

An Accurate Co-registration Method for Airborne Repeat-pass InSAR

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Abstract. Interferometric Synthetic Aperture Radar (InSAR) technology plays a significant role in topographic mapping and surface deformation detection. Comparing with spaceborne repeat-pass InSAR, airborne repeat-pass InSAR solves the problems of long revisit time and low-resolution images. Due to the advantages of flexible, accurate, and fast obtaining abundant information, airborne repeat-pass InSAR is significant in deformation monitoring of shallow ground. In order to getting precise ground elevation information and interferometric coherence of deformation monitoring from master and slave images, accurate co-registration must be promised. Because of side looking, repeat observing path and long baseline, there are very different initial slant ranges and flight heights between repeat flight paths. The differences of initial slant ranges and flight height lead to the pixels, located identical coordinates on master and slave images, correspond to different size of ground resolution cells. The mismatching phenomenon performs very obvious on the long slant range parts of master image and slave image. In order to resolving the different sizes of pixels and getting accurate co-registration results, a new method is proposed based on Range-Doppler (RD) imaging model. VV-Polarization C-band airborne repeat-pass InSAR images were used in experiment. The experiment result shows that the proposed method leads to superior co-registration accuracy.

1. Introduction

Synthetic Aperture Radar (SAR) [1,2,3], the main data source of Interferometric synthetic aperture radar (InSAR), has been a hot research issue in the fields of microwave imaging, opening numerous research areas and fields of applications. Comparing with spaceborne SAR, airborne SAR largely overcomes the problems of long revisit time and low-resolution images. InSAR is a promising recent technique for the generation of digital elevation models and the measurement of ground surface deformations. The co-registration is the first step in InSAR data processing, which is defined that the creation of the homologous points coordinate mapping and two images achieve the best space match. Airborne repeat-pass InSAR the same area's two or multiple images at different time or different angles. The differences of initial slant ranges and flight height lead to the pixels, located identical coordinates on master and slave images, correspond to different size of ground resolution cells. The reality lead to obvious mismatching of master and slave images.

Many works has been done on SAR/InSAR image co-registration. An accurate co-registration method of spaceborne repeat-pass SAR interferometry based on matrix transform is proposed in [4]. A three



processing procedures method is proposed to resolve the problem of the offset amount between images changing significantly in whole scene [5]. [6] presents a robust method which introduces the coarse-to-fine strategy, relaxation optimization technology and Maximum Spectrum Method to obtain the dense, reliable and accurate conjugate points for the registration of two single looking complex (SLC) SAR images. An adapted anisotropic Gaussian scale-invariant feature transform (AAG-SIFT) method is proposed in [7] to find feature matches for SAR image registration.

In the following sections, a novel method of accurate co-registration of airborne repeat-pass InSAR based on Range-Doppler (RD) imaging model [8] is proposed. RD imaging model with analytic geometry and physical significance is based on three function: Rrange Equation, Doppler Equation and Earth Ellipsoid Equation, conforming to the image formation theory of SAR[9]. RD imaging model is mainly used to calculate the correction values of initial slant ranges of overlapping swath and heights of the first and second flying paths.

2. Method

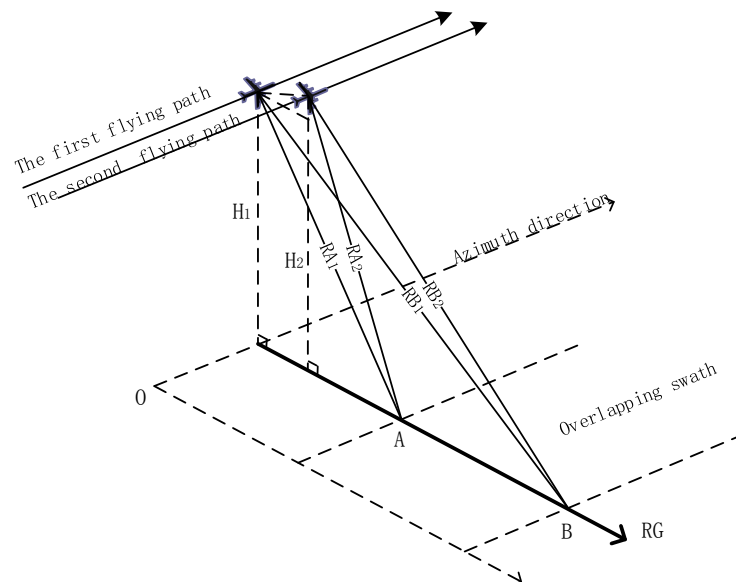


Figure 1. The geometric imaging model of airborne repeat-pass InSAR

As is shown in Figure 1, RA_1 and RB_1 are initial slant ranges of overlapping swath. RA_2 and RB_2 are maximum slant range of overlapping swath. H_1 and H_2 are respectively heights of the first and second flying paths. The pixel numbers of twice measurements are obviously different.

$$\frac{RB_2 - RA_2}{r} \neq \frac{RB_1 - RA_1}{r} \quad (1)$$

r is the range resolution.

RD imaging model is used to achieving that the pixels located identical coordinates on master and slave images correspond one-to-one. The main steps are

- Calculate the correction values of initial slant ranges of overlapping swath and heights of the first and second flying paths, using errors equation of RD imaging model, based on Position and Orientation System (POS) data and the location information of ground control points.
- Update the values of initial slant ranges of overlapping swath and heights of the first and second flying paths.
- Select one image as the master image and another as the slave image. According to geometrical relationship, only calculate the ground locations of pixels on master image.

- Calculate the coordinates corresponding to the ground locations on the slave images.
- Resample the slave image.

3. Experiment

VV-Polarization C-band airborne repeat-pass InSAR images were used in experiment. The platform acquiring these images operates in side-looking mode over Sanya of Hainan province in November, 2014. The basic information of SAR original echo shows in Table 1. The flight height of the master image is about 4459.97m, which of the slave image is 4446.57m. The initial slant range is 5644.84m. The velocity of the master image is 105.36m/s, which of the slave image is 103.43m/s. The baseline is 38.99m. The average height of object area is about 30m. Central incident angle of the image pair is about to 52° . The azimuth resolution of the image pair is 0.16m. The range resolution of the image pair is 0.2m.

Table 1. The basic of information of SAR original echo

Parameter	Value
Doppler central frequency	5.4e9
Bandwidth	5e8
Pulse width	2.0e-5
Pulse repetition frequency	1.25e3
Sampling rate	7.5e8
Antenna aperture	0.75
Doppler central frequency	5.4e9
Bandwidth	5e8
Baseline	38.99



Figure 2. The long slant range part of master image

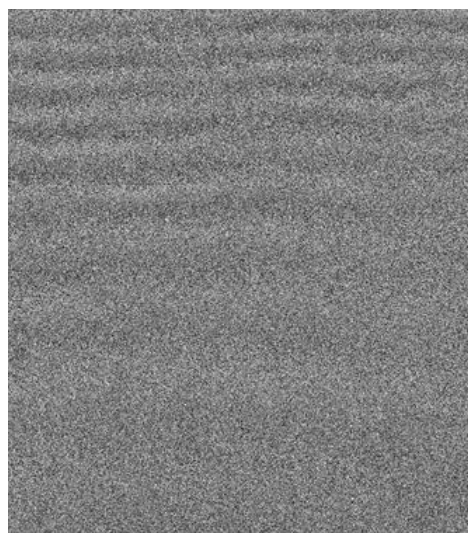


Figure 3. Interferogram of original image pair

Figure 2 only shows the long slant range part of the master image. The image size is: 10600 pixels in range direction and 9380 pixels in azimuth direction. Figure 3 shows the interferogram calculated from figure 2 and the slave image with identical coordinates and size. Three to five coordinate offsets along range direction lead to unsatisfactory result. The processing result of our image registration approach shows in Figure 4 and Figure 5. The new initial slant ranges of master and slave image are

respectively 5636.79m and 5639.965m. The new flight heights are respectively 4446.38m and 4434.51m. The results show that the proposed method leads to superior co-registration accuracy.



Figure 4. Coherence coefficient map of new image pair

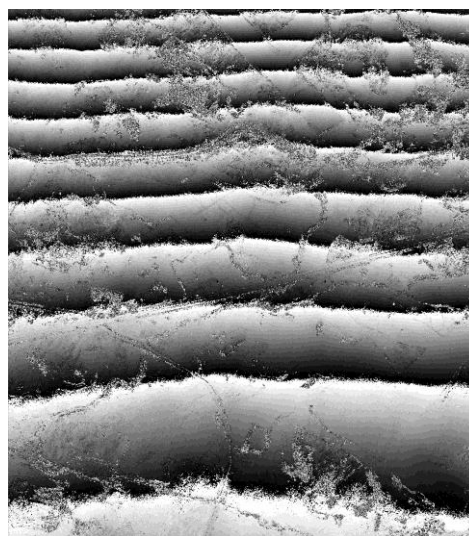


Figure 5. Interferogram of new image pair

Conclusion

In this paper, a new co-registration method based on RD imaging model is presented to the problem of pixels, located identical coordinates on master and slave images, corresponding to different size of ground resolution cells. Quality coherence coefficient map and interferogram were got from new method, which indicate that the proposed method performs superior co-registration accuracy to airborne repeat-pass InSAR images.

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