GEOMETRIC COREGISTRATION FOR TERRASAR-X INTERFEROMETRY

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ABSTRACT: The German radar satellite TerraSAR was launched in 2007. In this study, interferogram is generated using TerraSAR-X data and DEM (Digital Elevation Model). Coregistration procedures used with SAR images (i.e. master and slave) in traditional method results in serious errors for high resolution TerraSAR-X data because of the mutual shift of the master and slave images due to topography. This error becomes more serious in mountainous areas in which the coherence between interferometric pairs is relatively low. Here we processed a geometric coregistration with DEM exploiting height information. Through the method, interferometry processing is fulfilled to generate a qualified interferogram and coherence is improved. This approach will help high resolution X-band SAR interferometry in mountainous area.

KEY WORDS: Geometric coregistration, TerraSAR-X, Interferometry, DEM, Coherence

1. INTRODUCTION

The TerraSAR-X satellite was launched on 15 June 2007. It provides high resolution and short wavelength SAR imagery at a repeat cycle of only 11 days allowing new interferometric applications. Recently, several papers reported interferometric research results on DEM generation using TerraSAR-X data (Adam, 2007a; Adam, 2007b; Yamane, 2008). And Italian COSMO-SkyMed 1 and 2 satellites which are operated in X-band frequency launched in 2007. In 2010, KOMPSAT-5 X-band SAR satellite will be launched by South of KOREA. The X-band radar is capable of extracting unique surface features information compared with C-band and L-band SAR system.

X-band SAR is especially designed for high resolution image capability. While the high resolution capability is a big advantage over C- or L-band systems, different algorithms of the interferometric processing for high resolution SAR are required. For instance, the coregistration procedures used with the current sensors are not sufficient (Adam, 2007). Typically, a misregistration in the order of a 10th of a sample can be tolerated otherwise the interferometric coherence is reduced (Just, 1994). For the sensors ERS and ENVISAT the topography induced pixel shift can be modeled by low order polynomials for the whole scene.

The high resolution of the sensor TerraSAR-X results in a severe impact of the topography on the mutual shift of the master and slave samples (Bamler, 2005). Here we processed a geometric coregistration that exploits DEM and accommodate height variation in coregistration.

2. METHODLOGY

2.1 Data and study area

The study was carried out utilizing a pair TerraSAR-X images. The experiment regards the area of Bolivia (Figure 1), where a TerraSAR-X interferometric pair was acquired on July 15 and July 26, 2007. The interval to obtain the pairs of images was set at 11days (the shortest interval of satellite revisit). A pair is acquired by strip mode and is SSC (Single-look Slant range Complex) product level. NASA SRTM (Shuttle Radar Topography Mission) 3 arcsec resolution DEM data was utilized for geometric correction. Most parts of the study site are mountainous area with higher than 3,000 m in altitude. The accuracy of currently available DEMs, such as the SRTM data, makes the geometric registration approach feasible (Sansoti, 2006).

Figure 1. Study area of Quickbird image(©google)

2.2 Geometric coregistration

The high resolution of the sensor TerraSAR-X may result in a severe mutual shift of the master and slave samples. Equation (1) and (2) show local shift error is a function of topographic vertical error. To have an idea of the impact of this error on the registration process with ERS parameters, provide that a DEM is unavailable, the maximum allowed scene topography should be around 500 m to achieve a registration accuracy better than 1/8 of a pixel; therefore, registration with respect to a flat Earth model is only possible for very flat areas (or perfectly parallel tracks). Conversely, the accuracy of currently available DEMs, such as the SRTM one, is largely better than 500 m, thus making the geometric registration approach feasible in practical cases (Sansoti, 2006).

$$\delta(\Delta j) = \frac{B_v}{r \sin \vartheta} \cot \vartheta \frac{\delta h}{\Delta^{(az)}} \qquad (1)$$

where $\delta(\Delta j)$: Azimuth local shift error

B_v : Along-track baseline

r : Slant range

θ : Look angle

δ_h : Topographic vertical error

$\Delta^{(az)}$: v/PRF, azimuth pixel spacing

$$\delta(\Delta i) \approx \frac{B_\perp}{r \sin \vartheta} \frac{\delta h}{\Delta^{(rg)}} \qquad (2)$$

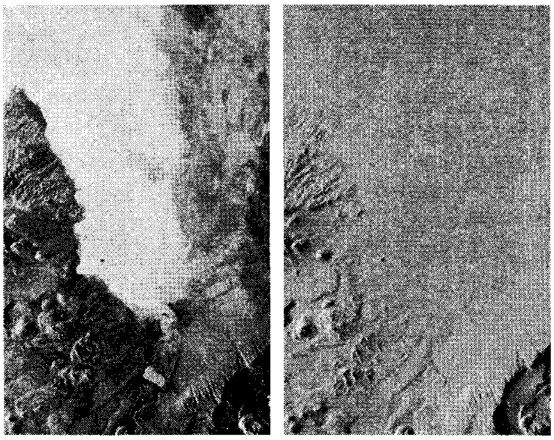
where $\delta(\Delta i)$: Range local shift error

$B_\perp$: Perpendicular baseline

$\Delta^{(rg)}$: c/(2×sampling frequency), range pixel spacing

2.3 InSAR processing

Firstly, DEM is simulated to a generate SAR amplitude image in radar geometry (Figure 2). As offsets due to topography are incorporated, coregistration procedure accuracy between master slave images will be improved. The flowchart of interferometric processing using geometric correction in this study is shown in Figure 3. And then interferogram and coherence image were analyzed. InSAR processing was conducted by GAMMA software in this study.



(a) (b)

Figure 2. (a) Amplitude of Master image (July 15, 2007) (b) Simulated SAR image from SRTM 3 arcsec resolution data

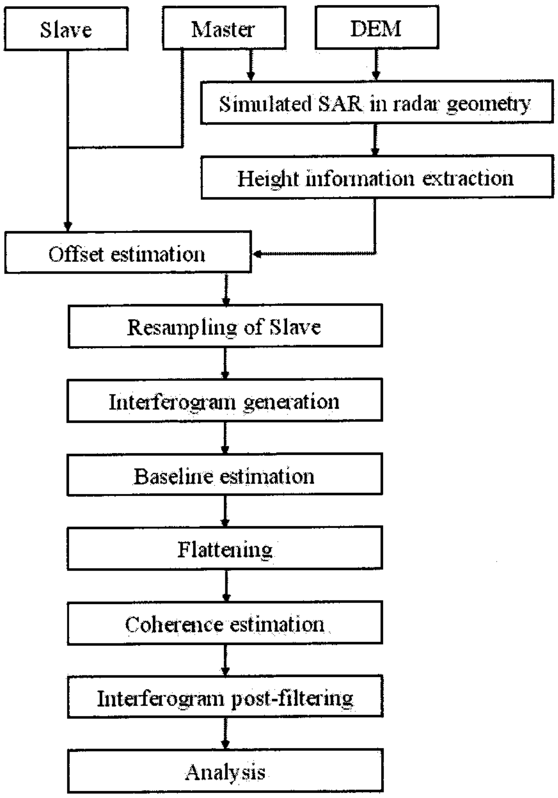


Figure 3. Flowchart of InSAR processing using geometric correction method in this study.

3. RESULTS AND DISSCUSSION

Though the TerraSAR-X has an X-band wavelength, an interferogram using geometric coregistration shows good quality (Figure 4). Considering most part of study site is higher than 3,000 m in altitude, the result is satisfied. Coherence is a degree of decorrelation between master and slave images (Equation 3), it is used to measure an interferogram quality. Table 1 shows interferometric coherence value of study area through two coregistration methods respectively. The TC in the Table 1 means 'Traditional Coregistration' method using master and slave images and the GC does 'Geometric Coregistration' method using the same data and SRTM data. The mean coherence value is 0.628 in geometric coregistration; it is better 0.033 than traditional coregistration coherence value, i.e. 0.595. The standard deviation is also improved about 0.028.

$$|\hat{\gamma}| = \frac{\left| \sum_{i=1}^{N} g_{1,i} g_{2,i}^{*} \right|}{\sqrt{\sum_{i=1}^{N} |g_{1,i}|^2 \sum_{i=1}^{N} |g_{2,i}|^2}} \quad (3)$$

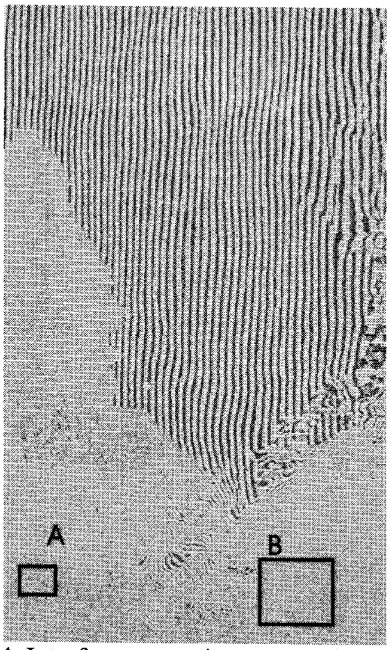


Figure 4. Interferogram using geometric correction method

Table 1. Comparison of interferometric coherence value between traditional coregistration (TC) method and geometric coregistration method (GC) in the full regions

	TC	GC	Improvement
Min.	0.00	0.00	-
Max.	0.896	0.905	0.009
Mean	0.595	0.628	0.033
Std.	0.196	0.168	0.028

Specially, improvement of coherence value shows high in mountain areas at the altitude of 4,000 m and above. For analysis in mountain areas, sub-areas 'A' and 'B' in the interferogram are selected and compared (Figure 4). Sub-area A is at about 4,500 m altitude and of 1,000 by 1,000 pixels. Sub-area B is at about 4,100 m altitude and of 2150 by 2260 pixels. Figure 5 shows interferogram of sub-area using geometric correction method. Figure 6 shows coherence images of sub-area using geometric correction comparing to tradition method. As a result of coherence value comparison is in Table 2. In sub-area A, the mean coherence value of geometric coregistration is 0.608; it is better 0.091 than traditional method. In sub-area B, the mean coherence value of geometric coregistration is 0.568; and increased by 0.091. Consequently, geometric coregistration has an advantage of interferogram generation in mountain areas.

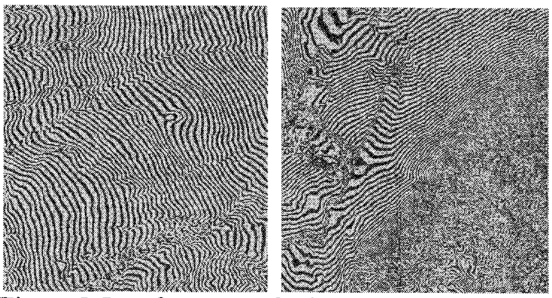
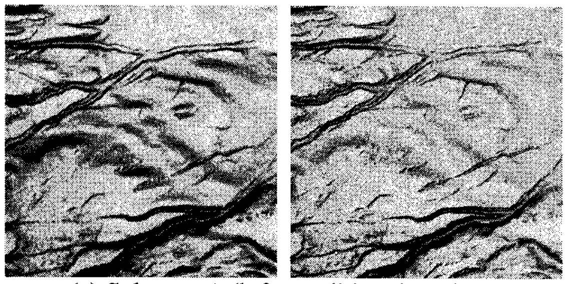
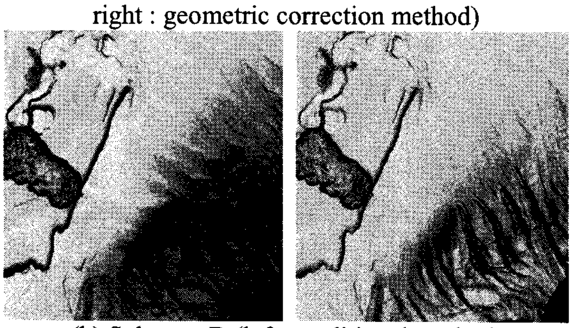


Figure 5. Interferogram of sub-area using geometric correction (left: sub-area A, right: sub-area B)



(a) Sub-area A (left : traditional method, right : geometric correction method)



(b) Sub-area B (left : traditional method, right : geometric correction method)

Figure 6. Coherence image of Sub-areas

Table 2. Comparison of coherence value in sub A and B areas

	Area A		Area B	
	TC	GC	TC	GC
Mean	0.517	0.608	0.477	0.568
Std.	0.150	0.132	0.196	0.156

To calculate a height using topographic fringe in the interferogram, it is convenient to use the notion of altitude of ambiguity (h_a). This sensitivity to topographic relief can be used to generate a digital elevation model (Massonnet, 1998). Altitude of ambiguity is dependent on baseline, slant range and incidence angle. In this study, altitude of ambiguity is about 20 m in center position of the SAR image. It is helpful to generate an accurate DEM in comparison with ERS tandem mode DEM that is about 30 m altitude of ambiguity. But, interferogram is not generating in some areas well. So, continuous research is required in these areas.

$$h_a = \frac{r_s \lambda \tan \theta_m}{2d} \tag{4}$$

where r_s : Slant range of slave

λ : Wavelength

θ_m : Incidence angle of master

d : Horizontal separation between satellites

4. CONCLUSIONS

The interferogram was generated using geometric coregistration by accommodating topographic effect for the TerraSAR-X data. As a result of interferometric coherence analysis, coherence value is increased by 0.033 in full regions and by 0.091 mountainous areas over the traditional coregistration method. However, interferogram is not generating in some areas well. It would be interesting and necessary as a future study to understand the causes of such phenomena.

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