Noise reduction of High-Resolution SAR image over Vegetation and Urban Areas by means of Savitzky-Golay filter

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Abstract— **In this paper we introduced new wavelet based algorithm for speckle reduction of synthetic aperture radar images, which uses combination of undecimated wavelet transformation, savizat filter (which is an adaptive filter) and mean filter. Algorithm for speckle reduction of synthetic aperture radar images, which uses combination of undecimated wavelet transformation, wiener filter (which is an adaptive filter) and mean filter. The reduction of speckle is necessary for any further processing of SAR image. A new adaptive filtering algorithm is proposed to remove speckle in SAR images in this paper.**

Keywords— **SAR (synthetic aperture radar), DEMs (digital elevation models) Electromagnetic (EM), Brute force thresholding, Directional smoothing, Direction dependent mask, undecimated wavelet transformation)**

I. INTRODUCTION

Nowadays, it is generally appreciated that the InSAR technique in geophysical applications is an appealing and powerful tool for mapping the dynamic change in Earth's topography. The InSAR technique uses the information contained in the phase of SAR images. A SAR interferogram is a superposition of information on the topography, the surface deformation between the two SAR acquisitions, the atmospheric propagation delays, and various noises (Tarayre and Massonnet, 1996). The so-called differential InSAR technique (D-InSAR), which subtracts the topographic phase from the interferogram, is an emerged technique for detection and mapping of surface displacements over large temporal and spatial scales at the accuracy of centimeter or even millimeter level. Other advantages of InSAR are the SAR data availability and competitive cost. This is of great importance for monitoring surface displacements described below.

Land subsidence, lowering of the land surface by groundwater pumping, affects an aggregate area of about 2300 km2 in the Bandung Basin, Indonesia. The subsidence poses severe problems including damage to building and infrastructures. The excessive groundwater extraction can also cause aquifer having a permanently-reduced capacity to hold water (i.e. a reservoir compaction). A Global Positioning System (GPS) survey, which is a traditional geodetic technique for land surface leveling with accuracy in order of millimeter, was conducted to investigate the characteristics of Bandung subsidence (Abidin et al., 2008). Abidin et al. (2008) also estimated the subsidence by using InSAR technique. However, they focused on GPS measurements and did not explore in detail the capability of InSAR to estimate the rate of the subsidence. They estimate the Bandung subsidence from InSAR during the period between June 2006 and March 2007. Otherwise, surface displacement in term of uplift can occur due to fluid injection in reservoir. SAGD (steam-assisted gravity drainage) is one of enhanced oil recovery (EOR) technique that has been applied to revolutionize the economic recovery of heavy oil and bitumen from the immense oil sands deposits in the Hanging stone field, Canada. This field has about 2.5 trillion barrels of oil in place. With steam injection, reservoir pressures and temperatures rise. These elevated pressure and temperatures alter the rock stresses sufficiently to cause dilatation within and beyond the growing steam chamber which can be observed at surface as displacements. From 1999 to 2008, conventional geodetic measurements, i.e. the network of 54 monuments surveys were carried out to investigate surface heaves in order to map the deformation due to SAGD process at Hangings tone's oil sand field (JACOS 2009). Even though the GPS surveys can provide subsidence information with high accuracy, it is costly, time consuming and sparse spatial resolution for a large and inaccessible area. Of course, both GPS surveys and an InSAR technique have advantages and disadvantages. Therefore, in order to optimize a combination of an accurate result and a cost-effective technique for the land subsidence monitoring it should be considered the InSAR technique as main tool, otherwise GPS surveys is as a validity data.

II. OBJECTIVE

Although InSAR technique is a powerful tool; it has also limitations due to noise, which is caused by decorrelation effects and water vapor in the atmosphere. Commonly, an InSAR processing for a refinement of lookup table is enough to make use of a simulated SAR intensity image in order to obtain positioning accuracies at sub-pixel level in the automatic registration with the actual SAR image. However, one of our study areas has very little topographic relief so that the co registration becomes not reasonable. It make a simulated SAR intensity generated from a SRTM DEM not well working used to improve the accuracy up to sub-pixel due to a high decorrelation between both images (SAR intensity from PALSAR and simulated SAR intensity from SRTM DEM). In this paper we present how to solve this problem so that the refinement of lookup table significantly improves the accuracy.

Moreover, a main problem in the InSAR processing is presence of residues in the phase unwrapping process. The residues are caused by noise over an interferogram. Goldstein and Werner (1998), Baran et al. (2003), and Li et al. (2006) developed the filtering method to reduce noise. So far, no literature presents comparison among these filtering methods based on the ability of the filter in reducing residues. Therefore, we need to compare the filtering methods before unwrapping differential interferogram phase, in order to choose a suitable method for optimally reducing noises over differential interferograms. We have also used other statistical parameters, such as sum of the phase difference (SPD) and normalized standard deviation (NSD), to examine these filtering methods for the interferograms.

III. Method

A. All Directional Smoothing

During despeckling edges are blurred so to protect edges from blurring directional smoothing filter is used [17].

• Select mask of size 3×3 or 5×5 or 7×7

• Take the average of pixels of each direction as shown in Fig. 1 and store in array v(n) where n =4

$$v(n) = 1/R\sum_{i}\sum_{j} y(m-i, n-j) \qquad (1)$$

$S_{i,A}^{(\in)}$

Find V1 (n) such that

$$V_1(n) = abs(v(n) - x(r,c)) \qquad (2)$$

For each mask. Where x(r, c) is central pixel of mask.

Find index of V_1 (n) that gives minimum value such that

Index = min (V_1) (3)

• Replace the pixel value of x(r, c) by v (index)

• Repeat the whole procedure until whole image is scanned by mask.

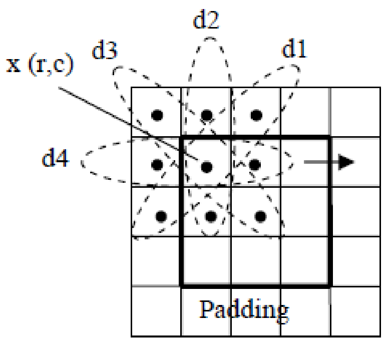


Fig. 1 Directional Smoothing

B. Brute Force Thresholding

Brute force thresholding always outclass other existing thresholding techniques in terms of better results. Algorithm for brute force thresholding is given

- Input wavelet sub band.
- Find maximum (max) and minimum (min) value of sub band coefficients.
- loop through (threshold=min to max) and execute desired algorithm
- save the results in array for each loop such that F= [threshold, result]
- When loop completed, select the (threshold) that gives best result.

IV. Proposed Algorithm

After Let assume that A is the original speckled SAR image. B is the wiener filtered SAR image of A and C is the mean filter SAR image of A.

• Decompose the images A, B and C into wavelet sub bands $S_{i,A}^{(\in)}$, $S_{i,B}^{(\in)}$, and $S_{i,C}^{(\in)}$ using undecimated wavelet transformation. Where (i) is decomposition level and (∈) denotes the detail sub bands such as horizontal detail, vertical detail and diagonal detail sub bands respectively. Decomposition up to level 3 is enough.

• Process each level of detail images of A by the following steps

1) Find minimum (min) and maximum (max) value of coefficients of each detail sub band at each level.

2) Loop (threshold = min to max) for each detail subband at each level

3) Determine whether each pixel of $S_{i,A}^{(\in)}$ High level or Low level. If (pixel < threshold) then it is low level otherwise pixel is high level.

4) If pixel is low level then replace the value of pixel of $S_{i,A}^{(\in)}$ by the corresponding pixel value of $S_{i,C}^{(\in)}$

5) To determine whether there exists edges around the pixels that are classified as high level pixels, a direction dependent mask is used as shown in figure 2. If the dark portion of mask or window contains at least one high level pixel, then keep the original value of pixel intact else replace the value of pixel of $S_{i,A}^{(\in)}$ by the corresponding pixel value of $S_{i,B}^{(\in)}$.

6) Apply the directional smoothing to each detail sub band of $S_{i,A}^{(\in)}|$ at each level as shown in figure 1.

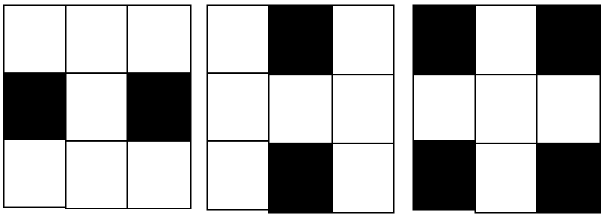
7) Reconstruct an image from the processed sub bands of $S_{i,A}^{(\in)}$ by using inverse undecimated wavelet transformation.

8) Save the results of each iteration in an array such as F= [threshold, result].

9) Return to step 2 until loop completed.

• Select the threshold value that gives best result and use that threshold for classification of high level pixels and low level pixels.

• Run the entire Algorithm and get the best results for despeckling of SAR images.



(a) (b) (c)

Fig. 2 Edge detection mask. (a) Mask for horizontal detail (b) Mask for vertical detail (c) Mask for diagonal detail

V. RESULT

Results are taken on image SAR image of size 610×421. Proposed algorithm is evaluated with two most commonly used assessment parameters. First is Peak signal to noise ratio and other is mean square error. Results shows that proposed algorithm shows better results than statistical filters and homomorphic based statistical filters. Same algorithm is executed with other commonly used thresholding techniques. But results proved that proposed algorithm that used brute force thresholding gives better results than other thresholding techniques.

Figure 3 SAR original images

Figure 3 shows the original image taken by the Synthetic apertature radar, in which objects are shown in the image. This represents original image of SAR, in which speckle noise is presented.

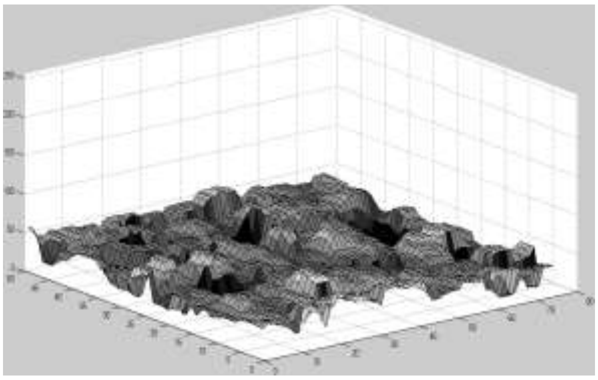


Figure 4 Histogram representation of the object

Figure 4 Histogram representation of the object presented in the SAR capture image with respect to their phase and azimuthal angle.

Figure 5Speckled form of input image

Figure 5 represents Speckled form of the original image, as per our proposed method image is applied in three format original image (A) , speckle image(B), and Savitzky-Golay Filtered (C) Image.

Figure 6 Savitzky-Golay Filtered form of original image

Savitzky-Golay smoothing filters (also called digital smoothing polynomial filters or least-squares smoothing filters) are typically used to “smooth out” a noisy signal whose frequency span (without noise) is large. In this type of application, Savitzky-Golay smoothing filters perform much better than standard averaging FIR filters, which tend to filter out a significant portion of the signal's high frequency content along with the noise. Although Savitzky-Golay filters are more effective at preserving the pertinent high frequency components of the signal, they are less successful than standard averaging FIR filters at rejecting noise. Figure 6 shows the Savitzky-Golay Filtered form of original image

VI. CONCLUSION

Detection of rapid surface displacement using InSAR is often inhibited from the long repeat cycle. Except for bare and sparsely vegetated fields, the interferometric correlation decreased too much. More technical developments and applications of InSAR are expected with the data available from fully-polarized SAR sensors. The proposed work is based on a new wavelet based method for despeckling of SAR images that uses combination of undecimated wavelet transformation, savitzkay golay filter and mean filter. Moreover instead of using existing thresholding techniques, it uses brute force thresholding that always outperforms the other existing techniques and also discuss the interferogarm of the SAR image. InSAR is a relatively new remote sensing technology.

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