SAR CLINOMETRY- AND INTERFEROMETRY-DERIVED DEM RECONSTRUCTION

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1. INTRODUCTION

The remote sensing technique has been widely applied in global topographic survey, e.g., for computing a digital elevation model (DEM). The synthetic aperture radar (SAR) is able to perform a synoptic monitoring of the Earth under all-weather and day-and-night conditions. Among the SAR-derived DEM reconstruction techniques, four different methods, i.e., clinometry, grammetry, interferometry and polarimetry, are developed and they are reviewed in [1]. Compared with only one method used in the DEM reconstruction, a combination of several ones can alternatively simplify the procedures or increase the accuracy, e.g., a combination of grammetry and interferometry [2], or a combination of clinometry and polarimetry [3].

In this paper, a novel method is proposed by combining of clinometry and interferometry to improve the accuracy of DEM reconstruction. The technical details of the clinometry method can be referenced in [4], and the interferometry method in [5]. Such a combination is also reasonable if considering the exploitation of both the intensity (clinometry) and phase (interferometry) of the plural SAR signal. From the experimental results with the Envisat data, the interferometry-derived DEM is much more accurate in regions of high coherence than the clinometry-derived result. However, in regions of low coherence, some pronounced errors are remained with the interferometry method due to phase unwrapping problems and other affects. On the other hand, the clinometry method can produce a more robust DEM reconstruction. Therefore a user-defined weighting factor is introduced to optimize the results by using the clinometry-DEM in regions of lower coherence, and the interferometry-derived DEM in regions of higher coherence. Finally, the accuracy of the fused DEM can be increased to a great extend.

2. CLINOMETRY- AND INTERFEROMETRY-DERIVED DEM

2.1. Test data set

An Envisat data acquired over the area of Bam in Iran is selected as our test data set. This data is cropped to 1024×1024 samples with a resolution of about 8 m × 4 m in range and azimuth direction, respectively. The master intensity image is shown in Fig. 1 (a), where the radar platform was moving from the top to the bottom of the image with near range on the left. The basic information of this data set can be found in [6].

The reference DEM was generated from the Shuttle Radar Topography Mission (SRTM) [7] with about 90 m pixel spacing. On 26 Dec. 2003, an earthquake struck Bam and made a mean deformation of about 25 cm [6]. However, the data set (on 3 Dec. 2003) and the SRTM DEM (in Feb. 2000) are both acquired before the earthquake; so no deformation is considered to the SRTM DEM as the ground truth.

2.2. Clinometry-derived DEM

Since the clinometry method is based on the intensity image (see Fig.1 (a)), the Lee speckle filter is first applied to pre-process the master image to reduce the effects of speckle. Then the range component of the slopes is calculated, and the elevation increment along each range direction is estimated. Finally the clinometry-derived DEM is shown in Fig. 2 (a). Due to some singular point and the linear integral method, some linear errors are apparent in the clinometry-derived DEM, which are the main errors of the clinometry-derived DEM.

2.3. Interferometry-derived DEM

The raw interferogram is generated by extracting the conjugated product of the master and slave single look complex (SLC) image. Then the raw interferogram is flattened and multi-looked by averaging eight pixels in azimuth and two in range (see Fig. 1 (b)). The coherence map shown in Fig. 1 (c) is estimated by applying a 3 × 3 averaging mask, where the lower coherence values are displayed in dark. Finally, the phase is unwrapped, and the interferometry-derived DEM is shown in Fig. 2 (b). According to Fig. 1 (c), it is apparent that in some lower coherence regions, the interferometry-derived DEM is irregular, which is the main error of the interferometry-derived DEM.

3. DEM CAMPARISON AND FUSION

In our experiment, SRTM DEM is introduced as the reference DEM to validate the clinometry- and interferometry-derived DEM. The difference between the SRTM reference and the reconstructed DEM is shown in Fig. 3 (a) and (b) as a function of the coherence map.

For the clinometry-derived DEM, the relationship between the clinometry height errors and the interferometric coherence map appears to be highly uncorrelated. Meanwhile, the clinometry method can produce a more robust result of DEM reconstruction, i.e. the global reconstruction error is stable at about 30-40 meters. However, for the interferometry-derived DEM, one can recognize that larger height errors tend to be associated with lower coherence values, which indicates that the interferometric coherence map is a useful quality measure for subsequent data fusion.

Therefore, a DEM fusion is performed from the clinometry- and interferometry-derived DEM by introducing a user-defined weighting factor c. This means that in regions with a reliable interferometric result, i.e., indicated by coherence values above c, the interferometry-derived DEM is used and the clinometry information is completely discarded. On the other hand, in strongly decorrelated regions characterized by values below c, the DEM is obtained by using only the clinometry-derived DEM. In out experiment, c is optimized as 0.45 manually, and the improved DEM is shown in Fig. 3 (c), where a better accuracy of the DEM reconstruction is clearly shown.

4. REFERENCES

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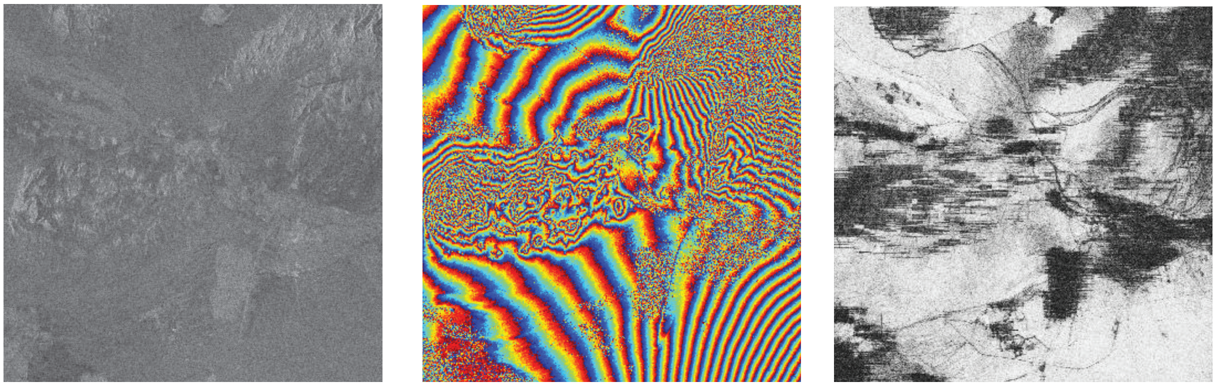

(a) (b) (c)

Fig. 1 Envisat data: (a) Master intensity image. (b) Interferogram. (c) Coherence map.

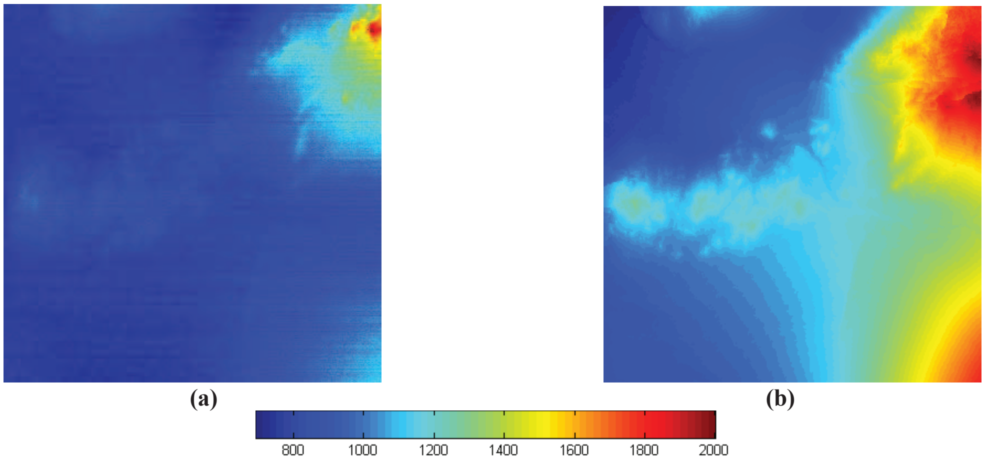

Fig. 2 Reconstructed DEM: (a) Clinometry method. (b) Interferometry method.

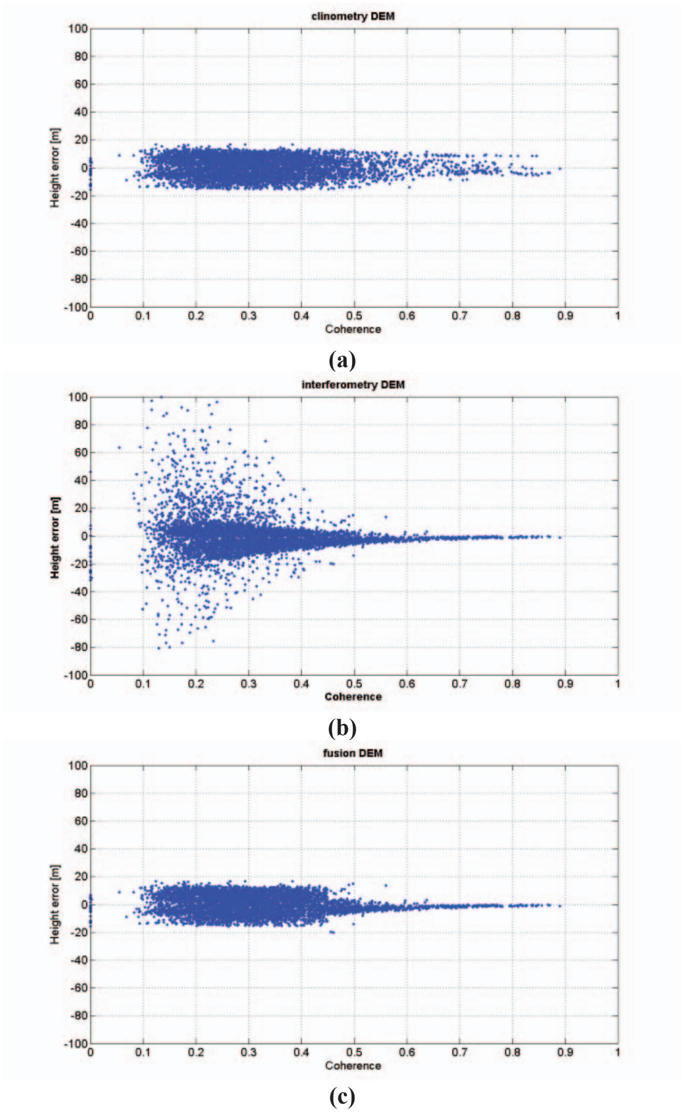

Fig. 3 Height error versus interferometric coherence: (a) Clinometry method, (b) Interferometry method, (c) Combined method proposed in this paper.