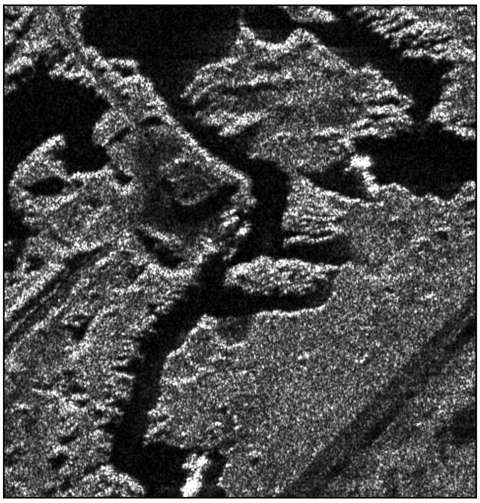
Lots of factors can cause SAR image deformations, and most of which can be corrected by the polynomial method. This method directly simulates the image deformation law by mathematics without considering the sensor imaging model. So, a quadratic polynomial method is proposed to filter the wrong matching points by formula (8) [8]. That is to say, when a matching point is obtained on the right image, using quadratic polynomial method to calculate its position on the left image, and compare with the base point, if beyond the tolerance, this point should be deleted. The polynomial parameters can be got at the same time with the establishment of "virtual epipolar" function.

$$\begin{aligned} x' &= a_0 + a_1 x + a_2 y + a_3 x^2 + a_4 xy + a_5 y^2 \\ y' &= b_0 + b_1 x + b_2 y + b_3 x^2 + b_4 xy + b_5 y^2 \end{aligned} \quad (8)$$

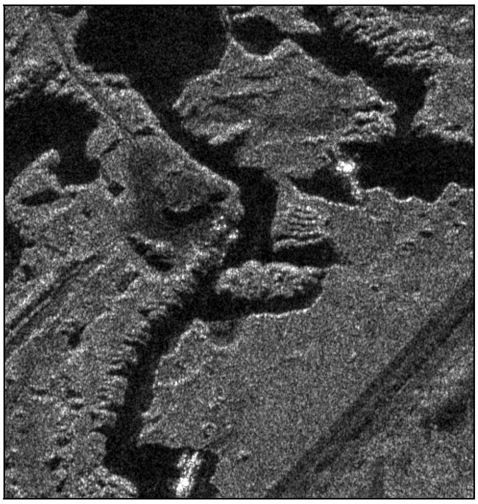
Where ( $x$ , $y$ ),( $x'$ , $y'$ ) are the same name image coordinates; $a_0$ - $a_5$ , $b_0$ - $b_5$ are the polynomial parameters.

## 5. EXPERIMENT RESULTS AND ANALYSIS

The SAR image pairs used for the study, which is shown in Figure 2, are captured in Chengdu at May, 2006. Its resolution is 1 m, the height of platform is about 5620 m, working band is X, and the initial slant is 11437.5m.



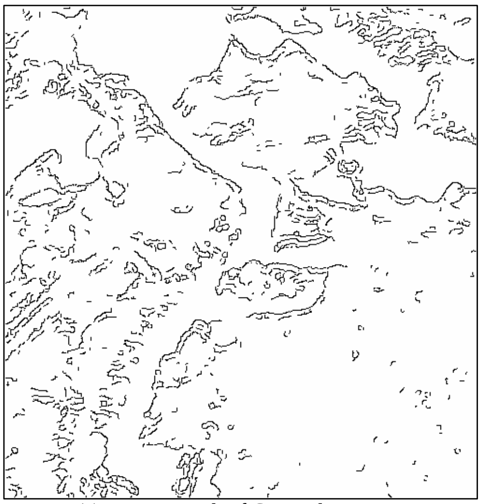
(a) Left image;



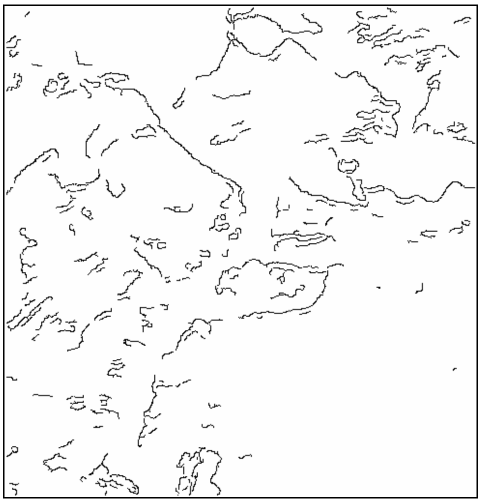
(b) Right image.

Figure 2 Image pairs to be matched

According to the matching flow proposed in this paper, using Canny operator and the integrative operator generated the edge of SAR image pairs separately, for the paper length limited, only the results of right image are shown in Figure 3. The following conclusions can be obtained: the edges generated by Canny operator are bigger influenced by speckle noises, also present more false edges, and the continuity is worse than the integrative operator. In addition, the numbers of edges in the results are relative to the threshold of the integrative detector, including the ratio of higher threshold in Canny operator and the value r in Ratio operator, which are 0.85 and 0.55 in this paper, so a few edges are detected and the continuity is not very well, this shall be improved in the future research.

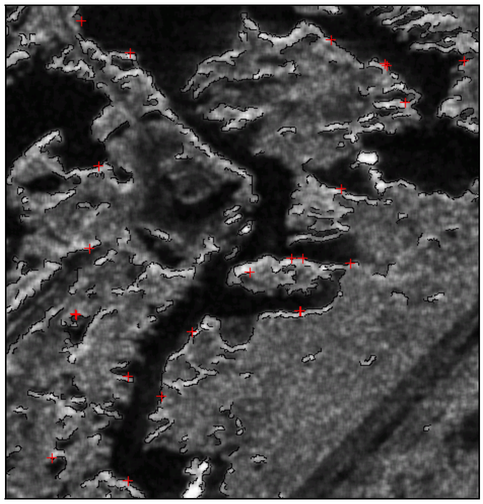


(a) Process result of Canny detector;

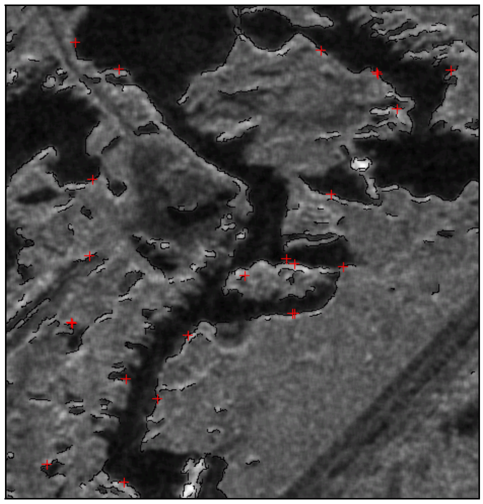


(b) Process result of integrative detector.

Figure 3 Binary images generated by different operators



(a) Left image;



(b) Right image.

Figure 4 Matching results

After generating the edges, if all points on each edge are matched, this will spend lots of time. In this case, it is easy to present the matching mistake, and difficult to make a quantitative description of matching precision. Therefore, in this paper, some edge points with more obvious characteristics are obtained by Moravec operator which can be regarded as a base points set. Then, according to searching strategies of "virtual epipolar", the corresponding points are generated. When correlation coefficients are calculated, due to the different edge having a bigger comparability in binary image, it isn't suitable for corresponding points being searched, so a method combining edge and gray is used. The gray level image is the result after gauss filtering in Canny operator. Finally, to get rid of the wrong corresponding points, a quadratic polynomial method is used. As a result, the image matching method studied in this paper is feasible, and the matching accuracy and velocity have improved much more than some other methods, which can be seen in Figure 4 and Table 1. Table 1 shows the matching time and the rate of accuracy, also gives a contrast with the traditional algorithm (gray correlation searching method).

| Method | Matching points | Right points | Accuracy (%) | Time (ms) |
|---|---|---|---|---|
| This paper | 23 | 20 | 86.96 | 1343 |
| Traditional algorithm | 23 | 15 | 65.22 | 29345 |

Table1 Comparison of different matching algorithm

## 6. CONCLUSIONS

Given the particular imaging mechanisms of SAR image, a new matching method and flow of SAR image based on edge detection and "virtual epipolar" are proposed and researched in this paper. And semi-automatic matching has been achieved. The experiment indicates that, the matching precision of this method is higher, and the searching time is shorter. Therefore, it is an effective semiautomatic matching method for SAR image.

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