MULTICHANNEL MAP HEIGHT ESTIMATOR ALGORITHM FOR DEM RECONSTRUCTION FROM DINSAR

Maged MARGHANY and Mazlan HASHIM

Institute of Geospatial Science and Technology (INSTeG)
Universiti Teknologi Malaysia
81310 UTM, Skudai, Johor Bahru, Malaysia,

E-mail: maged@utm.my,
: magedupm@hotmail.com

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Abstract: Interferometric synthetic aperture radar (InSAR or IfSAR), is a geodetic technique uses two or more single look complex synthetic aperture radar (SAR) images to produce maps of surface deformation or digital elevation. It has applications as well, for monitoring of geophysical natural hazards, for instance earthquakes, volcanoes and landslides, also in engineering, in particular recording of subsidence and structural stability. Over time-spans of days to years, InSAR can detect the centimetre-scale of deformation changes. Synthetic Aperture Radar interferometry (InSAR) is a relatively new technique for 3-D topography mapping. This work presents a new approach for 3-D object simulation using Differential synthetic aperture interferometry (DInSAR). In doing so, conventional DInSAR procedures are implemented to three repeat passes of RADARSAT-1 SAR fine mode data (F1). Further, The multichannel MAP height estimator is implemented with phase unwrapping technique. Consequently, The multichannel MAP height estimator is used to eliminate the phase decorrelation impact from the interferograms. The study shows the performance of DInSAR method using The multichannel MAP height estimator is better than DInSAR technique which is validated by a lower range of error (0.02±0.21 m) with 90% confidence intervals. In conclusion, integration of The multichannel MAP height estimator with phase unwrapping produce accurate 3-D coastal geomorphology reconstruction.

INTRODUCTION

This work hypothesizes that integration of The multichannel MAP height estimator algorithm with phase unwrapping can produce accurately digital elevation of object deformation. The aim of this paper is to explore the precision of the digital elevation models (DEM) derived from RADARSAT-1 fine mode data (F1) and, thus, the potential of the sensor for mapping coastal geomorphologic feature changes. Depending on the results, a wider application of F1 mode data for the study of Kuala Terengganu mouth river landscapes is envisaged.

Recently, Baselice et al., (2009) and Ferraiuolo et al., (2009) have developed multichannel MAP height estimator based on a Gaussian Markov Random Field (GMRF) to solve the uncertainties of DEM reconstruction from InSAR technique. They found that multichannel MAP height estimator have managed the phase discontinuities and improved the DEM profile. Taking advantage of the fact that The multichannel MAP height estimator for solving uncertainty problem because of decorrelation and the low signal-to-noise ratio (SNR) in data sets. InSAR has applications as well, for monitoring of geophysical natural hazards, for instance earthquakes, volcanoes and landslides, also in engineering, in particular recording of subsidence and structural stability (Rao et al., 2006). InSAR, consequently, provides DEMs with 1-10 cm accuracy, which can be improved to millimetre level by DInSAR. Even so, alternative datasets must acquire at high latitudes or in areas of rundown coverage Nizalapur et. al.,(2011). However, the baseline decorrelation and temporal decorrelation make InSAR measurements unfeasible (Rao and Jassar 2010).

METHODS AND EQUATION

Data Sets and Study Area

In the present study, RADARSAT-1 SAR data sets of 23 November 1999 (SLC-1), 23 December 2003 (SLC-2) and March 26, 2005, (SLC-3) of Fine mode data (F1) are implemented. These data are C-band and had the lower signal-to-noise ratio owing to their HH polarization with wavelength of 5.6 cm and frequency of 5.3 GHz.

The Fine beam mode is intended for applications which require the best spatial resolution available from the RADARSAT-1 SAR system. The azimuth resolution is 8.4 m, and range resolution ranges between 9.1 m to 7.8 m. Originally, five Fine beam positions, F1 to F5, are available to cover the far range of the swath with incidence angle ranges from 37° to 47°. By modifying timing parameters, 10 new positions have been added with offset ground coverage. Each original Fine beam position can either be shifted closer to or farther away from Nadir. The resulting positions are denoted by either an N (Near) or F (Far). For example, F1 is now complemented by F1N and F1F (RADARSAT 2012). Finally, RADARSAT-1 requires 24 days to return to its original orbit path. This means that for most geographic regions, it will take 24 days to acquire exactly the same image (the same beam mode, position, and geographic coverage). However, RADARSAT's imaging flexibility allows images to be acquired on a more frequent basis (RADARSAT 2012).

DEM Reconstruction Using Multichannel MAP Height Estimator

The multichannel MAP height estimator is used to solve the decorrelation problem with InSAR and DInSAR methods. This algorithm is adopted from the study of Baseliceet al., (2009). Following Baseliceet al., (2009), The interferometric phase signal can be expressed by the following mathematical formula (Baseliceet al., 2009),

$$\phi_{sn} = \left\langle \left(\frac{4\pi}{\lambda R_0 \sin\theta} \right) B_{\perp n} h_s + \alpha \right\rangle_{2\pi}, \quad n=1,2,\ldots\ldots,N; \quad s=1,2,\ldots\ldots\ldots,S \qquad (1)$$

where s is the pixel position inside the SAR image, n is considered interferogram channel, λ is sensor wavelength, R_0 is the distance between the center of the scene and the master antenna, $B_{\perp n}$ is the orthogonal baseline, h_s is height value, α is the phase decorrelation noise, and is θ incident angle. Further, $\langle . \rangle_{2\pi}$ represents the " modulo -2π ". Assume N is independent interferogram channels, then the problem involves in modeling the height values h_s is starting from the $Sx\ N$ estimated wrapped phase ϕ_{sn}. Following Ferraiuolo et al. (2004), the problem of modeling height can be solved using a MAP height estimation approach. In this regard, multichannel likelihood function F_{mc} is considered and is given by

$$F_{mc}(\phi_s | \varsigma_s) = \prod_{n=1}^{N} f((\phi_{sn} | \varsigma_s) \qquad (2)$$

Where $F(\phi_{sn} | \varsigma_s)$ is the signal channel likelihood function, ϕ_s is measured wrapped phase data referred to the pixel s, $\phi_s = [\phi_{s1}, \phi_{s2}, \ldots\ldots., \phi_{sN}]^T$, and ς_s is collected vector height values where $\varsigma = [\varsigma_1, \varsigma_2, \ldots\ldots., \varsigma_S]^T$. Following Ferraiuolo et at. (2004) and Baselice et al., (2009) a MAP height estimation can be given by

$$\hat{\varsigma}_{MAP} = \arg_{\varsigma} \max \ln \left[(\prod_{S=1}^{S} F_{mc}(\phi_s | \varsigma_s) g(\varsigma; \hat{\sigma}) \right] \qquad (3)$$

where $g(.)$ is a prior probability density function (pdf) which is adopted by using Gaussian Markov Random Field and $\hat{\sigma}$ is the hyperparmeter vector which is not a prior known. According to Baselice et al., (009), it has to be estimated starting from the measured interfergrams. This is accomplished by considering sub-bands, corresponding to different azimuth looks. In this reagrd, a Gaussian Markov Random Field (GMRF) as a-priori model. Although the reconstruction, considering the limited number of available data (four channels), is good, we want to improve its quality, particularly on the discontinuities. Then, algorithm is implemented based on the introduction of ground elevation data.

RESULTS AND DISCUSSIONS

Figure 1 shows the interferogram created from F1 data. For three data sets, only small portion of the scene processed because of temporal decorrelation. In fact, the SAR interferogram is considered to be difficult to unwrap because of its large areas of low coherence, which caused by temporal decorrelation. These areas of low coherence segment the interferogram into many pieces, which creates difficulties for the unwrapping algorithms (Zebker et al., 1997).

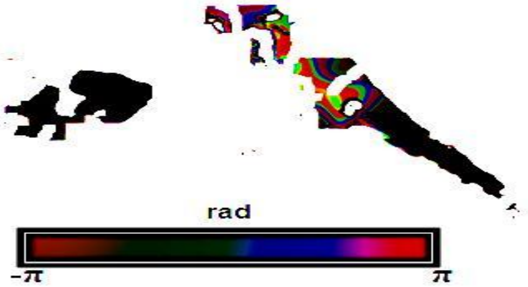

Figure 1: Interfeorgram generated from F1 mode data.

Figure 2 shows the interferogram created using multichannel MAP height estimator. The full color cycle represents a phase cycle, covering range between –π to π. In this context, the phase difference given module 2 π; is color encoded in the fringes. Seemingly, the color bands change in the reverse order, indicating that the center has a great deformation along the spit. This shift corresponds to 0.4 centimetres (cm) of coastal deformation over the distance of 500 m. The urban area dominated by deformation of 2.8 cm. Figure 3 represents 3-D spit reconstruction using multichannel MAP height estimator with the maximum spit 's elevation is 3 m with gentle slope of 0.86 m.

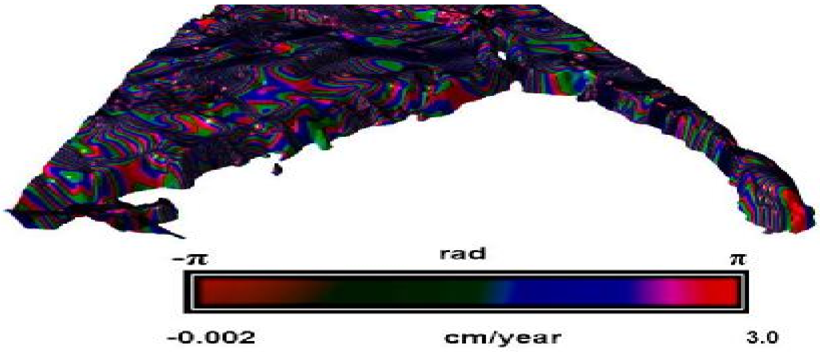

Figure 2: Fringe Interferometry generated by multichannel MAP height estimator.

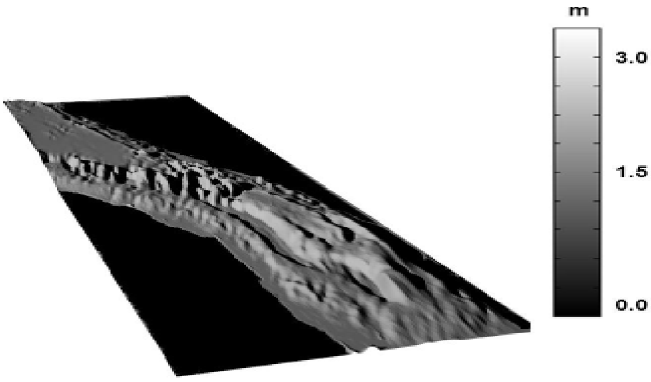

Figure 3: DEM of coastal spit from multichannel MAP height estimator**.**

The statistical comparison between the simulated DEM from the DInSAR, real ground measurements and with using multichannel MAP height estimator. This table represents the bias (averages mean the standard error, 90 and 95% confidence intervals, respectively. Evidently, the DInSAR using multichannel MAP height estimator has bias of-0.05 m, lower than ground measurements and the DInSAR method. Therefore, multichannel MAP height estimator has a standard error of mean of ± 0.034 m, lower than ground measurements and the DInSAR method.

Overall performances of DInSAR method using multichannel MAP height estimator is better than DInSAR technique which is validated by a lower range of error (0.02±0.21 m) with 90% confidence intervals (Table 1).

Table 1: Statistical Comparison between DInSAR and DInSAR- Multichannel MAP Height Estimator Techniques.

Statistical Parameters	**DInSAR techniques**	
	DInSAR	**Multichannel MAP Height Estimator**
Bias	2.5	-0.03
Standard error of the mean	1.5	0.02

CONCLUSION

Synthetic Aperture Radar interferometry (InSAR) is a relatively new technique for 3-D topography mapping. This work presents a new approach for 3-D object simulation using Differential synthetic aperture interferometry (DInSAR). In doing so, conventional DInSAR procedures are implemented to three repeat passes of RADARSAT-1 SAR fine mode data (F1). Further, the multichannel MAP height estimator is implemented with phase unwrapping technique. Consequently, The multichannel MAP height estimator is used to eliminate the phase decorrelation impact from the interferograms. The study shows the performance of DInSAR method using The multichannel MAP height estimator is better than DInSAR technique which is validated by a lower range of error (0.02±0.21 m) with 90% confidence intervals. In conclusion, integration of The multichannel MAP height estimator with phase unwrapping produce accurate 3-D coastal geomorphology reconstruction.

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