Automatic Generation and Error Analysis of High-Precision DEM Derived from Airborne Dual-antenna Interferometric SAR Data

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1. INTRODUCTION

As an advanced earth observation technology, airborne interferometric synthetic aperture radar (InSAR) has become an important tool for rapidly deriving three-dimensional topographic maps, especially in the tropics, mountainous and Polar Regions [1-3]. From the early 1990's, airborne InSAR has been increasingly applied for the measurement of the earth's topography and demonstrated the capability to generate high-precision digital elevation models (DEMs) in practice [3-8].

Over the last decade, the airborne InSAR systems TOPSAR, EMISAR, DO-SAR, IFSARE, E-SAR, AeS-1, STAR-3i and OrbiSAR-1 have demonstrated the capability to derive DEMs of land surface from radar images, with high spatial resolution and a height accuracy in an order of magnitude of meters [2][9][10]. In China, the Experimental Airborne InSAR System is the first Chinese single-pass InSAR system developed successfully by Institute of Electronics, Chinese Academy of Sciences (IECAS) in 2004 [11]. In 2005, the airborne X-band dual-antenna InSAR system is designed successfully by East China Research Institute of Electronics Engineering (ECRIEE), with a ground resolution up to 1m×1m and a height accuracy excelled in 5m in mountain area [12]. As an international advanced airborne InSAR system, the system can avoid time de-coherence existing in airborne single-antenna InSAR system or space-borne radar system, which has great advantage in topographic mapping. This paper describes how high-precision DEMs are derived from the airborne dual-antenna InSAR data, and quantificationally analyses the DEM error.

2. DATA PROCESSING

In this section, data processing of DEM generation is described (as shown in Figure 1), including complex image registration, phase flattening, phase filtering, phase unwrapping, antenna eccentricity correction, absolute phase estimation, parameter calibration, height derivation and geo-coding. In order to improve the precision, the antenna eccentricity correction and parameter calibration based on Least Square Method (LSM) are proposed.

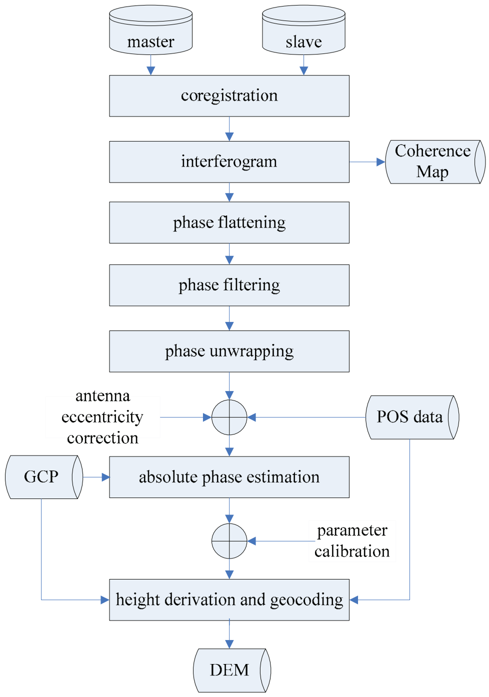
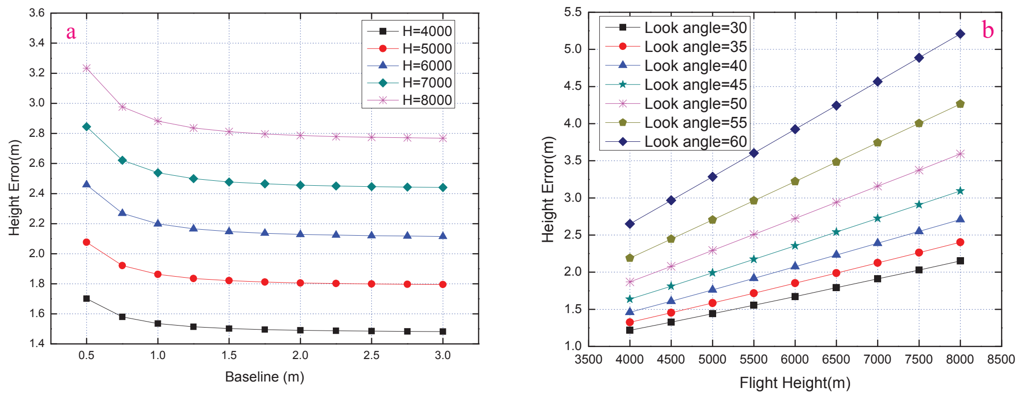


Fig.1 The data processing flowchart for DEM generation using airborne dual-antenna InSAR data

3. THEORETICAL ERROR ANALYSIS

Based on airborne dual-antenna InSAR bore-sight model, section 3 summarizes the main factors which affect accuracy of DEM in airborne dual-antenna InSAR data processing, including platform height, slant range, phase, baseline length, baseline angle, the center Doppler frequency and carrier aircraft attitude (pitch angle, yaw angle, roll angle and carrier aircraft velocity), and analyses the error of those factors. Then, the paper mainly analyses the quantitative relationship between the platform height, baseline length, baseline angle, look angle and DEM error (height error and point error). As shown in Figure 2, the quantitative relationship between the platform height, baseline length, baseline angle, look angle and DEM height error is given.



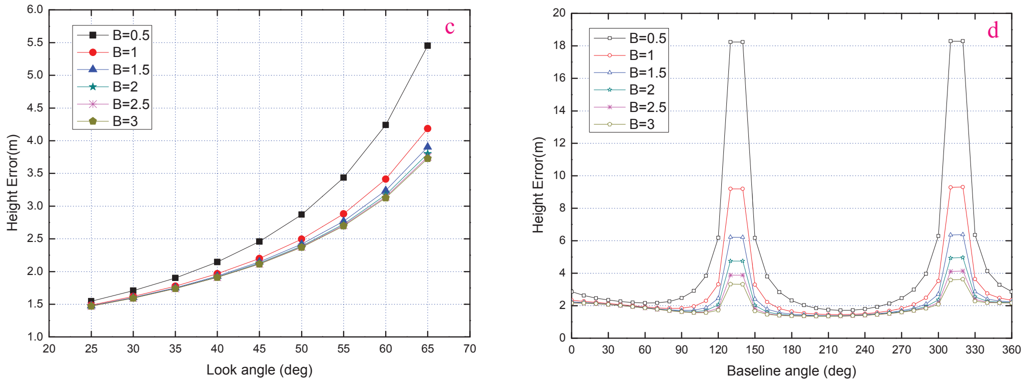


Fig.2 the quantitative relationship between the platform height, baseline length, baseline angle, look angle and DEM error.

4. EXPERIMENT AND ACCURACY ANALYSIS

In the section 4, the experimental data used is airborne dual-antenna X-band InSAR single-look complex (SLC) image pairs (spatial resolution is 2m×2m). The processing results are derived and analyzed. The Figure 3 shows the DEM generated from the airborne dual-antenna InSAR data. The measured ground control points (GCPs) are used to validate the DEM precision. The root mean square error of height of DEM is $\pm 2.584m$ (as shown in Figure 4) and the mean square error of a point of DEM is $\pm 3.547m$, which meet the requirements of 1:50000's DEM accuracy. The airborne InSAR system provides the new technique for large area topographic mapping.

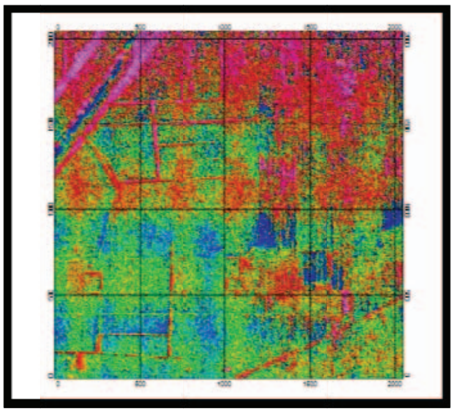


Fig.3 the DEM derived from airborne dual-antenna InSAR data

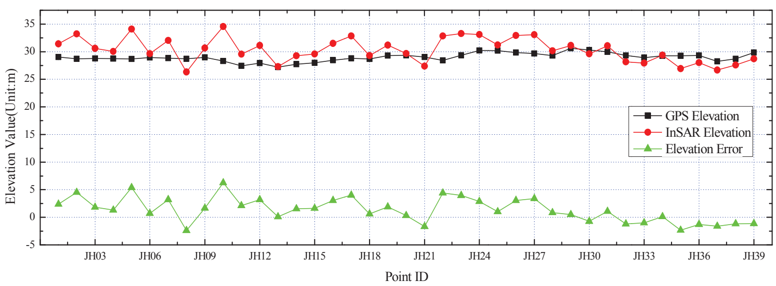


Fig.4 The elevation error statistics graph between the GPS elevation and InSAR elevation

REFERENCE

[1]Graham L. C. "Synthetic Interferometer Radar for Topographic Mapping." *Proc. IEEE*, vol.62. pp. 763-768.1974.

[2]Zebker H., Goldstein R. "Topographic Mapping From Interferometric Synthetic Aperture Radar Observations." J. *Geophys. Res.*, vol.91. pp. 4993-4999.1986.

[3]Wimmer C., Siegmund R., Schwisch M., *et al*. "Generation of high-resolution DEMs of the Wadden Sea with airborne interferometric SAR." *IEEE Transactions on Geoscience and Remote Sensing*, vol. 38. no. 5. pp. 2234-2245. 2000.

[4]Hagberg J. O., Ulander L. M. H. "On the Optimization of Interferometric SAR for Topographic Mapping." *IEEE Trans. On Geosci. and Remote Sens.,* vol.31. pp. 303-306. 1993.

[5]Zebker H.A., Madsen S.N., Martin J., *et al*. "The TOPSAR Interferometric Radar Topographic Mapping Instrument." *IEEE Trans.Geosci. Remote Sens.*, vol.30. pp. 933-939. 1992.

[6] Madsen S.N., Zebker H.A., Martin J. "Topographic Mapping Using Radar Interferometry: Processing Techniques." *IEEE Trans.Geosci. Remote Sens.,* vol. 31. pp. 246-256.1993.

[7] Zebker H. A., Farr T. G., Salazar R. P., *et al*. "Mapping the World's Topography Using Radar Interferometry: The TOPSAT Mission." *Proc. of the IEEE,* vol. 82. pp. 1774-1786.1994.

[8] Rabus B., Eineder M., Roth A., *et al*. "The shuttle radar topography mission- a new class of digital elevation models acquired by spaceborne radar." *J. Photogramm. Rem. Sens.,* vol. 57. pp. 241-262. 2003.

[9] LI, X., BAKER, A. AND HUTT, T. (2002): *Accuracy of Airborne IFSAR Mapping.* In: FIG, XXII International Congress, April 19th – 26th, 2002.

[10] M. Rombach and J. Moreira. "Description and applications of the multipolarized dual band OrbiSAR-1 InSAR sensor." *In Proc. International Radar Conference (RADAR'03)*, pp. 245–250, Adelaide, SA, Australia, September 2003.

[11] XIANG Maosheng, WU Yirong, LI Shaoen, *et al*. "Introduction on an Experimental Airborne InSAR System." *Proceedings of IGARSS'* 2005, pp.4809-4812.2005.

[12] SUN Long, ZHANG Changyao, HU Maolin. **"**Performance Analysis and Data Progessing of the Airborne X-Band InSAR System." *Proceedings of IGARSS'2007,* pp.541-545.2007.