SAR Interferogram Phase Filtering Using Wavelet Transform

Vahid Akbari
Norwegian Institute of Bioeconomy Research

Mahdi Motagh
Helmholtz-Zentrum Potsdam - Deutsches GeoForschungsZentrum GFZ

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V. Akbari, M. Motagh and M. A. Rajabi

[1] Dept. o Surveying Eng., University College of Eng., University of Tehran, Tehran, Iran
va2akbari@yahoo.com, motagh@gfz-potsdam.de and marajabi@ut.ac.ir

Abstract:

The application of SAR Interferometry (InSAR) especially in Digital Elevation Modeling as well as deformation monitoring encounters problems due to noise in the interferogram phase. The noise is mainly caused by temporal and baseline decorrelation as well as changes in atmospheric conditions that makes the process of phase reconstruction difficult and reduces the accuracy. The quality of digital elevation models and displacement maps can be improved by filtering the interferometric phase. This paper reviews the methods of for noise reduction of interfermetric phase. It discusses a new algorithm based on wavelet transform which reduces the noise without reducing the spatial resolution or using any window over the interferogram. Comparing this algorithm with the other existing methods shows its strength in reducing the noise and preserving the signal. The effectiveness of the proposed filtering algorithm is tested by applying it to the InSAR results of the Bam earthquake. The results show that the filtering algorithm using wavelet transform is very successful in reducing noise in the interferogram.

Keywords: SAR Interferometery; Wavelet Transform; Deformation Monitoring; Inteferogram; Wavelet Transform; Noise Filtering.

Introduction

SAR interferometry has proven to be an extremely powerful tool for topographic and deformation mapping. The so-called differential InSAR method (D-InSAR) represents a unique method for detection and mapping of surface displacements over large temporal and spatial scales with cm-accuracy. This is of great importance for earthquake and volcanic research, glaciology and ice sheet monitoring, studying tectonic processes, monitoring land subsidence due to mining, gas, water, and oil withdrawal, etc [2].

Various noise sources such as temporal and spatial decorrelation, thermal noise and so on, reduce the quality of interferometric phase, corrupting the signal and reducing fringe visibility [7]. This precludes accurate phase unwrapping unless an effective filtering is applied to reduce the phase noise [3].

There are several filters that reduce the interferometric phase noise. The simplest one is the box car filter that makes a simple multilook or averaging but leads to a degradation of spatial resolution and edge blur [4].Another method proposed by Goldstein and Werner, is called adaptive phase noise filtering which works based on filleting in Fourier domian [5].The proposed algorithm in this paper is based on the wavelet transform in order to denoise the interferometric phase without windowing process. This approach can reduce phase noises while retaining spatial resolution of the original interferograms. Furthermore, it can preserve detailed edges or interesting targets in areas with discernible fringes [6].

By using a real noisy interferogram, the performance of this algorithm, in terms of noise reduction, spatial resolution maintenance, and computational efficiency, is reported and compared with other conventional filtering approaches [7].

2. Wavelet Transform and Denoising

Fourier transform-based spectral analysis is the dominant analytical tool for frequency domain analysis. However, Fourier transform cannot provide any information of the spectrum changes with respect to time. To overcome the deficiency of Fourier transform to analyse nonstationary signals, Gabor proposed in 1964 a modified short time Fourier transform that allows to represent the signal in both time and frequency domain through time windowing function [29]. The window length determines a constant time and frequency resolution. Thus, a shorter time windowing is used in order to capture the transient behavior of a signal at the expense of sacrificing the frequency resolution. The nature of nonstationary signals is nonperiodic and transient; such signals cannot easily be analyzed by conventional transforms. So, an alternative mathematical tool- wavelet transform must be selected to extract the relevant time-amplitude information from a signal. In the meantime, we can improve the signal to noise ratio based on prior knowledge of the signal characteristics.

3. Experimental results

To test the performance of the proposed algorithm, we apply it to the InSAR results of the Bam earthquake. The data have been acquired from Envisat ASAR sensor (ASAR Image Mode (IM), 16 bit, Swath 2, VV polarization, C-Band) in track 120. The master and slave date are December 3, 2003 and February 11, 2004, respectively and the baseline is 14.3m [Table 1]. The interferometric processing was done using the Doris software. The goal is to maintain the fringe information and denoise the inteferogram.

Table1. The characteristics of SAR SLC images as acquired by Envisat to form interferogram

Data of Acquisition	Pass	Track	Orbir	Upper Left Latitude	Upper Left Longitude	Lower Right Latitude	Lower Right Longitude	Width	Height
December 3, 2003	Descending	120	9192	29° 42' 29" N	58° 08' 44" N	28° 38' 17" N	58° 59' 55" N	5167	26897
February 11, 2004	Descending	120	10194	29° 29' 14" N	58° 05' 38" N	28° 35' 31" N	58° 56' 43" N	5167	26897

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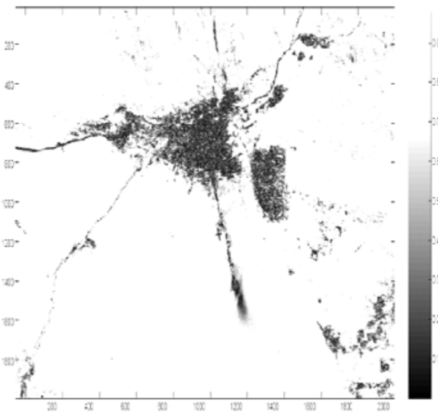

Figure 1. Coherence image

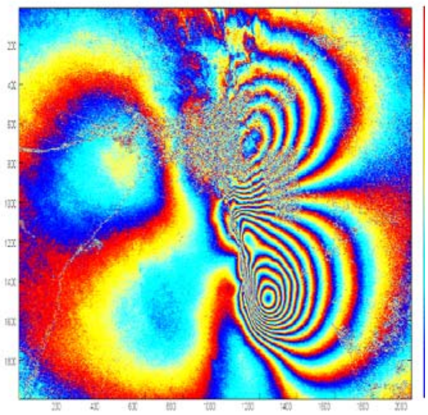

Figure 2. Original Interferogran

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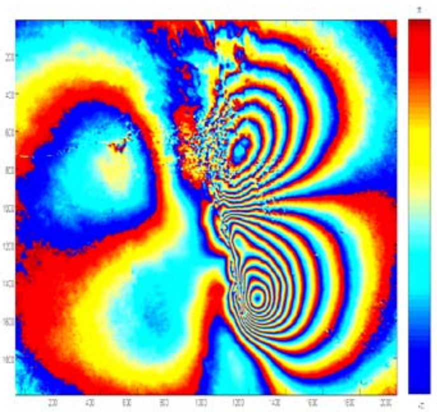

Figure 3. Filtered Interferogram with Goldstein&Werner

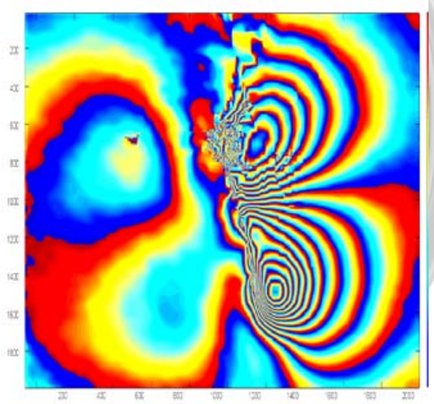

Figure 4. Filtered Interferogram with Wav Transform

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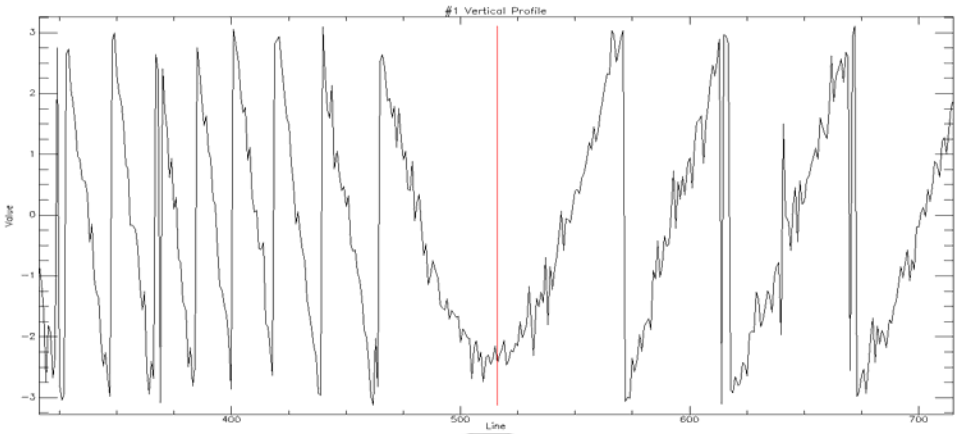

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5. Profile of the 755 column of Original Interferogram

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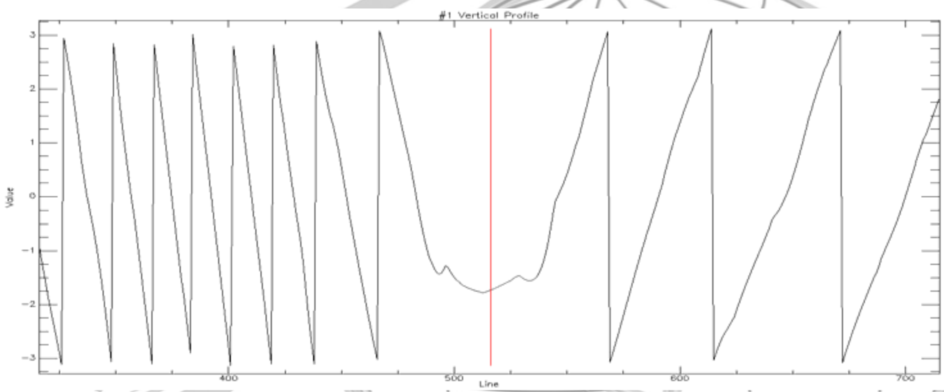

Figure 6. Profile of the 755 column of Filtered Interferogram with Goldstein&Werner

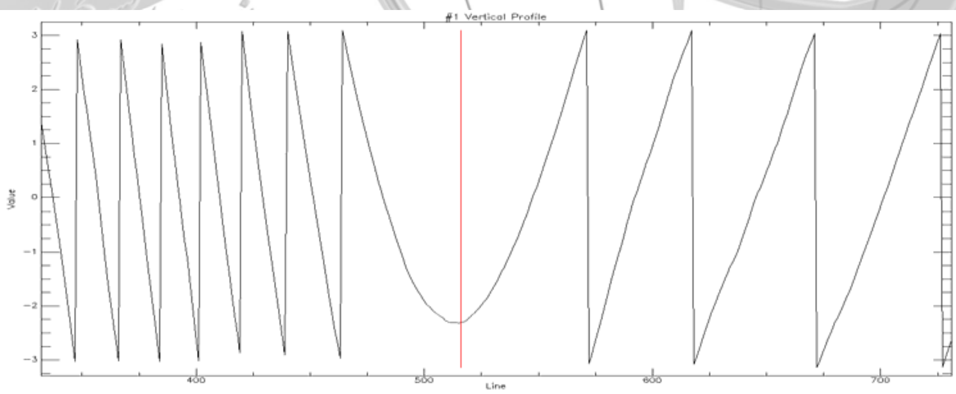

Figure 7. Profile of the 755 column of Filtered Interferogram with Wavelet Transform

The Figure 2 shows a real interferogram of Bam earthquake. Since this interferogram contains the variety properties such as dense and non-dense fringes, the areas with low,

moderate and high noise, hence it would be the suitable option to test this algorithm. Most noise of this interferogram is the result of the temporal decorrelation due to the damage of the builidings of Bam and Beravt city during the earthquake occurrence. (See the figure 1: Coherence image).
Having induced the wavelet transform, the ratio of noise reduces considerably and also the dense fringes retain in filtered interferogram (Figure 4). To validate this algorithm, the Goldenstein & Werner was forced over the interferogram (Figure 3). Comparing with figure 2, the fringes of figure 4 also enhanced well after filtering.
In Figure 7, it is obvious to see that the profile is smoother than the one in figure 5. This column drawn in the original interferometric phase (Figure 5) was noisy. After the noise is filtered successfully, we also can preserve the signature and sharp from profile of Figure 7.

4. Conclusion

The noise not only worsen the fringe visibility, but also hinder phase unwrapping which is necessary to convert the phase to height or deformation. In this paper, an approach to phase noise reduction was proposed based on the wavelet transform. The results showed that the proposed approach can reduce phase noises with retained spatial resolution of the original interferograms while preserving edges.
The different criteria such as the signal to noise ratio, Root Mean Square Error, The correlation of the simulated interferograms and retaining dense interferograms after filtering the real interferograms shows the ability and potential of this algorithm to retain the original signal.

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