PARETO ANT COLONY ALGORITHM FOR FOUR DIMENSIONAL COASTAL EROSION FROM INTERFEROMETRIC SYNTHETIC APERTURE RADAR

Maged Marghany
Geoinformation Global Space Technology
130B, Jalan Burhanuddin Helmi,
Taman Tun Dr. Ismail,
60000 Kuala Lumpur
Email:magedupm@hotmail.com

KEY WORDS: Pareto ant colony algorithm, Four-dimensional best-path avoiding singularity loops, decorrelation, interferogram, coastal volume erosion.

ABSTRACT: The paper has demonstrated InSAR phase unwrapping using Pareto ant colony algorithm (PACA). The four-dimensional phase unwrapping is performed using four-dimensional best-path avoiding singularity loops (4DBPASL) algorithm. Further, the combination between PACA and 4-DBPASL is used to eliminate the phase decorrelation impact from the interferograms. The study shows that InSAR produces discontinues interferogram pattern because of the high decorelation. In conclusion, PACA algorithm can be used to solve the problem of decorrelation and produced accurate 4-D coastline deformation using ENVISAT ASAR data.

1. INTRODUCTION

Nowadays, interferometric synthetic aperture radar (InSAR) techniques have glorious potentials to disclose the millimeter-scale of the planet 's surface deformation (Hai and Renbiao 2012). Conversely, the most drawback is raised in InSAR techniques is phase unwrapping issues. In agreement with, Zebker et al., (1997), nevertheless, unwrapped phase image is extraordinarily challenged by many factors. Specifically, these vital factors are concerned multiplicative speckle noises, shadow, foreshortening, layover, temporal, geometric and atmospherically decorrelations (Marghany 2012 and Pepe 2012) that are negatively created space of non-standard phase i.e. quality space (Zebker et al., 1997 and Hai and Renbiao 2012). In this understanding, inferiority space can contribute to vital decorrelation problems within the phase unwrapping procedures. Many phase unwrapping algorithms are introduces to resolve the critical issue of inferiority space and also the decorrelation. These algorithms are categorised into: (i) path-following algorithms and (ii) minimum-norm algorithms (Zhong et al., 2011). Afterwards, minimum-norm algorithms categorical the unwrapping issue in terms of diminution of the world perform as compared to path-following algorithms. Conversely, the constraint of minimum-norm algorithms cannot be concerned each individual pixels within the phase unwrapping procedures (Hooper et al., 1997).

Lately, Baselice et al., (2009) and Ferraiuolo et al., (2009) have developed multichannel MAP height computer supported a mathematician Markoff Random Field (GMRF) to unravel the uncertainties of DEM reconstruction from InSAR technique. They found that multichannel MAP height calculator have managed the phase discontinuities and improved the DEM profile. Taking advantage of the actual fact that the multichannel MAP height computer for finding uncertainty drawback owing to decorrelation and therefore the low S/N (SNR) in information sets (Schwarz 2004). InSAR has applications likewise, for observation of geology natural hazards, as an example earthquakes, volcanoes and landslides, additionally in engineering, especially recording of subsidence and structural stability (Rao et al., 2006). InSAR, consequently, provides DEMs with 1-10 cm accuracy, which might be improved to millimeter level by DInSAR. Even so, different datasets should attain at high latitudes or in areas of summary coverage Nizalapur et. al.,(2011). However, the baseline decorrelation and temporal decorrelation build InSAR measurements impracticable (Rao and Jassar 2010).

In this paper, we have a tendency to address the question of utilization of Pareto ant colony algorithmic rule (PACA) as associate optimisation methodology to model the four-dimensional (3-D) of rate changes of shoreline. In this context, Marghany (2014a) used three-dimensional sorting reliabilities algorithmic rule (3D-SRA) phase unwrapping for modelling volume rate changes of shoreline. However, 3D-SRA was not ready to take away the artifacts in DEM because of radiolocation shadow, layover, multi-path effects and image misregistration, and eventually the signal-to –noise magnitude relation (SNR) (Rao et al., 2006). In fact, 3DSRA does not establish singularity loops in any respect. It is be determined by utterly a high quality measure to uncover the phase volume. Ignoring singularity loops could cause the unwrapping path to penetrate these loops and errors could propagate within the unwrapped phase map.

2. STUDY AREA

The study area is located along the coast of Johor in the southern eastern part of Peninsular Malaysia. The area is approximately 20 km of Johor (Fig. 1), located in the South China Sea between 1° 57´ N to 2° 15´ N and 103° 51´ E to 104° 15´ E. This coastline is exhibited a variety of geomorphologies that includes sandy beaches, rocky headlands which is broken by small river mouths. In addition, the coastline has hilly terrain with steep slopes and deep narrow valleys. Further, the coastline is bordered with varying width of alluvial plains. Further, sand materials make up the entire of the eastern Johor shoreline. Consistent with Marghany (2003) (2011), this area lies in an equatorial region dominated by two seasonal monsoons and two inter monsoon periods. According to Marghany (2014b) the maximum wave height during the northeast monsoon season is 4 m. The minimum wave height is found during the southwest monsoon which is less than 1 m (Marghany 2013).

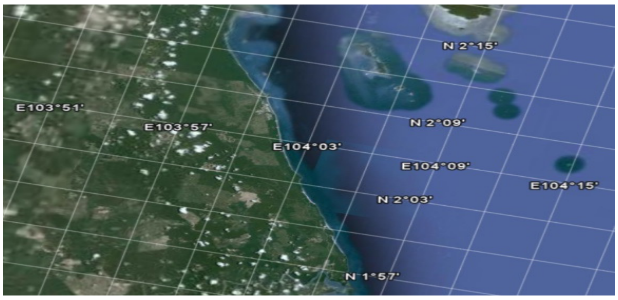

Fig. 1: Location of study area.

3. FOURTH-DIMENSIONAL USING HOLOGRAPHIC INTERFEROMETRY

On the word of Hussien et al., (2005), the maximum gradient method indicates the badness rather than the goodness of the unwrapped-phase data, so the quality is calculated using the reciprocal of the unwrapped phase gradient of Equation (1.0)). Further, Hussien et al., (2005) and Marghany (2014c) agreed that quality-guided phase unwrapping algorithms is function of the quality of the voxels themselves to conduct the unwrapping path and to minimize error propagation during the unwrapping procedure. In this respect, the unwrapping path algorithm is function of the quality of the edges as an intermediate stage, rather the quality of the voxels. Following Hussien et al., (2005) and Marghany (2015), the quality map of voxels can be given by

$$Q_{i,j,k,p} = \sqrt{H_x^2(i,j,k,p) + V_y^2(i,j,k,p) + N^2(i,j,k,p) + O^2(i,j,k,p)} \qquad (1.0)$$

where *Hx, Vy*, and *N,O* are the horizontal, vertical, and normal second differences, respectively (Marghany 2015), where,

$$H_x(i,j,k,p) = \left[\frac{\partial \phi_{i,j,k,p}^{\,x}}{[\phi_{i+1,j,k} - \phi_{i,j,k}]}\right][\Delta\phi(i-1,j,k,p) - \Delta\phi(i,j,k,p)] - \qquad (1.1)$$
$$\left[\frac{\partial \phi_{i,j,k}^{\,x}}{[\phi_{i+1,j,k,p} - \phi_{i,j,k,p}]}\right][\Delta\phi(i,j,k,p) - \Delta\phi(i+1,j,k,p)],$$

$$V_y(i,j,k,p) = \left[\frac{\partial \phi_{i,j,k,p}^{\,y}}{[\phi_{i,j+1,k,p} - \phi_{i,j,k,p}]}\right][\Delta\phi(i,j-1,k,p) - \Delta\phi(i,j,k,p)] - \qquad (1.2)$$
$$\left[\frac{\partial \phi_{i,j,k,p}^{\,y}}{[\phi_{i,j+1,k,p} - \phi_{i,j,k},p]}\right][\phi(i,j,k,p) - \phi(i,j+1,k,p)],$$

$$N(i,j,k,p) = \left[\frac{\partial \phi_{i,j,k,p}^{\,z}}{[\phi_{i,j,k+1} - \phi_{i,j,k,p}]}\right][\Delta\phi(i,j,k-1,p) - \Delta\phi(i,j,k,p)] - \qquad (1.3)$$
$$\left[\frac{\partial \phi_{i,j,k,p}^{\,z}}{[\phi_{i,j,k+1,p} - \phi_{i,j,k,p}]}\right][\Delta\phi(i,j,k,p) - \Delta\phi(i,j,k+1,p)],$$

$$O\,(i,j,k,p) = \left[\frac{\partial \phi_{i,j,k,p}{}^{o}}{[\phi_{i,j,k,p+1} - \phi_{i,j,k,p}]}\right][\Delta \phi(i,j,k,p-1) - \Delta \phi(i,j,k,p)] - \left[\frac{\partial \phi_{i,j,k,p}{}^{o}}{[\phi_{i,j,k,p+1} - \phi_{i,j,k,p}]}\right][\Delta \phi(i,j,k,p) - \Delta \phi(i,j,k,p+1)], \qquad (1.4)$$

where i,j,k,p are the neighbors' indices of the voxel in 3 x 3 x 3x3 hypersphere, and $\frac{\partial \phi_{i,j,k,p}{}^{o}}{[\phi_{i,j,k,p+1} - \phi_{i,j,k,p}]}$ defines a unwrapping operator that unwraps all values of its argument in the range $[-\pi, \pi]$. This can be done by adding or subtracting an integer number of 2π rad to its argument (Hussien et al., 2005). Equations 10.0 to 12.0 are represented 4-D array of the unwrapped-phase gradients $(\partial\phi^{x}, \partial\phi^{y}, \partial\phi^{z}, \partial\phi^{o})$ and each has the same dimensions as the unwrapped-phase volume. In addition, the maximum phase gradient measures the magnitude of the largest phase gradient that is, partial derivative or wrapped the phase difference in a $v*v*v$ volumes (Hussien et al., 2005 and Marghany 2015).

Pareto ant colony algorithm (PACA) is an intellectual optimization method based on species group. It possesses high concurrency, especially in finding solution for multi-objective problem. In PACA, K objects must correspond to K pheromones, t. In the early stage, mark weighing quantity which correspond to objective function as which is expressed by pheromone quantity $\tau_{i,j,k,p}$ .In the early stage, mark weighing quantity which correspond to objective function as

$$W = \{w_1, w_2, ..., w_N\}^T \qquad (2.0)$$

Let $x_0, x_1, x_2 \in F$, and F is a feasible region. And x_0 is called the Pareto optimal solution in the minimization of $\tau^{K}{}_{i,j,k,p}$ if the following conditions are satisfied

If $f(\Delta \tau^{1}_{i,j,k,p}) = \frac{C_1}{\min\{f\}}$ (3.0)

is said to be partially greater than

$$f(\Delta \tau^{2}_{i,j,k,p}) = \frac{C_2}{\min\{f\}} \qquad (4.0)$$

where C_1 and C_2 is constant and f is objective function value of the quality map. When all the residues are connected by groups of branch cuts, phase integration over the whole interferogram without those branch cuts can be conducted to finally obtain the unwrapped phase (Wei et al., 2008).

4. RESULTS AND DISCUSSION

The Pareto ant colony algorithm (PACA) three dimensional phase unwrapping algorithm has been investigated using a computer-simulated wrapped phase volume, that was created like this. The computer-generated wrapped quadrangular object which is consisted of 28 x 28 x 500 pixels (Fig.2a). Although the quadrangular object is wrapped between –π to π using the arctangent function, which terminated by speckle noise (Fig.2a). Figure 2b shows the despeckle wrapped quadrangular object using Gaussian algorithm. Indeed blur wrapped is generated by Gaussian algorithm which confirm the work of Karout (2007);Marghany 2015; Marghany and Mansor (2016a)(2016b).

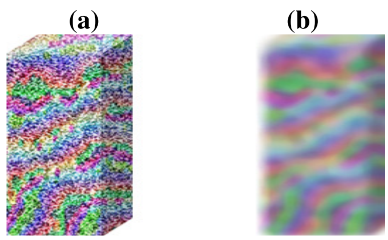

Figure 2. Computer-generated quadrangular object (a) wrapped speckle and (b) Gaussian despeckle.

Figure 3 shows the interferometry fringes produced by using Pareto ant colony algorithm (PACA). It is interesting to find that the proposed algorithm has produced clear features detection of infrastructures without residues of branch cut compared to Flynn's algorithm and (Figure 3a) unwrapped phase map using 3DBPASL (Figure 3b). In fact, the proposed algorithm has minimized the error in interferogram cycle due the low coherence in vegetation zones and along the wet sand of coastline.

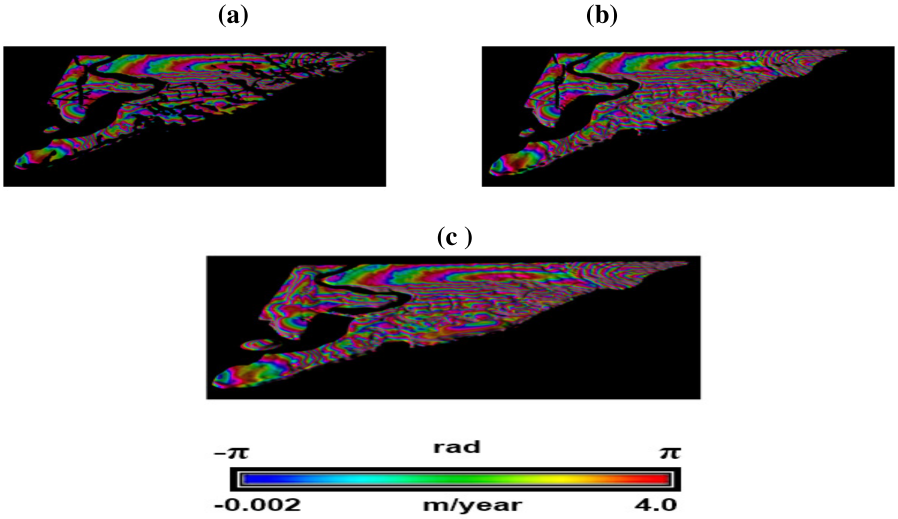

Figure 3. Interferometry produced by (a) InSAR (b)Flynn's algorithm and (c) 3DBPASL algorithm.

Figure 4 shows the results of Pareto ant colony algorithm. It is interesting to find that the optimization algorithm of Pareto ant colony algorithm can produce a clear 4-D fringe patterns which are unlike 3DBPASL algorithm. The fourth coordinate is indicated by deep of fringe pattern volumes and additionally clear edges. In fact, a clear edges of coastline because of the fourth coordinate O that is added in eq. 1.4.

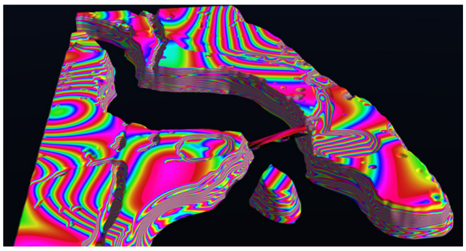

Figure 4. Interferometry produced by 4-DBPASL Pareto ant colony algorithm.

The interferogram fringes produced by using the combination of four-dimensional best-path avoiding singularity loops (4-DBPASL) algorithm and Pareto ant colony algorithm (PACA). Clearly, the proposed algorithm for 4-D phase unwrapping produced vibrant fringe. This study confirms the work done by Marghany (2015). In fact, The Pareto ant colony algorithm (PACA) algorithm acquires an optimal unwrapping path, whereas it is also taking into account the effect of singularity loops. In addition, zero-weighted edge is used zero-weighted edges to adjust the optimal path and avoid these singularity loops. In line with Saravana et al., (2003); Hussien et al., (2005); Wei, et al., 2008; Marghany and Mansor (2016a), the Pareto ant colony algorithm (PACA) not only identifies these singularity loops, but it also calculates the quality of each voxel to ensure that the most reliable voxels are unwrapped first and thus the effects of singularity loop ambiguities are minimized or removed entirely. Therefore, the combination of Pareto ant colony algorithm (PACA) for phase unwrapping produced more precisely fringe cycle.

6. CONCLUSIONS

The paper is focused on three-dimensional (4-D) coastline deformation from interferometry synthetic aperture radar (InSAR). In doing so, conventional InSAR procedures are implemented to three repeat passes of ENVISAT ASAR data. Further, the three dimensional phase unwrapping is performed using Flynn's algorithm, four-dimensional best-path avoiding singularity loops (4-DBPASL) algorithm and Pareto ant colony algorithm. The study shows that Pareto ant colony algorithm performed accurately compared to Flynn's algorithm, four-dimensional best-path avoiding singularity loops (4-DBPASL) algorithm. In conclusion, integration of the Pareto ant colony algorithm with 4-DBPASL phase unwrapping produce accurate 4-D coastline deformation because of reduction the length of the branch cuts and improving the quality edge of phase unwrapping.

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