Chapter 5
3D InSAR Phase Unwrapping within the Compressive Sensing Framework

Wajih Ben Abdallah
University of Carthage, Tunisia

Riadh Abdelfattah
University of Carthage, Tunisia

ABSTRACT

This chapter presents a new phase unwrapping algorithm for the 3D Interferometric Synthetic Aperture Radar (3D InSAR) volumes. The proposed approach is based on the relationship between the gradient vectors of the observed wrapped phase and the true phase respectively, when the Itoh condition is satisfied. Since this relationship is violated by the residue pixels in the observed wrapped phase, a general problem formulation which takes into account the estimation error due to these residue values is proposed. This approach exploits the temporal inter correlation between the interferometric frames within a compressive sensing framework. The 3D discrete curvelet transform is used in order to ensure a suitable sparse representation of the phase volume. The performance of the proposed 3D phase unwrapping algorithm is tested on simulated and real SAR 3D datasets

INTRODUCTION

The Interferometric Synthetic Aperture Radar (InSAR) is an image processing technique that exploits the phase difference between two acquired complex SAR images, over a given area, in order to extract the elevation information (Abdelfattah & Nicolas, 2002). The main application of the InSAR technique is to generate the Digital Elevation Model (DEM) (Abdelfattah & Nicolas, 2002). When more than two complex SAR images are used, the InSAR technique allows to map the temporal variations of the Earth's surface that are due to natural disasters such as earthquakes, landslides, or even artificial phenomena (Leva, Nico, Tarchi, Fortuny-Guasch, & Sieber, 2003). The interferometric phase image, known as the interferogram, is composed of a suite of fringes where the phase is known only modulo 2π. This is known

DOI: 10.4018/978-1-5225-0937-0.ch005

as the wrapped phase. It is due to the complex representation of the phase. However, this will cause,that the information provided by the interferogram is not directly exploitable. Since the phase values in the InSAR image are between $-\pi$ and $+\pi$, so it is impossible to extract the true topography of the terrain and its temporal variations due the wrapping effect. For this reason a phase unwrapping step is needed to expand the phase to its true values between 0 and $2k\pi$.

In the other hand, the 3D phase unwrapping is a process operating in the space-time domain. The 3D interferometric volume dataset is composed of many frames where each of them represents an InSAR phase image acquired at a specified time. The 3D InSAR concept leads to an improvement in the accuracy of the true phase solution since the unwrapping process is performed taking into account the correlation between InSAR frames (Hooper, Segall & Zebker, 2007). In the literature, the 3D phase unwrapping problem has a growing up interest and most of the proposed approaches perform a series of independent 2D phase unwrapping processing.

In this chapter, the authors give first an overview on 2D and 3D interferometric SAR formation and concepts. Then, they present the sparse recovery technique which is the key of the main contribution of this chapter. After that, the authors describe in details a new phase volume unwrapping algorithm that exploits the temporal inter correlation between the interferometric frames. This algorithm is based on the sparse recovery technique and the 3D discrete curvelet transform to ensure a suitable sparse representation of the phase volume. Finally, the proposed approach is tested and validated using simulated and real SAR 3D datasets.

2D Interferomteric SAR formation

Based on the acquisition geometry of the SAR system (Hanssen, 2001), the radar cannot distinguish two different targets on the ground when they having the same range distance but different angles with respect to the sensor. In order to overcome this detection problem, and obtaining phase measurements as well as amplitude, one can use acquisitions provided from two different antennas or a unique one at two different times. These two solutions enabled the scientists to compute the topography mapping from the phase difference images called interferograms SAR (Hanssen, 2001).

Phase Difference Principle

The distance between the antenna and the target is obtained from road trip time of the emitted pulse. The Figure 1(a) shows that the two points *P* and *P'* situated on the same slant range and on different horizontal positions cannot be distinguished. Although the intensity of the reflected waves from *P* and *P'* may give information about the topography, it cannot provide exact information. This problem can be resolved by using the phase difference between the two targets by considering *P'* as reference point. The computation of this phase difference is equivalent to calculate the phase gradient between two neighbors pixels in the radar image. These two pixels refer to the points whose geographic positions are slightly different (see Figure 1(b)).

Thus, let define the distance between the two sensors as *baseline B* and the distance that is perpendicular to the incidence angle as *effective baseline* $B_{\perp}$ (see Figure 1).

By neglecting the time delay due to the atmospheric effect, the observed phase can be considered as the sum of two values: the phase proportional to the distance R_1 and the phase due to pixel dispersion