DEM GENERATION FROM MULTI_SENSOR SAR IMAGES

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ABSTRACT

In order to realize mapping the areas that are covered by clouds all the year round, it is an efficient way to combine multi_sensor images to do stereocopy. The paper discusses the theoretical basis of using different sensor SAR images to extract DEM, which key point lies in space intersection and image match. For the sake of improving the quality of DEM acquired by using radar stereo photogrammetrical method, radarclinometry is adopted to do further refinement. The experiment results show that using same side ERS-1 and RADARSAT-1 data with 20° intersection angle to acquire DEM, the accuracy of plane is 70m and that of height is 28m.

1 INTRODUCTION

Synthetic Aperture Radar (SAR) is a kind of microwave sensor developed in the later 1950s, and is one of most effective and fastest developed earth-observation system in the field of microwave sensor. It has such features：

（1）all-weather and all-day work ability, which can remedy the imaging blind areas caused by the restriction of optical sensors in work time and weather；

（2） having a certain ability of penetration, which can penetrate the earth surface cover and gain the underground information；

（3） providing more abundant earth surface information, which can remedy the defect of other sensors' not getting enough information.

For these outstanding advantages, SAR is applied widely. It has more superiority especially in the field of mapping the areas covered by clouds all year round. In the respect of extracting DEM from SAR, current main technique ways include radargrammetry, InSAR and radarclinometry. Comparatively speaking, InSAR sets strict demands on initial data, and it suffers much limitation and always cause the coherent results can't meet the needs of practical requirement for data difficult to meet the interference conditions. Similarly, applying stereo photogrammetry theory to extract DEM from SAR images will also cause the quality of the extracted DEM bad on account of the lower resolution and not ideal intersection conditions. Simultaneously, radarclinometry (or. shape from shading, SFS) demands quite a much boundary conditions and initial values for calculation. The paper uses SAR images from different sensors to reduce the limitation of imaging condition and construct the stereo model having good intersection angle, then to extract DEM automatically and do further refinement on the achieved DEM data, so as to survey the corresponding areas'.

2 THEORETICAL BASIS

2．1 Imaging equation of SAR images

For SAR images have the characters different from common photogrammetry ones, the projection equation and image matching are two main problems that should be solved to realize stereocopy using SAR images with different look angles. The Range_Doppler equation (Raggam, 1989) is the earlier geometry model used to describe the relation between SAR image coordinates and ground ones. The researchers at home and abroad have used the equation to research the stereocopy of SAR images

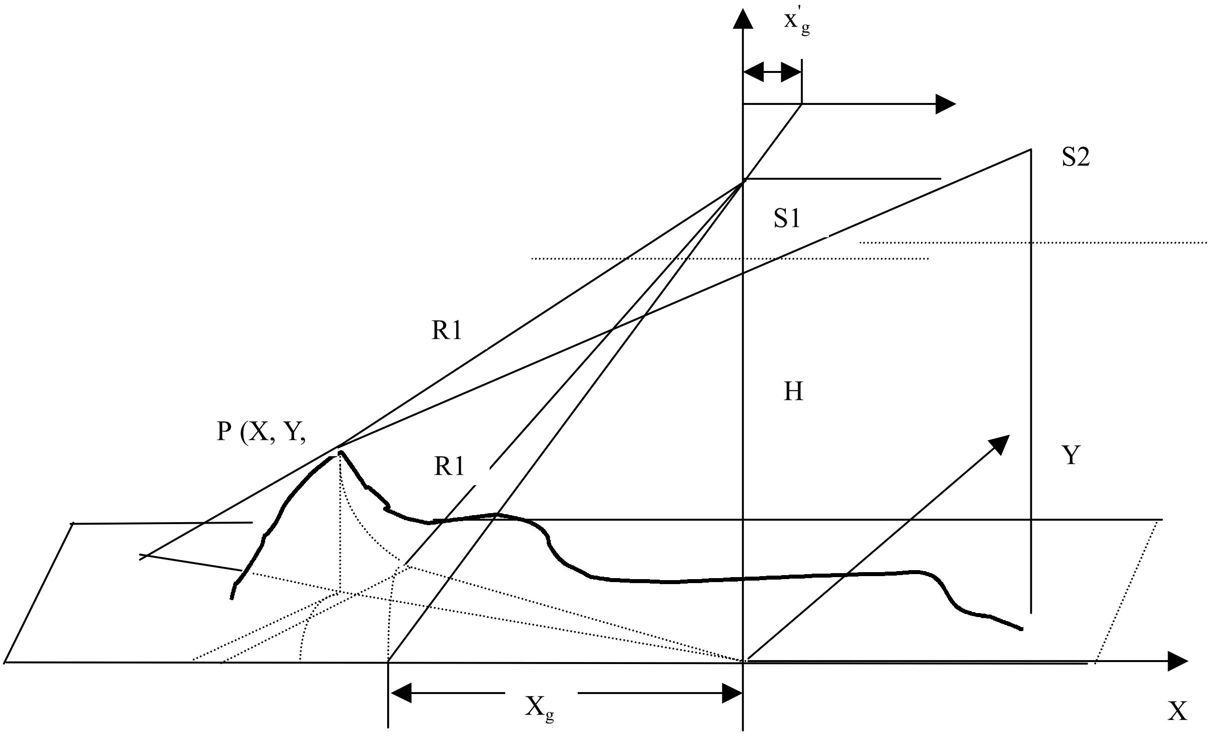

Figure 1. Geometrical relation between distance projection and center projection

in 1980s and obtained quite good results. Later, Konecny (1988) put forward the equivalent co_linear equation. The equation used the co-linear equation quite exactly to express the relationship of SAR imaging geometry. It is not only accustomed to photogrammist' using, but also considers the imaging orient element's change of SAR, so it's more rigorous than Range_Doppler equation and is used extensively in survey research of SAR.

Konecny equation：

$$x_g^{'} = x_g + r_0 = -f \frac{a_{1i}(X - \Delta X - X_{si}) + b_{1i}(Y - \Delta Y - Y_{si}) + c_{1i}(Z_0 - Z_{si})}{a_{3i}(X - \Delta X - X_{si}) + b_{3i}(Y - \Delta Y - Y_{si}) + c_{3i}(Z_0 - Z_{si})}$$

$$y_g^{'} = 0 = -f \frac{a_{2i}(X - \Delta X - X_{si}) + b_{2i}(Y - \Delta Y - Y_{si}) + c_{2i}(Z_0 - Z_{si})}{a_{3i}(X - \Delta X - X_{si}) + b_{3i}(Y - \Delta Y - Y_{si}) + c_{3i}(Z_0 - Z_{si})} \qquad (1)$$

where $a_{1i}, a_{2i}, a_{3i}, b_{1i}, b_{2i}, b_{3i}, c_{1i}, c_{2i}, c_{3i}$ is the direction cosine of the ith line

X_{si}, Y_{si}, Z_{si}; is the projection center of the ith line;

$$\Delta X = P \times (X - X_{si})$$

$$\Delta Y = P \times (Y - Y_{si})$$

$$P = \frac{((X - X_{si})^2 + (Y - Y_{si})^2)^{1/2} - ((X - X_{si})^2 + (Y - Y_{si})^2 + (Z - Z_{si})^2 - H^2))^{1/2}}{((X - X_{si})^2 + (Y - Y_{si})^2)^{1/2}}$$

X,Y,Z is the ground pionts'coordinates, Z_0 is the altitude of data's programming plane .

The independent element in the direction cosine are three angle elements Φ , Ω , K , they change with time, so formula (1) can also be expressed as the motion equation depends on the change of SAR image y coordinate.

$$X_{si} = X_{s0} + X_s^{'} \times y + X_s^{''} \times y^2$$

$$Y_{si} = Y_{s0} + Y_s^{'} \times y + Y_s^{''} \times y^2$$

$$Z_{si} = Z_{s0} + Z_s^{'} \times y + Z_s^{''} \times y^2$$

$$\Phi_i = \Phi_0 + \Phi^{'} \times y$$

$$\Omega_i = \Omega_0 + \Omega^{'} \times y \qquad (2)$$

$$K_i = \mathrm{K}_0 + K^{'} \times y$$

where: X_{s0}, Y_{s0}, Z_{s0}, Φ_0, Ω_0, K_0 is the outer orientation elements of the center scan line.

X_s'、Y_s'、Z_s'、Φ'、Ω'、K' is the corresponding first rank change rate;

X_s、Y_s、Z_s is the second rank change rate of projection center position.

In order to solve the above equations, at least nine control points well distributed in the overall image can then be stable solution.

2．2 Space intersection

Below formula can be obtained from (1):

$$
\begin{aligned}
(1-P)(X-X_{si}) &= (Z_0 - Z_{si})\frac{a_{1i}(x_g + r_0) - a_{3i} f}{c_{1i}(x_g + r_0) - c_{3i} f} \\
(1-P)(Y-Y_{si}) &= (Z_0 - Z_{si})\frac{b_{1i}(x_g + r_0) - b_{3i} f}{c_{1i}(x_g + r_0) - c_{3i} f}
\end{aligned}
\qquad (3)
$$

From the formula we can see that using classical forward intersection can't resolve the altitude Z of ground points,

$$
1-P = \frac{((X-X_{si})^2 + (Y-Y_{si})^2 + (Z-Z_{si})^2 - H^2))^{1/2}}{((X-X_{si})^2 + (Y-Y_{si})^2)^{1/2}} \qquad (4)
$$

For P and X,Y can't be determined at the same time, the space coordinates triangular intersection is an iteration course. When the forward intersection differential results of left and right image is smallest in the distance direction, the iteration convergence, the altitude of the ground points is achieved from formula (3).

2．3 DEM auto extraction

SAR images belong to distance projection ones. It is greatly influenced by the terrain relief and speckle noise. It will only get very rough results if original data are used directly to do area matching (Leberl, 1994). The match scheme showed in figure 2 is adapted in the paper. Using VLL image match method(Shen,1995）, the space coordinates of DEM grid points can be obtained directly. In addition, using multi-resolution scheme can overcome the local twist of image and the influence of speckle noise, at the same time it can improve the match speed.

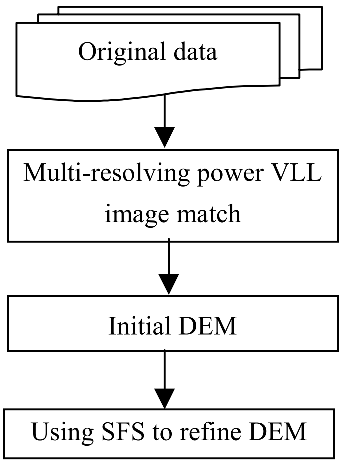

Figure 2. Matching scheme

The DEM obtained through matching seems in tatter, which shows that the results achieved by gray match are not very reliable. The main factors lie in that two images have differences in image time and parameters. In order to do refinement on DEM, radarclinometry is adapted to correct the discontinuous part of the DEM countering the character of SAR images. (Paquerault,1996）

Radarclinometry based on the following principle. The terrain relief will lead to the change of ground surface's trend and cause the change of the separation angle between incident ray direction and ground surface normal line direction, at last cause the change of gray smoothness of corresponding area's SAR image. So the information of surface direction strike can be restored from the gray picture that can change smoothly and using the obtained information as restrain condition for DEM refinement. For the discontinuous parts of the DEM mainly appear in the relief area, and radarclinometry is just suited to obtain the slope information of relief area, so it is adapted to do refinement on DEM.

3、EXPERIMENTS

The experiment data are ERS-1 and RADARSAT-1 images, the circumstances of the data see table 1. The experiment area belongs to moderate relief terrain, the altitude range from tens meters to hundreds meters. The control points are composed of distinct surface features points in 1:50000 map.

	Display model	Side view angle	Resolving power
ERS-1	Oblique distance	19.458°	12.5m
RADARSAT-1	Ground distance	39.927°	9.76m

Table 1. Experiment data

In order to guarantee the images of different sensors have the same geometry features, slant range projection corrected to ground projection is first done to ERS-1 image, which makes the ERS-1 image to ground range image. Then using control points to solve the outer orientation elements of two images separately in according to formula (1), using formula (4) to check the accuracy of the forward intersection. The results refer to table 2. Because the dealing way of changing the slant range display images to ground range images is not completely the same for two images, there exists difference between the range accuracy of the two. The main affect factor rests with the difference between data programming plane.

	number of control points		accuracy of direction		accuracy of intersection	
	number of control points	number of check points	accuracy of resolution	accuracy of checking	plane	altitude
ERS-1	11	4	±26.3m	±52.1m	±72.34m	±28.76m
RADARSAT-1	11	4	±57.3m	±65.4m		

Table 2. Accuracy of absolute orientation and forward intersection

In order to give consideration to the speed and reliable degree of DEM collection by image matching, three-level image pyramid is constructed in each matching. Correlation coefficients are calculated at the top level, which can not only guarantee that each match has larger correlation window, at the same time reducing the calculation quantity, but also restrain the influence of speckle and resolution.

Through the original math we can see that owing to the influence of different imaging condition and different side look angle, the local of image is leaded to geometry change and the radiation character isn't consistent yet. So using the method provided by Paquerault (1996) to form reflective map to restrain the search range of VLL match so as to improve the reliability. The improved match results are showed in figure 3, and through artificial check we can see that the effect is very distinct. Further quantity analyze is still in progress.

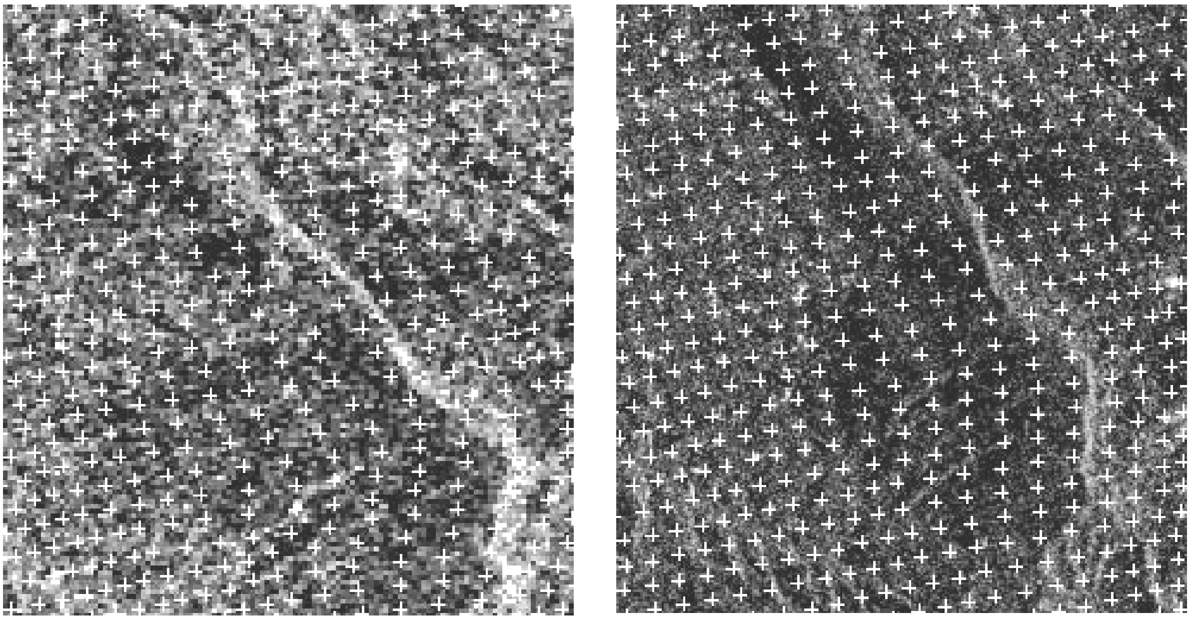

Figure 3. Final match results (partial)

4 CONCLUTIONS

The paper analyses the theory and method using different sensor SAR image to extract DEM, the key point lies in space intersection of three-dimensional coordinates and the image match. To SAR image's space intersection of three-dimensional coordinates, it should guarantee that the corresponding image has the same projection character first of all. It is an iterative course to intersect space coordinate through using relevant pixel. Using image match to extract DEM, radarclinometry can be used to reduce the effect of the difference due to imaging conditions and look_angle. In addition multiple_layer image matching can reduce matching time and the affect of speckle and resolution difference. What need further be improved include (1) improving control point accuracy; (2) unifying programming plane height;(3)making reflective map more precise;(4) iterative orthorectification etc.

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