Comparison of Elevation Derived from InSAR Data with DEM from Topography map in Son Dong, Bac Giang, Viet Nam

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Abstract. Digital Elevation Models (DEMs) are used in many applications in the context of earth sciences such as in topographic mapping, environmental modeling, rainfall-runoff studies, landslide hazard zonation, seismic source modeling, etc. During the last years multitude of scientific applications of Synthetic Aperture Radar Interferometry (InSAR) techniques have evolved. It has been shown that InSAR is an established technique of generating high quality DEMs from space borne and airborne data, and that it has advantages over other methods for the generation of large area DEM. However, the processing of InSAR data is still a challenging task. This paper describes InSAR operational steps and processing chain for DEM generation from Single Look Complex (SLC) SAR data and compare a satellite SAR estimate of surface elevation with a digital elevation model (DEM) from topography map.

Keywords: InSAR, DEM, Processing steps, ERS1/2, DORIS

1. Introduction

Synthetic Aperture Radar Interferometry (InSAR) is a technique that two SAR images acquired in the same area with a nearly identical incidence angle (one usually regarded as master and the other slave) are combined to produce a phase interference image called an interferogram [1]. SAR images have two components: magnitude (brightness) and phase values. Often the phase information is thrown away; however, if it is retained, the SAR image is described as being complex [1]. The phase in a complex SAR image is a coherent signal containing information about the distance between a resolution cell on the ground and the radar antenna, as well as information about the texture of terrain within a resolution cell. Using the phase information in the interferogram, it is possible to extract topographic height information (DEM), height change information, and fine scale temporal change measurements [1].

To measure the topography and monitor deformation of earth surface, traditional geodetic measurements, geotechnical instrumentation, GPS-based systems, and many other geodetic techniques are also available. The stereo aerial photography or photographs taken by satellites are also used to construct topographic maps. A major problem for optical imagery in tropical areas like Viet Nam is cloud cover that prevents imaging of the ground surface from space. However, most of them are point-based measurement techniques and are too costly if a very large area needs to be monitored. InSAR technique has emerged as the state-of-the art technique of measuring dense points in an area accurately, economically, conveniently and efficiently, and without any effect from cloud cover [1, 2]. This paper describes an InSAR operational steps and processing chain for DEM generation from SAR data which is suitable for adaptation in an organization for both industrial and scientific applications. Each processing step can be automated in an organizational workflow to make for efficiency.

2. Proposed InSAR processing stages

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The proposed overall InSAR processing stages are Data Search, Data Processing, and Data Validation (Figure 1). Description of each component of the processing stage follows.

![Data Search](image1) ![Data Processing](image2) ![Product Validation](image3)

**Fig. 1: Overall InSAR Processing Stages**

### 2.1. Data Search

The data search stage consists of searching for appropriate data that will ensure adequate data quality and capable of yielding optimal result for the InSAR processing. The search is usually made to agencies responsible for SAR data provision. Currently there are two agencies operating SAR satellites in the civilian sector, the Canadian Space Agency (CSA), the European Space Agency (ESA), the National Space Development Agency of Japan (NASDA) and Infoterra GmbH (Germany). CSA has had two SAR satellites, RADARSAT-1 (C Band) in orbit since 1996 and RADARSAT-2 (C Band) in orbit since 2007. Table 1 gives summary of current satellite radar missions.

#### Table 1: Satellite radar missions

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Country</th>
<th>Year</th>
<th>Band</th>
<th>Frequency (GHz)</th>
<th>Wavelength (cm)</th>
<th>Polarization</th>
<th>Resolution class (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERS-2</td>
<td>Europe</td>
<td>1995</td>
<td>C</td>
<td>5.25GHz</td>
<td>5.7</td>
<td>HH</td>
<td>20</td>
</tr>
<tr>
<td>ENVISAT</td>
<td>Europe</td>
<td>2002</td>
<td>C</td>
<td>5.25GHz</td>
<td>5.7</td>
<td>All</td>
<td>20-200</td>
</tr>
<tr>
<td>RADARSAT-1</td>
<td>Canada</td>
<td>1995</td>
<td>C</td>
<td>5.35GHz</td>
<td>5.7</td>
<td>HH</td>
<td>10-100</td>
</tr>
<tr>
<td>RADARSAT-2</td>
<td>Canada</td>
<td>2007</td>
<td>C</td>
<td>5.405GHz</td>
<td>5.7</td>
<td>All</td>
<td>10-100</td>
</tr>
<tr>
<td>TERRASAR-X1 (TSX-SAR)</td>
<td>Germany</td>
<td>2007</td>
<td>X</td>
<td>9.6GHz</td>
<td>3.1</td>
<td>HH</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>ALOS(PALSAR)</td>
<td>Japan</td>
<td>2006</td>
<td>L</td>
<td>1.275GHz</td>
<td>23.5</td>
<td>All</td>
<td>5-20</td>
</tr>
</tbody>
</table>

### 2.2. Data processing

The data processing stage consists of five distinct steps: Data pre-processing, Co-registration and Resampling, Computation of Interferogram, Phase un-wrapping, and Geocoding. In this work, the data processing stage is performed using Delft Object-oriented Interferometric Software (Doris) [1, 2]. Doris uses other public domain software to perform dedicated tasks that can be handled well by these programs. This software have also been used for this processing that includes getorb which is for getting precise orbital data records for the ERS satellites [1], SNAPHU for phase unwrapping [1], GMT for general plotting and gridding [1], and PROJ.4 for coordinate transformations [1].

#### 2.2.1. Step 1. Data input, data cropping, and over-sampling

This first step in the Data Processing stage consists of input of both master and slave data sets for the InSAR processing. Only Single Look Complex (SLC) data are processed. This excludes the pre-processing of the raw data, both radar and orbit.

#### 2.2.2. Step 2: Co-registration and resampling

In this step the co-registration polynomial that describes the transformation of the slave to master image, which is subsequently used for the re-sampling of slave image to the master grid is determined.

#### 2.2.3. Step 3: Computation of interferometric products

In this step the complex interferogram and the coherence image are generated. In Doris, interferogram is by default computed using a multilook factor of 5 in azimuth and 1 in range. The interferometric phase is corrected for the phase of a reference body.

#### 2.2.4 Step 4: Phase Unwrapping

This is the reconstruction of the original phase from the wrapped phase representation. Doris calls the SNAPHU phase unwrapping software for the phase unwrapping computations.

#### 2.2.5 Step 5: Geocoding
In this step the unwrapped phase is converted to a height, and the pixel coordinates are geo-referenced. The output of this step is the height for a large number of pixels at an irregular grid of (longitude, latitude) pair.

2.3. Product Validation

This stage includes all aspect of quality assessment of the InSAR products through comparison with reference models obtained from independent sources.

3. Processing ERS 1/2 Data Set

In order to test the processing steps described in section 2, we computed the topography of Luc Ngan, Bac Giang in Viet Nam. The ERS data of this area was kindly provided by. The temporal baseline is only 1 day, resulting in minimal temporal decorrelation for this area, the perpendicular baseline is 78.1 (m) and the parallel baseline is 49.1 (m).

3.1. Introduction to study area

Research area of the northern district of Son Dong, Bac Giang province. This area is a mountainous district of Bac Giang. From the town center district of Son Dong northern city about 80 km. Southern and southeastern border province of Quang Ninh, west and northwest border of Lang Son Province, west Luc Ngan, Luc southwestern borders Vietnam (Figure 2).

3.2. Results

The interferogram was computed using a multilook factor of 5 in azimuth and 1 in range. To generate the DEM, the projection is set to UTM 48 and the horizontal and vertical datum is set to WGS84. The resulting
topography interferogram created from two ERS 1/2 SLC images (master orbit 24154 and slave orbit 4481) and geocoding image are shown in Figure 3.

4. Comparison of SAR elevation estimates with DEM Topography

To assess the accuracy of DEM, the cross section was formed from pairs of SAR images interference and the authors have compared DEM with DEM topography (scale 1: 50,000).

4.1. Comparison of DEM in plain and low hills.

Longitudinal follow up of these areas were performed on both DEM model (DEM interpolated from the map, DEM from INSAR techniques) and the results are presented in Figure 4.

Cross section of the DEM

Fig. 4: Results comparing the corresponding cross section

4.2. Comparison of DEM in high mountainous areas

Longitudinal follow up of these areas were also conducted on both DEM model (DEM interpolated from the map, DEM from INSAR techniques) and the results are presented in Figure 5.

Cross section of the DEM

Fig. 5: Results comparing the corresponding cross section

5. Conclusion

This paper has presented steps for processing InSAR data for DEM generation using SLC data. It has implemented a sequential approach for organizing SAR image processing steps in a way to minimize disk space, RAM access, and image cache size, as well as minimize inter-process communication and message passing between different steps. It has been implemented in a PC (Pentium 3), thereby taking full advantage of low-cost computing hardware. Also it provides a complete environment for batch processing, and utilizes one of the best of the open source InSAR software (Doris). Practical application of the InSAR processing steps described in this paper has been tested with the processing of the Luc Ngan, Bac Giang ERS1/2 data set to yield DEM of the area. The InSAR processing steps described in this work can be adapted to form a data processing workflow for an organization for both commercial exploitation of SAR data and for scientific investigation, using any software capable of InSAR processing.

In general the value of DEM elevation established from the topographic map is lower than DEM are formed from pairs of SAR images, isolated in some areas high values between 2 DEM data almost equal. The reason is because DEM InSAR is essentially the model of terrain (DTM - Digital Terrain Model), rather than digital elevation model (DEM - Digital Elevation Model), i.e. it always gives real difference compared
to an approximately true altitude by the height of the object's location on the ground as trees, houses. At the top of the mountain, where less is actually the height of the INSAR DEM and DEM Topographic map are rather similar where many places coincide. The seat height anomalies (there is a large difference in height between the two DEM) may be due to errors in the process of building INSAR DEM.

InSAR technique is a breakthrough technology in the field of remote sensing technology and has opened a modern technique for DEM construction. However, there is a technical difficulty in processing which requires high precision, right from the image registration step.

The initial results achieved show that the accuracy of DEM InSAR can achieve high accuracy in mountainous areas than in plains area. However, the accuracy of the results depend on many different factors such as acquisition SAR sensors, line spacing, the correlation of pairs of images, the algorithm for problem resolution opening phase. In particular, the problem should be open phase accurately and requires control points to be measured directly on the field.

6. Problems

There are several problems in the paper. First of all, we don't have ground truth data (GCPs - Ground Control Points) to assess the accuracy the DEM INSAR. For data selection, very strict criteria were used because of the fear of coherence lost due to vegetation and atmosphere. There is also another deformation pair selected, but there are some problems with co-registration so an interferogram cannot be generated. This problem is probably caused by convergence of orbits and therefore the re-sampling step cannot be covered by the polynomial transformation. Another problem of our application are the orbit and atmospheric errors which cannot be distinguished their influence is very similar and both can be corrected by the same procedure – setting the “artificial” baseline.

7. Acknowledgements

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8. References