DEM GENERATION USING SAR INTERFEROMETRY TECHNIQUE BASED ON ERS SAR IMAGES

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ABSTRACT

DEMs (Digital Elevation Models) derived from survey data are accurate but they are very expensive and time-consuming. In recent years, the ability of application of satellite remote sensing images to generate a DEM has been considering as an efficiency method, especially for mountainous or deep forest areas. In this research, we developed the methods to generate a DEM using the Synthetic Apenture Radar Interferometry (InSAR) technique and shows the result of experiment in Kon – Ha Thanh river in Binh Dinh province. The accuracy of DEM derived from InSAR technique is evaluated in comparison with DEM (reference) generate from contours in topographical map.

1. INTRODUCTION

DEM (Digital Elevation Model) data of the area of Kon Ha Thanh river, Binh Dinh province plays the very important role in the fields of flood hazard prediction and water resource management. In traditional methods, DEM generation has been mainly based on contours in topographical maps produced from field surveys or photogrammetry techniques. However, DEMs derived from survey data are accurate but they are very expensive and time-consuming, in order to solve these problems, utilization of satellite remote sensing data has been considering as an efficiency solution and the stereoscopic images of SPOT or ASTER has been applied and provided the important information for creating DEM of this area in flood forecast modelling.

In recent years, The Synthetic Aperture Radar (SAR) is a technique for obtaining high resolution radar images from a relatively small antenna and from two SAR images, the DEM can be generated by using the phase of the radar signal (Interferometric techniques).

SAR interferometry for DEM generation was proposed by Graham in 1974 [Graham 1974] and this technique applied airborne data for the first time in 1986 [Zebker and Goldstein 1986]. After that, it is continued to develop by Li and Goldstein (1990), Rodriguez and Martin (1992) and Zebker et al (1994). SAR data from several space borne sensors (e.g. ERS-1, ERS-2; JERS-1, Radasat, ENVISAT,..) are available and large number of research groups are working on InSAR DEM generation.

This paper introduces the concept of InSAR technique and shows the result of experiment in the area of Kon Ha Thanh river, Binh Dinh province based on the suggested technique.

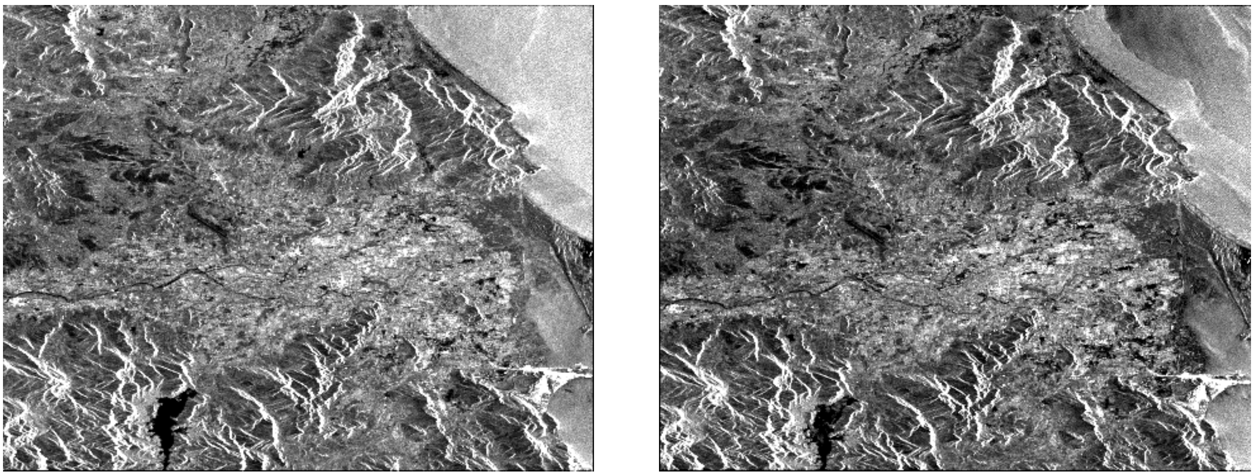
2. STUDY AREA

The Kon and Ha Thanh river basin belongs to Binh Dinh province, has a very complex river-network and topography divided clearly in two parts: mountain area in the upstream and plain area in downstream of river basin.

This area is one of the most frequent flooding areas in VietNam. Therefore, many flood-preventing solutions have been made and the flood hazard prediction map also plays a quite important role to provide the helpful information in preventing and reducing losses caused by floods. DEM is a source that providing basic information for investigation of relationships between spatial flood characteristic and the measurements of ground hydrometrical stations.

Figure 1: Study area

SAR images use for this research are ERS-1 (Earth Resources Satellite-1) and ERS-2 (Earth Resources Satellite-2) which are provided by European Space Agency. Two satellite were lauched on July 1991 and April 1995. A full ERS scene covers an area of 100km x 100km with 30 spatial resolution. Two satellite support for acquisition data in the same area with one-day internal betwwen two SAR images. The one-day offset offered by the tandem mission increases the probability of having high coherence between the acquired data. This is excellent data for applications in SAR interferometry.



a. SAR SLC (ERS-1: 12 Apr 1996) b. SAR SLC (ERS–2: 13 Apr 1996)

Figure 2: ERS SAR SLC (B = 117m)

3. SAR INTERFEROMETRY

The first requirement is the availability of two SAR images in complex form. Complex SAR data refer to a set of data that has a real (cosine) and an imaginary (sine) component. The two values combine as vectors to provide the overall phase and intensity of a wave.

The selection of the images is made on the basis of baseline length and the time period between two image acquisitions. Depending upon the application and the spatial resolution of the data, the baseline length can be chosen. For example, in the case of ERS–1 and 2, the baseline may be taken as 150 to 300m for topographic applications, 30 to 50m for surface change detection and up to 5m for surface feature movement studies such as crustal deformations, lithospheric movements, movement of glaciers etc,... Also, the time gap between two passes of satellite may not be kept large as there may be some changes in the scene that may lead to temporal de-correlation. However, the temporal de-correlation, in the case of ERS-1 and 2 may be taken care of by tandem operation of two satellites at a small temporal resolution of as low as one day.

After selection of images, we align the images from the two antennas and calculate the phase difference.

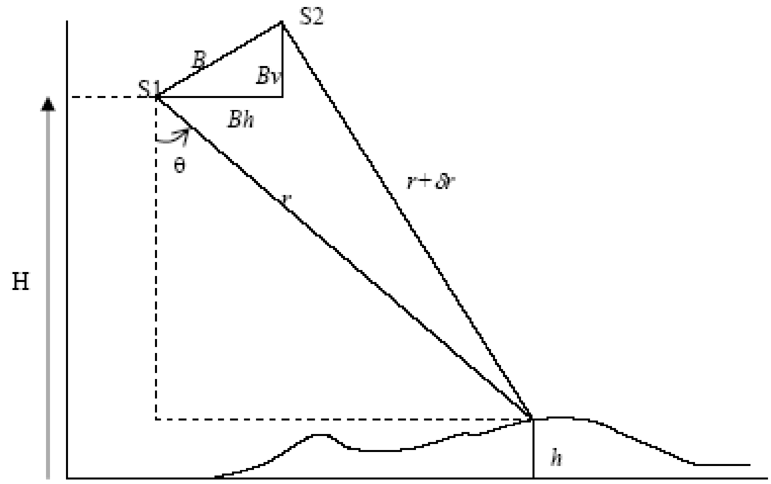


Figure 3: InSAR Geometry

The phase difference ϕ between two Radar signals acquired from the same surface element at the two antenna positions according to Li and Goldstein, 1990, can be calculated as:

$$\phi = \frac{4\pi(\delta r)}{\lambda} = \frac{4\pi(B_h \sin\theta - B_v \cos\theta)}{\lambda}$$

where λ is the wavelength, δr is the range difference, B_h, B_v are baseline horizontal component, baseline vertical component and θ is the look angle

Based on the range difference and the look angle changes through the scene, the phase difference (interferometric phase) between two sensor positions and the target terrain point (pixel wise) can be generated as:

$$\Delta h = \frac{\lambda r \sin\theta}{4\pi B} \Delta\phi$$

r is the range in the first image, $\Delta\phi$ is the change in phase
B is normal base line

Thus, the relationship between the heights and the phase differences can be determined. The height determined for each pixel of SAR image form the necessary DEM in raster form.

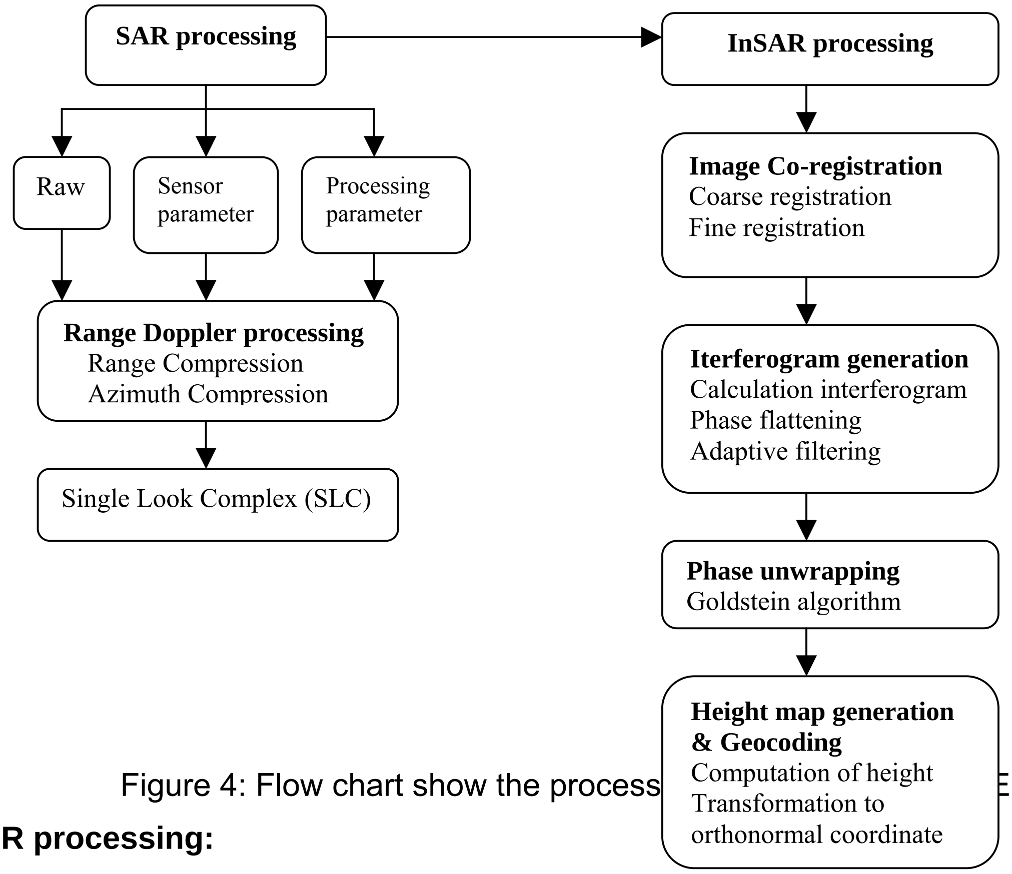


Figure 4: Flow chart show the process EM

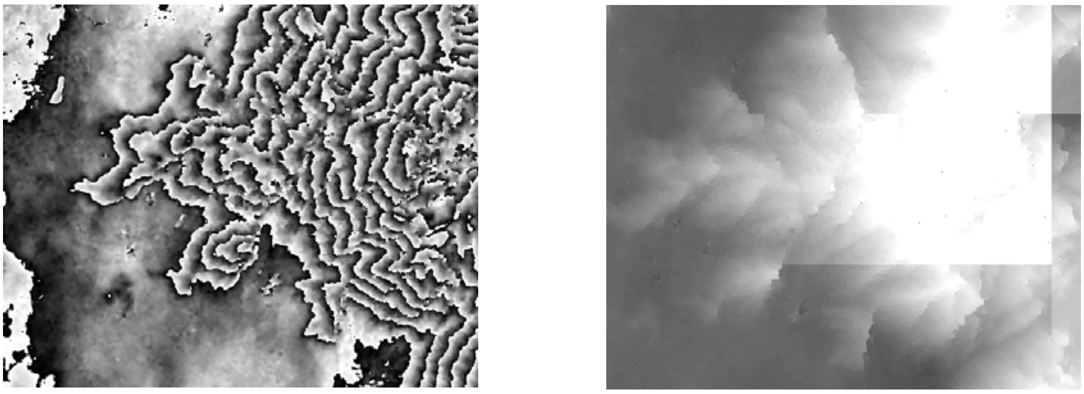
InSAR processing:

Step 1: **Image Co-registration**
Interferometric processing of complex SAR data combines two single look complex (SLC) image in to an interferogram. Precise coregistration of coherence interferometric SAR image pairs is essential for the generation of SAR interferogram.

Step 2: **Interferogram generation**
In order to reveal information about the third dimension (elevation) of the object and to measure small displacements of objects between the two image acquisitions. An interferogram is an image acquired by making the phases of two SAR images of the same terrain to interfere. Thus, after registration, the complex interferograms are formed by multiplying each complex pixel of the first image by the complex conjugate of the same pixel in the second image. The interferogram thus generated is a complex image itself. The intensity of the interferogram is a measure of cross correlation of the images.
Before unwrapping, we do a few things to the data that make the phase unwrapping easier. The first of these is to reduce the noise and the second is to reduce wrapping frequency in the interferometric phase function (phase flattening).

Step 3: **Phase unwrapping**

As the height of the terrain increases, the phase also increases steadily. Since phase values are periodic functions of 2π, they automatically get wrapped after reaching 2π, which is not a desirable situation. Phase unwrapping is a technique that permits retrieving the unwrapped phase from the wrapped phase, which for the InSAR, is a necessary step for the generation of DEM.



a. Wrapped phase $(-\pi, \pi]$ b. Unwrapped phase

Hình 5: Unwrapped phase

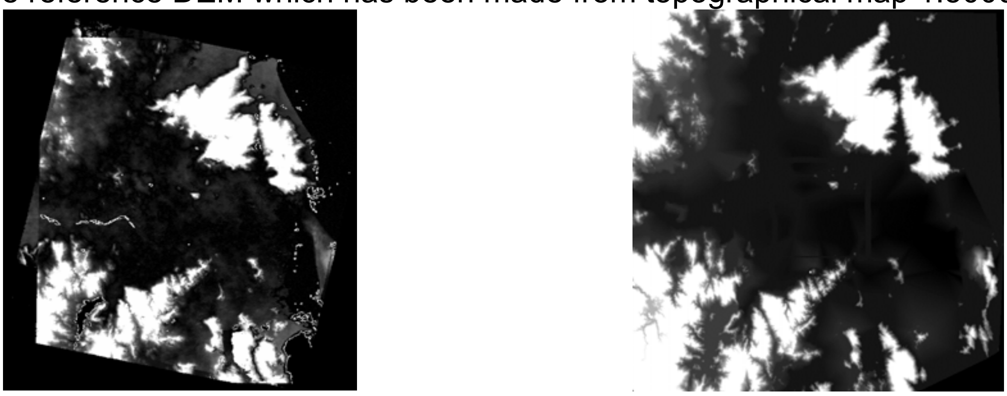
Step 4: **Height map generation & Geocoding**

After unwrapped phase, it converts the unwrapped phase value to height value for each pixel of the SAR image form the necessary DEM in raster form. The orthocorrected InSAR DEM is remapped from the SAR coordinate system to cartographic orientation and projection.

4. RESULTS

The raw data has been processed by PulSAR software with the functions: Doppler ambiguity estimation, missing line detection, range compression, focusing azimuth compression. The results are Single Look Complex (SLC) image.

Next, following the InSAR processing, DEM has generated by InSAR Toolkit software. Figure 6.a shows DEM generation from InSAR technique and figure 6.b shows the reference DEM which has been made from topographical map 1:50000.



a. InSAR DEM b. Reference DEM

Hình 6: Keát quaû DEM

The height profile between InSAR DEM and reference DEM in typical location has made to compare the precision as figure 7.

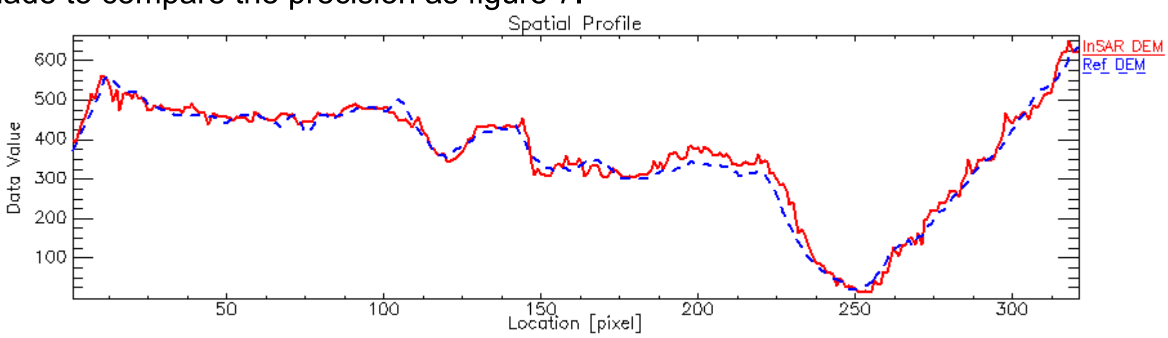


Figure 7: Height profile InSAR DEM vs. reference DEM

The figure 7 shows that the relation between two profile are closed, the mean height diference equal 16.9m and in full image, the mean height difference equals 14.7 m.

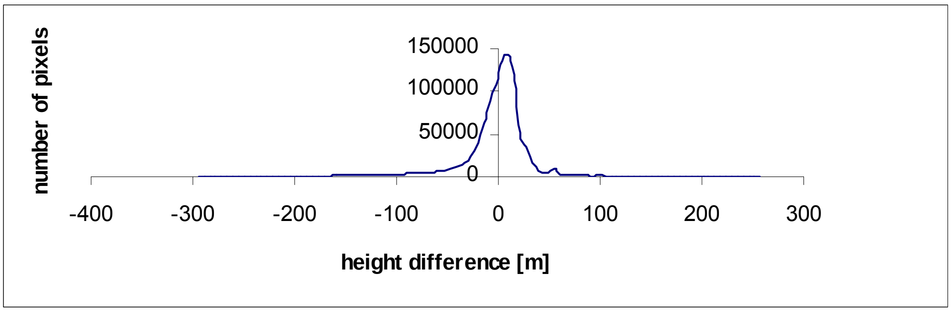


Figure 8. The difference between InSAR DEM vs. reference DEM

5. CONCLUSION

In this case study, we also realize that ERS SAR images are very useful to provide basic information for DEM generation. The first results has demostrated the accuracy of InSAR DEM about 15m suitable with the surface of terrains in Kon - Ha Thanh river and the suggested technique can be used in establising the flood hazard prediction map that can obtain an appropriate accuracy, short a time and low cost. However, it works best when coherence, baseline and phase unwrapping are balanced optimally.

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