STUDY ON AIRBORNE SAR IMAGE MATCHING USING EPIPOLAR GEOMETRY

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ABSTRACT:

Aerial photos are broadly used to generate the 4D(DEM, DOM, DLG, DRG) products in photogrammetry, but there are some difficult areas where are usually rainy and cloudy, so in these areas optical image is hard to acquire. The airborne SAR has advantage to solve this problem, and in order to generate 4D products from SAR image, the study of Radar photogrammetry becomes more and more significant. This research is about airborne SAR image matching using similar corresponding epipolar line based on photogrammetry theory. First the epipolar geometry of aerial photo is analyzed, second SAR image is done some preprocessing (such as building pyramid-layered image and filter), third the image equation of stereo SAR is build to borrow optical method of epipolar geometry, finally result resampling image is test for image matching. This research is the basic preparation for building the stereo SAR, and makes the well technique foundation of generation 4D products.

1. INTRODUCTIONS

4D products are the basic digital product for national departments and various projects, which could offer lots of information. Optical image is usually used to generate the 4D products, but in some difficult areas, optical image is hard to acquire due to the rainy and cloudy weather. As an effective earth observation technique, Synthetic aperture radar (SAR) is being paid importance to and complementary to optical remote sensing owing to its all-weather and all- time capability. There are two important kinds of SAR platform: airborne SAR and space-borne SAR. The airborne SAR can acquire data according to requirement, and it's more flexible than the space-borne SAR, which could choose the imaging target in pertinence. The resolution of the airborne SAR image is mostly higher than that of space-borne SAR. The more important characteristic is that it can offer the real time image for the disaster prevention and military reconnaissance. In order to generate 4D products from SAR image, the study of Radar photogrammetry becomes more and more significant.
In the processing, the first step is to construct the stereo image pair. So using an appropriate method of image matching is important.

Image matching is the process of transforming the different sets of data which were acquired by the same or different sensors, from the same or different viewpoint, from different perspectives geometry into one coordinate system. In a whole, like the traditional image registration methods, the means of SAR image matching can be classified into two categories: feature-based and intensity-based methods. Though the intensity-based image matching costs much time to compute, it is more reliable and it could keep the whole image information. In order to enhance the search efficient, the similar corresponding epipolar line method based on photogrammetry theory is used in this paper.

2. THEORY OF EPIPOLAR GEOMETRY

The eqipolar line is the basic concept of photogrammetry, it is the line where left or right photograph intersect with epipolar plane[1] (the plane including photographic baseline and ground point). According to the geometric definition of eqipolar line, the corresponding image points must in corresponding epipolar line. So it is more convenient to using corresponding epipolar line to search the corresponding image points. But the mechanism of the SAR imaging is different from the photogrammetric imaging. The appearance of SAR image in range direction is linear image, and in azimuth direction SAR image lays over the whole strip，so the whole SAR image is equal to multi-central projection linear array image which is similar to the Linear Array Push-broom image. According to the imaging equation of linear CCD Push-broom sensor, we can build the SAR row-center projection equation [2].

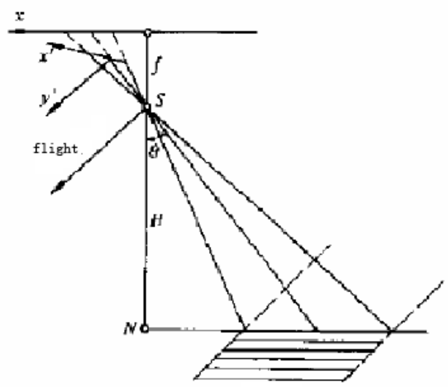

Fig 1. Row-Center Projection

$$\begin{bmatrix} x_i \\ 0 \\ -f \end{bmatrix} = \lambda M_\theta{}^T M_i{}^T \begin{bmatrix} X - X_{si} \\ Y - Y_{si} \\ Z - Z_{si} \end{bmatrix}$$

Where M_θ, M_i = rotate matrix which are denoted by the elements of exterior orientation from the i row.

let $$M_\theta M_i = \begin{bmatrix} a_1' & a_2' & a_3' \\ b_1' & b_2' & b_3' \\ c_1' & c_2' & c_3' \end{bmatrix}$$

so

$$x_i = -f\,\frac{a_1'(X - X_{si}) + b_1'(Y - Y_{si}) + c_1'(Z - Z_{si})}{a_3'(X - X_{si}) + b_3'(Y - Y_{si}) + c_3'(Z - Z_{si})}$$

$$y_i = 0 = -f\,\frac{a_2'(X - X_{si}) + b_2'(Y - Y_{si}) + c_2'(Z - Z_{si})}{a_3'(X - X_{si}) + b_3'(Y - Y_{si}) + c_3'(Z - Z_{si})}$$

This model is an approximate model which assumes the elements of exterior orientation are the linear function of time. Through this approximate model, the epipolar geometry could be used in SAR image.

Scholars have put forward several epipolarity models in photogrammetry. One is based on the polynomial fitting of conjugate points. And, another one based on changing the height of the corresponding object point along the light ray is named as projection track method [4]. This paper based on theory of projection track method. Since looking the SAR image as the multi-central projection linear array imagery, according to the characteristic of central projection imagery, changing the height of the corresponding object point along the ray connecting the perspective centre and projecting the object points onto the other image, the track of a series of pixels obtained is the epipolar curve, then corresponding image points could be searched in the epipolar curve.

3. EXPERIMENT METHOD

After analyzing the epipolar geometry theory in SAR image, the detail approach of the research is as follow steps:

Firstly, we chose a pair of airborne SAR images. In order to improve the effective of matching, the pyramid-layered method has been adopted in this research. The bottom of the pyramid-image is the original airborne SAR image. The top of the pyramid-image is formed by putting together 2*2 pixels from the bottom of the pyramid-image. After extracting feature points in the left image as control points, we extracted the grid points of the left image as the feature points, and computed out the coordinate of these points.

Secondly, we built the SAR imaging equation. Based on the imaging model of CCD push-broom imagery, the SAR row-center projection equation is built to represent the relationship between the image coordinate and space coordinate. Assuming that point q(x_l,0) is the point in the i scan line of left image, so we can construct a function to represent the space coordinate of point Q(X,Y,Z), which is in the line of Sq by the row-center projection equation(S is the projection center of them i scan line)[4].

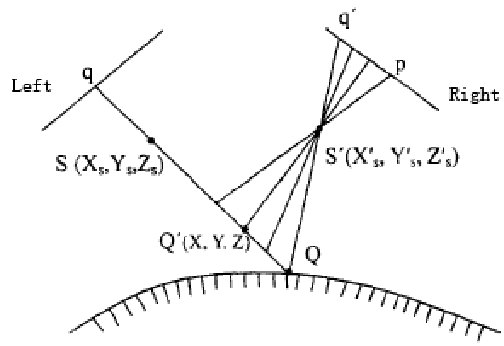

Fig 2. Epipolar Geometry of projection track method

$$(X, Y, Z)^T = (X_{si}, Y_{si}, Z_{si})^T + \lambda \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix} \begin{bmatrix} x_l \\ 0 \\ -f \end{bmatrix}$$

Where λ = proportional divisor,

r_{ij} = coefficient of rotate matrix in left image,

(X_{si}, Y_{si}, Z_{si}) = coordinate of left photographic centre

If point Q is also projected in the j scan line of right image, the space coordinate of point Q would be satisfied the projection equation of the right image.

$$x_r = -f\,\frac{\dot r_{11}(X - X'_{sj}) + \dot r_{21}(Y - Y'_{sj}) + \dot r_{31}(Z - Z'_{sj})}{\dot r_{13}(X - X'_{sj}) + \dot r_{23}(Y - Y'_{sj}) + \dot r_{33}(Z - Z'_{sj})}$$

$$0 = \dot r_{12}(X - X'_{sj}) + \dot r_{22}(Y - Y'_{sj}) + \dot r_{32}(Z - Z'_{sj})$$

Where $\dot r_{ij}$ = coefficient of rotate matrix in right image,

$(X'_{sj}, Y'_{sj}, Z'_{sj})$ =coordinate of right photographic centre.

Then using the simultaneous equations to obtain the epipolar line equation, the correlativity of left and right image would be constructed

$$l_1 x_r + l_2 y_r + l_3 x_r y_r + l_4 = 0$$
$$l_1 = m_1 y_l + m_2$$
$$l_2 = (m_3 x_l + m_4) y_l + (m_5 x_l + m_6)$$
$$l_3 = m_7 y_l + m_8$$
$$l_4 = (m_9 x_l + m_{10}) y_l + (m_{11} x_l + m_{12})$$

Where l_i(i=1,⋯12) is the constant,

(x_r,y_r) and (x_l,y_l) are the coordinate of the homologous image points

Though from this equation, the epipolar curve is the hyperbola, but in the certain value range, it behaves as the line. So the corresponding epipolar line could exist in the two images. According to the above formula, the epipolar line in right image could be computed, then use the points in this line to compute the corresponding points in left image, so the epipolar line in left image could be computed.

Successively, due to corresponding epipolar lines been found in the left and right image, the next step is epipolar resample in the right image. Along the slope of the epipolar lines, resampling the two images, the method of image resampling adopted in this research is bilinear interpolation method. Using the pixels around the target position, the new value of the pixel could be computed.

$$d_i(x_i, y_i) = (1-(y_i - y_{li}))*d_{li}(x_i, y_{li}) +$$
$$(y_i - y_{li})*d_{li+1}(x_i, y_{li+1})$$
$$y_i = x_i * \tan k$$
$$y_{li} = \text{int}(y_i)$$
$$y_{li+1} = \text{int}(y_i)+1$$

Where
tanK = the slope of the epipolar line
$d_i(x_i, y_i), d_{li}(x_i, y_{li}), d_{li+1}(x_i, y_{li+1})$ = the gray value

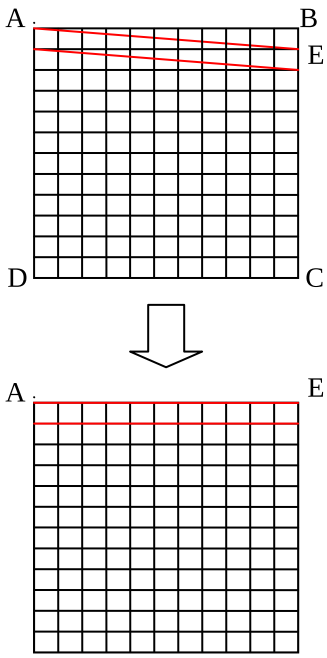

Fig 3. Epipolar Line Resampling

After the resampling against to each epipolar line, the epipolar line image could be generated. Then using the traditional method like correlation coefficient method, the two SAR image could be matched.

4. RESULT

The original SAR image is airborne SAR image which is acquired from Chengdu area. The resolution of these images is 1m, and this image pair is obtained in same side stereo mode. The following images are the original images.

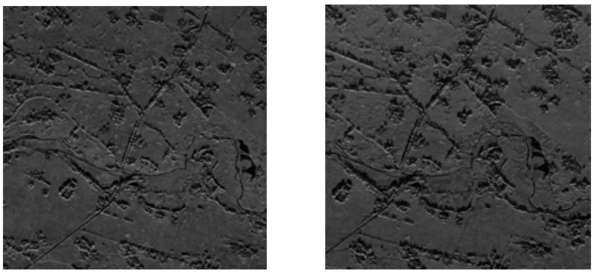

Fig 4. Original Image Pair

After using epipolar line to resample two image, we could do image matching with these new resample image, the result is as followed.

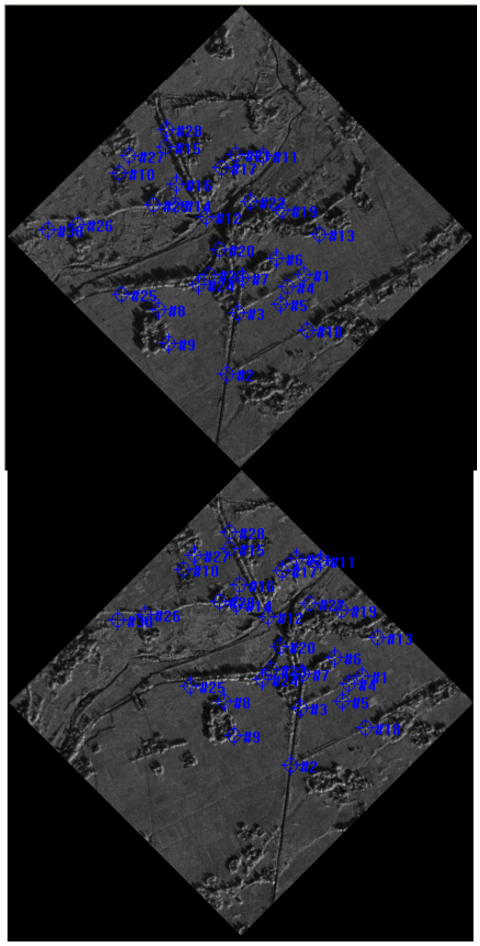

Fig 5 Experiment Result

This is the part of the match result of this experiment, there are 30 point matched in image pair. The RSM of full image is 1.407671 pixels.

	△X	△Y	RMS
1	0.322828	1.234063	1.275590
2	-0.281435	0.114012	0.303652
3	-0.571951	0.151998	0.591804
4	-1.363073	-0.120744	1.368410
5	1.160844	-0.569849	1.293169
6	0.763924	-1.034136	1.285697
7	0.460943	0.234793	0.517297

Fig 6 Accuracy Assessment Table

5. CONCLUSIONS

According to the experiment result, the method of airborne SAR image matching based on similar corresponding epipolar line has been testified effectively, which also was proved able to enhance the speed of the matching at certain extent.

This research is a tentative method of SAR image matching, it establishes a new method for airborne SAR image matching quickly, different from the ordinary ones. And, it was proved a beneficial attempt for the further effective study on SAR image matching.

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