SAR MAPPING TECHNOLOGY AND ITS APPLICATION IN DIFFICULTY TERRAIN AREA

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ABSTRACT

In western China, there is a large area perennially covered by cloud, fog, ice, and snow. It is very difficult to acquire optical image for mapping in this area, so high resolution spaceborne synthetic aperture radar (SAR) images have to be used to make topographic maps. A scheme of SAR mapping technology is proposed in this paper. Digital elevation model (DEM) was extracted with stereo radargrammetry (StereoSAR), and topographic map was created with ideal SAR stereoscopic image pairs. Due to the difficult terrain, parallax edit under stereoscopic observation is used for improving matching result from stereo images. Ideal SAR stereoscopic image pairs generated with image simulation based on DEM are used for stereoscopic observation to extract topographic features. Ascending and descending image data were combined to solve the problem of lack of information caused by shadow and layover. Mapping experiment in western China shows that SAR data with resolution of 3-8 meters can be used to make topographic map at scale of 1:50,000 by the scheme of SAR mapping introduced in this paper.

Index Terms— StereoSAR, parallax edit, ascending and descending, DEM, topographic map

1. INTRODUCTION

SAR technology provides a new effective way on mapping where qualified optical image is difficult to acquire. In western China, State Bureau of Surveying and Mapping of China is conducting the Western China Mapping Project, which aims to generate 1:50,000 scale topographic and other thematic maps. In Hengduan mountain area, large area is perennially covered by cloud, fog, ice and snow. SAR mapping technology could offer strong advantages over this area.

StereoSAR and interferometric SAR (InSAR) are two kinds of methods for topographic map and DEM extraction with SAR images[1] [2]. Theoretically, InSAR could achieve higher precise elevation information of ground objects. But InSAR technology possesses restrictive conditions for system parameters and time interval of image data, acquiring ideal interferometric image pairs is difficult. Because of abrupt terrain and thick vegetation coverage in Hengduan mountain area, InSAR data is provided with low coherence seriously during a certain time interval, and it couldn't get the satisfactory results in large area. Different to InSAR data, stereo SAR data could be acquired much easier. As another way, stereo radargrammetry is a feasible technique to extract DEM and topographic map in this area.

A scheme of StereoSAR mapping is described in this paper in detail. Experiments on high resolution SAR images in Hengduan mountain area prove that the technical scheme is feasible.

2. EXTRACTION OF DEM WITH STEREOSAR

The main sub-sections of StereoSar include image matching and stereo intersection solution[3]. Because of the complicated terrain and geometry distortion, image matching may be more difficult. Parallax edit under stereoscopic observation could improve matching result. The complicated terrain also led to serious shadow and layover, utlizing ascending and descending data complementary solved missing information majority. The processing flow chart of this paper is shown in Fig1.

2.1. Parallax Edit

After matching, parallax data can be used to rectify one image of the matching pair to the other. The rectified one is called rectified image, and the other is called reference image.

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Observed under stereo viewing environment, the surface of the rectified and reference images would be flat theoretically if matching result is correct. It is a visible method to check the matching quality. But the actual results are usually not ideal, especially in complicated terrain area. In mismatching area, there would be ups and downs or confusion while stereo viewing. Parallax edit corrects the parallax by fitting and interpolating parallax value based on parallax feature vectors. Feature vectors are created artificially under stereoscopic observation. Parallax edit is divided to two steps.

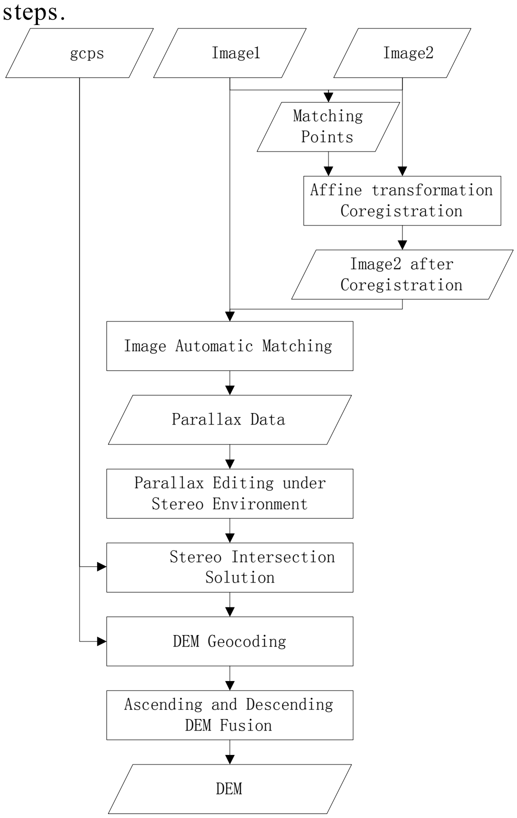


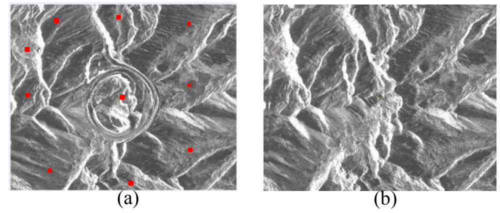
Fig1. DEM generation by StereoSAR

The first step is sample correction. In area with mismatching, some parallax feature points are collected, and then parallax values can be fitted. The fitting formula is:

$$\begin{aligned} \Delta i &= a_i \cdot i + b_i \cdot j + c_i \\ \Delta j &= a_j \cdot i + b_j \cdot j + c_j \end{aligned} \tag{1}$$

$\Delta i, \Delta j$ are horizontal and vertical parallax values of pixel (i, j), $a_i, b_i, c_i, a_j, b_j, c_j$ are correction coefficients.

Math image rectified with the parallax of sample correction is shown in Fig2. (a) is rectified result with parallax of automatic matching, and the red points is parallax feature points. (b) is rectified result with parallax of sample correction. Apparently, (b) is more better compared with (a).



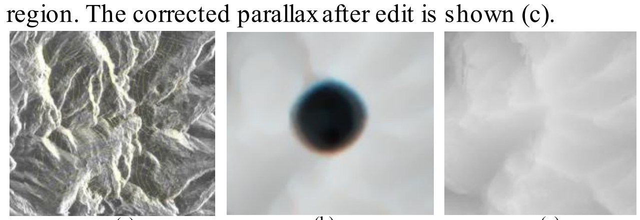
(a) (b)

Fig2. Sample correction

Due to the sample correction is coarse correction, the rectified image with parallax of sample correction still cannot be identical with the reference image completely.

The second step in parallax edit, precise correction, is correcting parallax with parallax feature vectors (feature points, feature lines and feature contour lines) collected under stereoscopic observation. The parallax feature vectors construct triangulation network (TIN) and are applied to interpolate the parallax of this region. The collected vectors are shown in (a) of Fig4.

The parallax images before and after parallax edit are shown in Fig3 (b) and (c). The black hole in (b) is mismatching region. The corrected parallax after edit is shown (c).



(a) (b) (c)

Fig3. Precise correction vectors and result of parallax edit

2.2. Ascending and Descending DEM Fusion

Due to the complicated terrain of Hengduan mountain area, the manifestation of shadow and layover are common in the SAR images and will lead to lack of information. Then precise 3D information cannot be extracted in shadow and layover areas. Analyzing slant range imaging characteristic of SAR, layover area on ascending images may be better on descending ones, then information of ground features may be reserved on the different orbit. So DEM fusion from both sides may compensate missing information. The two DEMs are extracted from two different orbits stereo image pairs (an ascending pair and a descending pair).

DEM fusion is based on the mask of shadow and layover areas which are extracted according to DEM and SAR orbit information. In mask areas, elevation is filled by valid value, and in other areas weighted fusion of elevation is done according to image process information, such as correlation coefficients of image match.

3. EXTRACTION OF TOPOGRAPHIC FEATURES

Topographic features (such as contour lines, ground features and so on) should be collected and edited under stereoscopic observation. The basis of stereoscopic observation is ideal stereoscopic image pair in which the vertical parallax is eliminated and the horizontal parallax is reconstructed [4]. In optical photogrammetry, ideal stereoscopic image pair can be generated by epipolar resampling [5]. Epipolar is not existed in SAR image because of slant range projection, so the method of optical photogrammetry is no suitable for SAR stereoscopy. In this paper, ideal SAR stereoscopic image pair is generated by resampling based on DEM. The stereo extraction workflow is shown in Fig4.

The procedure of extracting stereoscopic image is actually a process of image simulation. The key point is establishing the map between simulated image coordinates and original SAR image coordinates with simulated imaging orbit and parameters, and then resampling to obtain stereoscopic image.

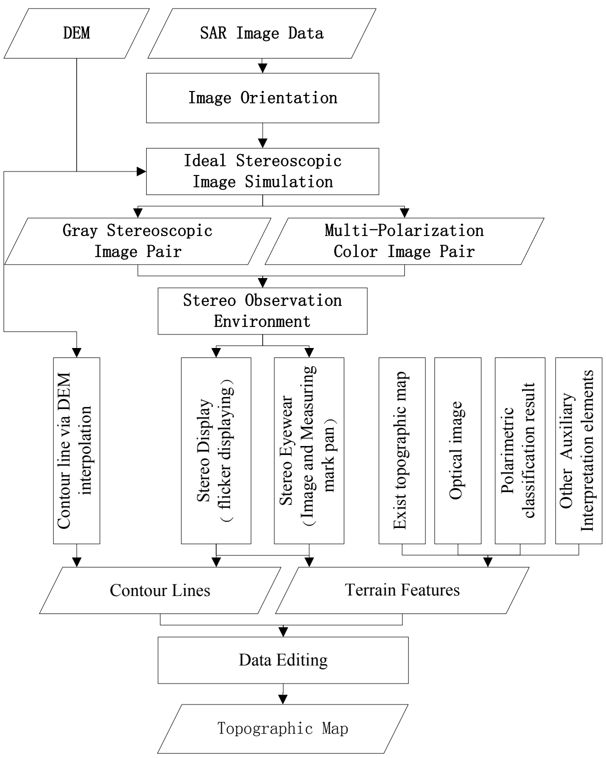


Fig4. Topogrphic features extraction

3.1. Ideal stereoscopic image pair

Stereoscopic image generation is a resampling process. The image resampling depends on DEM in the same direction, so two maps should be established. One is the map between original image and geographic coordinates, the other is between geographic and simulated image coordinates. In this way, the vertical parallax will be eliminated, and the map between original image and simulated image coordinates is established indirectly. The resampling procedure is shown in Fig5.

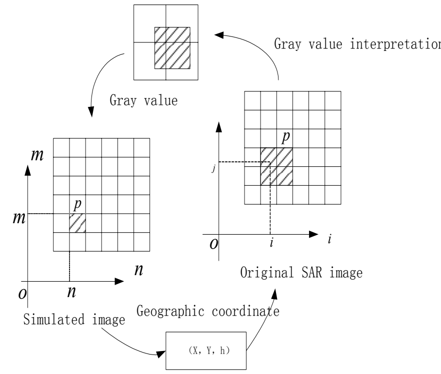
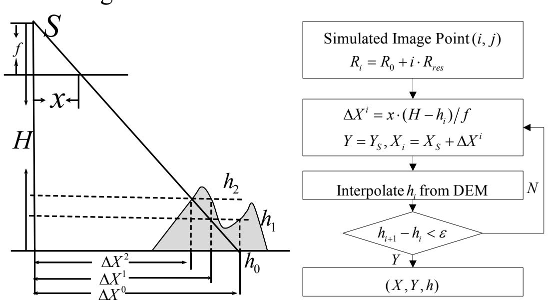


Fig5. Image Resampling

The map between original image and geographic coordinate can be established according to SAR geometric model. The map between geographic and simulated image coordinates is established according to simulation imaging model, central projection is selected in this paper [4]. The solution from simulated image coordinates to geographic coordinates is shown in Fig6.

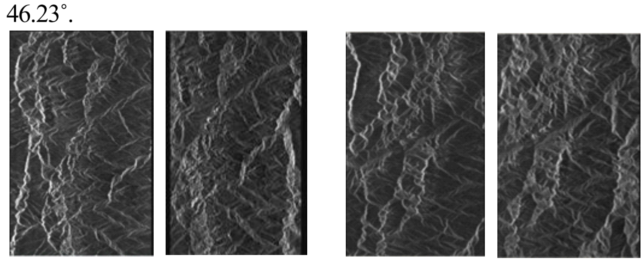


(a) Sketch map (b) Procedure

Fig6. Geo-location of simulated image

4. EXPERIMENT RESULTS

Experiment was carried out in this paper on two TerraSAR-X stereo image pairs, an ascending and a descending image pair, which are shown in Fag7.The images are located at Hengduan erea, and resolution is 3m. The elevation variation is more than 2500m. Incidence angles of ascending pair are 29.09° and 46.06°, and that of descending pair are 29.00° and 46.23°.



(a) ascending pair (b) descending pair

Fig7. Dual-side stereo image pair

DEMs were extracted from the two stereo pairs separately. Shadow and layover areas were detected according to elevation information and SAR satellite orbit. Ascending and descending DEMs along with shadow and layover masks are shown in Fig8.

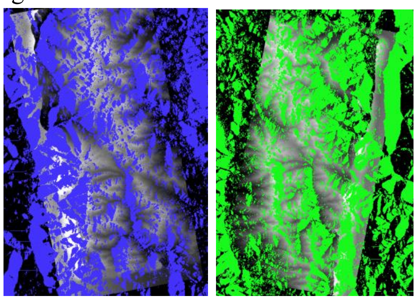


Fig8. Ascending and descending DEMs, shadow and layover detection

Ascending and descending DEMs were merged according to shadow and layover masks and shown in Fig9. Accuracy of ascending, descending and fusion DEMs were checked with ground control points (GCPs) and shown in Table3.

Table3 DEM accuracy

DEM	Ascending	Descending	Fusion
RMS(m)	18.67	21.87	16.69

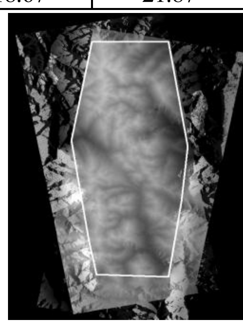


Fig9. Fusion DEM

Ideal stereoscopic image pairs were generated from SAR stereo image pairs. Well stereo observation effects can be gained from the pair under stereoscopic observation. The vertical parallax was eliminated effectively. Stereoscopic image pair and contour lines from ascending stereo pair are shown in Fig10. Topographic features were collected under stereoscopic observation, and the topographic map is shown in Fig11.

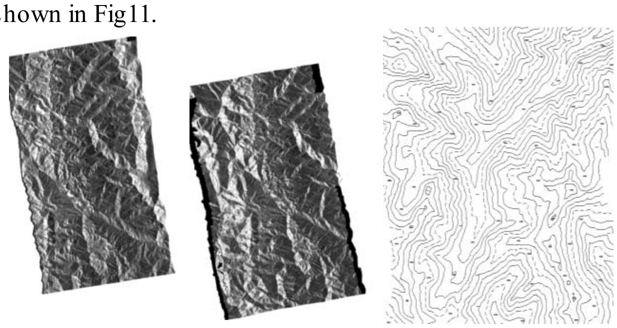


Fig10. Stereoscopic image pair and Contour lines

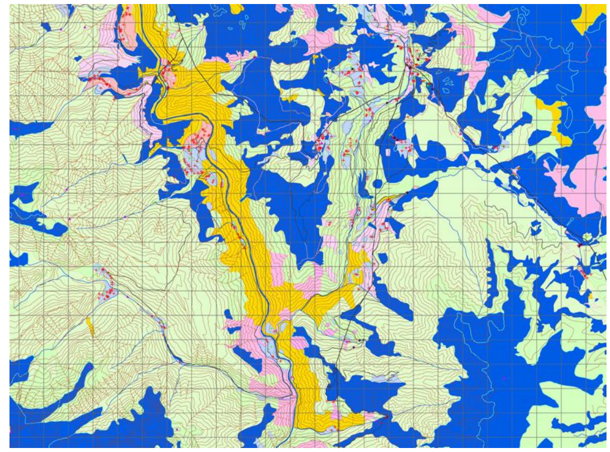


Fig11. Topographic map

5. CONCLUSION

In this paper, SAR mapping technical scheme is proposed. Parallax edit under stereoscopic observation and combination of dual-side image pairs were applied to solve the difficult terrain. Experiment of DEM extraction was carried out, and the result can meet the precision requirement with the scale of 1:50,000 in difficult area. Ideal stereoscopic image pairs were generated with high resolution SAR images. Well stereoscopic vision and well elimination of vertical parallax were achieved. The contour lines mapped with the image pairs can meet the requirements of producing topographic maps. Experiments demonstrated that the proposed mapping method is feasible.

6. REFERENCES

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