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Four-Dimensional Earthquake Deformation Using Ant Colony Based Pareto Algorithm

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Four-Dimensional Earthquake Deformation Using Ant Colony Based Pareto Algorithm

ABSTRACT: This work has demonstrated a new approach for 4-D phase unwrapping technique to retrieve earthquake displacement due to the fact of Nepal earthquake, 2015. In doing so, conventional InSAR procedures are implemented to two repeat passes of Sentinel-1A satellite 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 the 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-DBPASLphase unwrapping produce accurate 4-D. Earthquake deformation because of reducing the length of the branch cuts and improving the quality edge of phase unwrapping.

KEYWORDS: Pareto ant colony algorithm, Sentinel-1A satellite data, Phase unwrapping, Earthquake displacement, Quality map.

1. INTRODUCTION

At present, the digital elevation model (DEM) of Earth is of low resolution, inconsistent or incomplete. The temporal, geometric and atmospheric decorrelations are most quintessential issues, which are considered on in several studies (Pepe 2012; Marghany 2012; Marghany 2014a). The Fourth Dimension is dissected with the aid of scientists, psychologists, mathematicians and physicists, later the 1800s. Indeed, scientists have utilized 4-D principles to explicate roughly of the universe. At an early stage, scientists created 4-D from 3-D with the aid of spinning 3-D about its image or itself. Scientists, therefore, have deliberated the time as a dimension besides the 3-D. Nevertheless, this concept scientifically is no longer precise. The fourth Dimension axis which goes by using the Z, Y and Z. The 4-D object has 4 quintessential unite: width, length heights and 4-D which is W. A hypercube, for instance, has a length, width, top and a fourth dimension that is perpendicular to all three of the different units. Consequently, 4-D is exploring the internal objects of 3-D. an In a remote sensing satellite-based interferometric synthetic aperture radar (InSAR) is a manageable device for unique measurements of 3-D ground shifts caused off by earthquakes or landslides.

Consistent with Zebker et al., (1997), reported that rapid temporal baseline, high-quality spatial baseline, respectable climate events and ascending and descending SAR files are consistent standards to restrain decorrelation and noise to produce a dependable DEM. ERS-1 and ERS-2, Terara X-SAR in tandem mode are excellent examples of short temporal resolution. In other words, multiplicative speckle noises, shadow, foreshortening, layover, temporal, geometric and atmospherically decorrelations. But, the two-dimensional unwrapping methods may want to introduce discontinuous areas when the noise is high. The resulting in consistent baselines within a slice might produce an incorrectly unwrapped baseline. Then the only-dimensional baseline unwrapping may want to deliver wrong consequences. A few of the techniques practised to fine map to the manual the unwrapping methods. The first-class map turned into defined with the first-class of the edges that connect dual neighbouring voxels and unwrap the most dependable voxels first (Marghany 2013). Consequently, 3-dimensional segment unwrapping technique, which considers the temporal domain and the spatial domain restrictions concurrently (Marghany 2014a).

In this understanding, inferiority space can contribute to vital decorrelation problems within the phase unwrapping procedures. Many phase unwrapping algorithms are introduced 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. With an extensive range of contexts, TanDEM-X and TerraSAR-X are imaging the terrain beneath them simultaneously, from exclusive angles Marghany (2014b). These images are processed into particular elevation maps with a 12 m resolution and any vertical accuracy better than 2 m. Image coregistration, InSAR an interferometric section estimation (or noise filtering) and interferometric phase unwrapping (Zebker et al., 1997; Hussien 2005; Marghany 2012) are three keys processing processes of InSAR. It is properly regarded that the overall performance of the interferometric phase estimation suffers severely from poor picture coregistration. Interferogram filtering algorithms such as an adaptive contoured window, pivoting imply filtering, pivoting median filtering, and adaptive phase noise filtering are the main techniques for the traditional InSAR interferometric phase estimation (Pepe 2012). Recently, Pepe (2012) referred to that DInSAR has recently utilized with success to look at the temporal evolution of the detected deformation phenomena throughout the technology of displacement time-series. In this context, two most important classes of advanced DInSAR methods of deformation time-series era have been proposed in the literature, often referred to as Persistent Scatterers (PS); and small Baseline

(SB) techniques, respectively. The PS algorithms pick out all the interferometric data pairs with reference to a single frequency master image, barring any constraint on the temporal and spatial separation (baseline) amongst the orbits (Hai and Renbiao (2012). Further, Marghany (2003) and Marghany (2011) introduced holographic interferometry techniques for modelling shoreline changes from SAR data.

In this paper, we have a tendency to address the question of the utilization of Pareto ant colony algorithmic rule (PACA) as an associate optimisation methodology to model the four-dimensional (4-D) of Nepal earthquake. In this context, Marghany (2014) implemented three-dimensional sorting reliabilities algorithmic rule (3D-SRA) for phase unwrapping. However, 3D-SRA was not ready to take away the artefacts in DEM because of radiolocation shadow, layover, multi-path effects and image misregistration, and eventually the signal-to-noise magnitude relation (SNR) (Zebker et al.,1997). In fact, 3DSRA does not establish singularity loops in any respect. It is being 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. ALGORITHMS

In this study, the algorithm used to simulate 4-D the Nepal earthquake deformation is based on the Pareto ant colony algorithmic rule (PACA). To this end, PACA is implemented to retrieve precise 4-D phase unwrapping. In other words, two algorithms are used (i) 4-D phase unwrapping; and (ii) Pareto ant colony algorithmic rule (PACA).

2.1. Four-dimensional Phase Unwrapping

The initial population is generated by creating an initial solution using one of the Qualityguided phase unwrapping algorithm (BPASL algorithm) (Hussien et al., 2005). Following Karout (2007), the initial solution is approximated using a 'polynomial Surface-fitting weighted least-square multiple regression' method. The initial population is then generated based on the initial solution. In doing so, every a_g in each chromosome in the population, a small number relying on the accuracy of the gene that is added or subtracted to the value of the gene as given by,

$$a_g = a_g + (\pm 1)\{10^{[\log(a_g)+\Re]}\} \tag{1}$$

where a_g is the coefficient parameter stored in gene *g*, and $\Re$ is a random number generated between the values.

The 4-D unwrapping is built through the use of the temporal phase unwrapping method with the pace of ground movement which is encoded rather than time as the unwrapping course. This method uses 4 dimensions: x, y, t and V. Every voxel (x, y, t) is unwrapped independently of the relaxation of the voxels using the speed encoding measurement. Following Karout (2007), the HGA set of rules is based on estimating the parameters of the n^{th} order-polynomial to approximate the unwrapped floor solution from the wrapped segment statistics. The coefficients of the polynomial that fine unwrap the wrapped phase map are received with the aid of an initial solution of the GA algorithm to avoid long-term to converge to the global optimal answer. In this context, GA minimizes minimum 4-DBPASL and errors between the gradient of the polynomial unwrapped surface answer and the gradient of the authentic wrapped segment map. In other words, extra precision and lower minimum 3DBPASL and errors are made by means of increasing the order of the polynomial. This proposed set of rules is especially applicable to adjoining segment distributions (albeit with gaps). Any optimization, trouble using a GA calls for the problem to be coded into GA syntax shape, that's the chromosome form. On this trouble, the chromosome consists of a number of genes in which every gene corresponds to a coefficient within the n[th]-order surface fitting polynomial as described in equation 1

$$f := n \to \sum_{V}^{n} \sum_{k=0}^{n}\sum_{j=0}^{n}\sum_{i=0}^{n} a_{i,j,k}\, \hat{\phi}_0^{\,i}\, \hat{\phi}_0^{\,j}\, \hat{\phi}_0^{\,k}\, \hat{\phi}_0^{\,V} \tag{2}$$

where $a[0....n]$ are the parameter coefficients which are retrieved by the genetic algorithm to approximated the unwrapped phase that can achieve the minimum 4DBPASL and $Q_{i,j,k,V}$ errors. Further, *i,j, k and V* are indices of the pixel location in the unwrapped phase respectively, *n* is the number of coefficients (Hussien et al., 2005 and Marghany 2014c).

Following De la Torre et al., (2010), 4-D holographic interferometry can be given by

$$FFT\{I_N\} = \sum_{N=1}^{4}[A_N(f_x + f_y + f_z) + B_N(f - f_{Nx}, f - f_{Ny}, f - f_{Nz}) + B_N^{*}(f - f_{Nx}, f - f_{Ny}, f - f_{Nz})] \tag{3.0}$$

where N represents fourth -dimensional are used, A_N is the incoherent in 4-D holographic interferometry. B_N and B_N^{*} are lobes for each illumination wavelength in SAR satellite data. The relative optical phase difference can be associated to a physical displacement through the sensitivity vector found in the hologram interferometry in two satellite data which can be expressed in 4-D as (Marghany and Mansor 2016a and 2016b),

$$\begin{pmatrix} \Delta\Phi_1 \\ \Delta\Phi_2 \\ \Delta\Phi_3 \\ \Delta\Phi_4 \end{pmatrix} = \frac{2\pi}{\lambda} \begin{pmatrix} \vec{d}_{1i} & \vec{d}_{1j} & \vec{d}_{1k} & \vec{d}_{1p} \\ \vec{d}_{2i} & \vec{d}_{2j} & \vec{d}_{2k} & \vec{d}_{2p} \\ \vec{d}_{3i} & \vec{d}_{3j} & \vec{d}_{3k} & \vec{d}_{3p} \\ \vec{d}_{4i} & \vec{d}_{4j} & \vec{d}_{4k} & \vec{d}_{4p} \end{pmatrix} \begin{pmatrix} U \\ V \\ W \\ O \end{pmatrix} \tag{4.0}$$

where d is the displacement in along orthogonal components of *U,V,W,O,* in *i,j,k*, and *p* , respectively. Phase unwrapping in Equation 4 can be extended to fourth-dimensional by given equation,

$$\sum_{i,j,k,p} W^{x}_{i,j,k,p}\left|\Delta\phi^{x}_{i,j,k,p} - \Delta\psi^{x}_{i,j,k,p}\right|^{L} + \sum_{i,j,k,p} W^{y}_{i,j,k,p}\left|\Delta\phi^{y}_{i,j,k,p} - \Delta\psi^{y}_{i,j,k,p}\right|^{L} + \sum_{i,j,k,p} W^{z}_{i,j,k,p}\left|\Delta\phi^{z}_{i,j,k,p} - \Delta\psi^{z}_{i,j,k,p}\right|^{L} + \sum_{i,j,k,p} W^{z}_{i,j,k,p}\left|\Delta\phi^{w}_{i,j,k,p} - \Delta\psi^{w}_{i,j,k,p}\right|^{L} \tag{5.0}$$

where $\Delta\phi$ and $\Delta\psi$ are the unwrapped and wrapped phase differences in *x,y,z,w* respectively, and *W* represents user-defined weights. The summations are carried out in both *x ,y, z,* and *w* directions over all *i,j,k,* and *p* respectively. L^L-norm which uses similar methods like the two previous least square methods to solve the phase unwrapping problem. However, this method does not compute the minimum L^2-norm but the general minimum L^L-norm. In essence, by computing the minimum L^L-norm where p≠2; this method can generate data dependent weight, unlike the weighted least-square method. The data-dependent weights can eliminate iteratively the presence of the residues in the unwrapped solution.

2.2 Pareto ant colony Algorithm

Calculate the objective values of chromosomes in the population and record the Pareto optimal solutions.

Definition: Pareto Optimal Solutions

Let $\phi_i, \phi_{i,j}, \phi_{i,j,k}, \phi_{i,j,k,p} \in F$, and F is a feasible region in the 4-D coordinate . And ϕ_0 is called the Pareto optimal solution in the minimization problem of 4-D phase unwrapping if the following conditions are satisfied.

1. If $f(\phi_1)$ is said to be partially greater than $f(\phi_2)$, i.e
   $f_i(\phi_1) \geq f_i(\phi_2), \forall N = 1, 2, \ldots, n$ and $f_i(\phi_1) > f_i(\phi_2), \exists N = 1, 2, \ldots, n,$ (6.0)
   Then ϕ_1 is said to be dominated by ϕ_2 .
2. If there is no $\phi \in F$ s.t. ϕ dominates ϕ_0, then ϕ_0 is the Pareto optimal solutions (Marghany 2015).

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

$$W = \{w_1, w_2, ..., w_N\}^T \tag{7.0}$$

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

If $$f(\Delta\tau^1_{i,j,k,p}) = \frac{C_1}{\min\{f\}} \tag{8.0}$$

It is said to be partially greater than

$$f(\Delta\tau^2_{i,j,k,p}) = \frac{C_2}{\min\{f\}} \tag{9.0}$$

where C_1 and C_2 are constant and f is the objective function value of the quality map. When all the residues connect with 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).

3. RESULTS AND DISCUSSION

On April 25, 2015, at eleven:56 NST Gorkha earthquake occurred and killed multiplied than 10,000 human beings and injured greater than 23,000 populace. Its epicentre flips out to be east of the district of Lamjung, and its hypocentre was as soon as with about intensity of 15 km with most magnitude two of 8.1 M_w. Hence, the epicentre of a predominant aftershock used to be as soon as shut to the Chinese border between the capital of Kathmandu and Mountain (Figure 1) of Everest with a 7.3 M_w (Rajghatta, 2015).

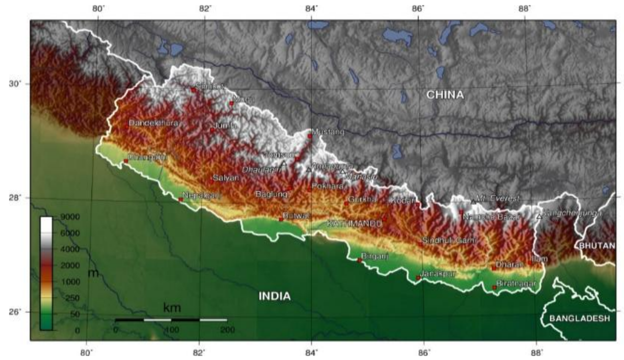

Figure 1. The epicentre of Nepal's earthquake.

In fact, the quake follows the identical pattern as a pair of huge tremors that passed off over 700 years ago, and significances from a great impact of pressure relocating across the tectonic fault. The last time the fault ruptured at this vicinity used to be again in 1344. It used to be preceded in 1255 by means of a big tournament to the east of Kathmandu. The remaining rupture there was in 1934, hinting strain might accumulate westward. This ability that 2015's quake follows the pattern with a gap between the events of eighty years or so. In this understanding, the essential frontal thrust, in common an exquisite earthquake takes place each and every750 ± 140 and 870 ± 350 years in the east Nepal area (Marghany 2015 and Ravilious 2015).

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 consists of 28 x 28 x 500 pixels (Fig.1a). Although the quadrangular object is wrapped between –π to π using the arctangent function, which terminated by speckle noise (Figure 2a). Figure 2b shows the despeckle wrapped quadrangular object using the Gaussian algorithm. Indeed blur wrapped is generated by a Gaussian algorithm which confirms the work of Hussien et al., (2005); Marghany (2017).

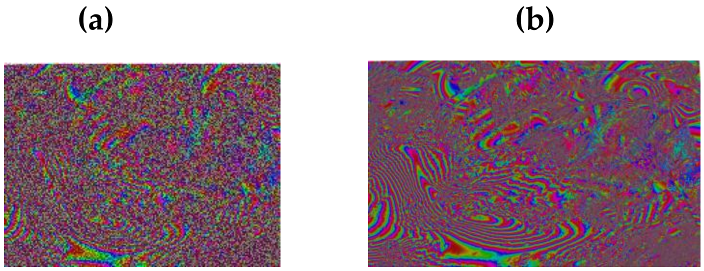

Figure 2. Computer-generated quadrangular object (a) wrapped speckle and (b) Gaussian despeckle.

Figure 3 shows the 3-D phase unwrapping, respectively. It is clear that the 3-D phase unwrapping is providing complete fringe cycles. In fact, 3-D phase unwrapping shows continuities fringes. In fact, 3-D phase unwrapping reduces the impact of the low coherence as results of existing of dense vegetation covers and water bodies such as a lake or river.

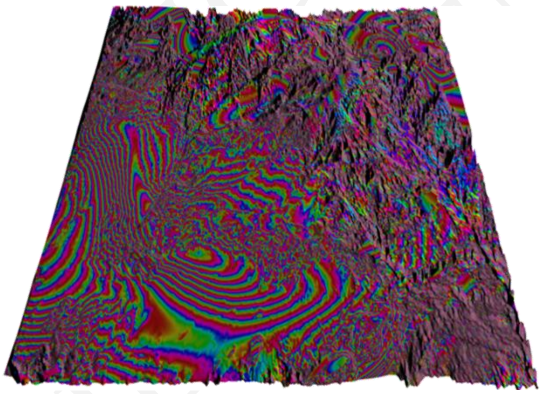

Figure 3. The interferogram is generated by the 3-D phase unwrapping algorithm.

Figure 4 shows the results of the Pareto ant colony algorithm. It is interesting to find that the optimization algorithm of the Pareto ant colony algorithm can produce a clear 4-D fringe pattern, which is unlike the 3DBPASL algorithm. The fourth coordinate is indicated by deep of fringe pattern volumes and additionally clear edges. In fact, clear edges of coastline because of the fourth coordinate *O* that is added in equation 1.4. Clearly, the proposed algorithm for 4-D phase unwrapping produces bright fringe cycles which point out crucial floor motion of 8.5 cm, which is coincided with floor motion of 1.4 m north of Kathmandu (Figure 3). This ought to be enchantment of such previous work of Hussein et al. (2005); Karout(2007);Marghany (2015).

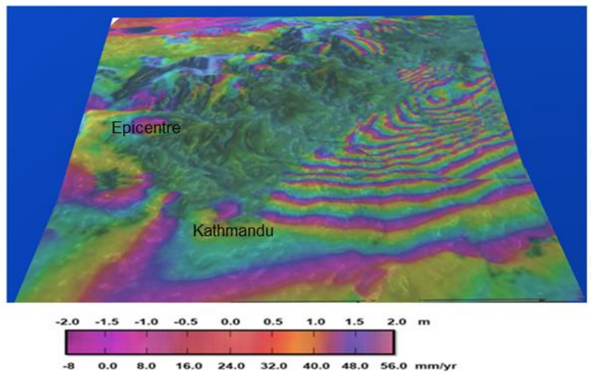

Figure 4. Interferometry produced by 4-DBPASL Pareto ant colony algorithm.

In line with Hussien et al., (2005); Marghany and Mansor (2016); Saravana et al., 2003; Wei, et al. (2008). 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 produces a more precisely fringe cycle.

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 produces vibrant fringe. This study confirms the work done by Marghany (2015)and (2017). 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, the zero-weighted edge is used zero-weighted edges to adjust the optimal path and avoid these singularity loops.

4. CONCLUSIONS

This work has demonstrated a new approach for 4-D phase unwrapping technique to retrieve earthquake displacement due to the fact of Nepal earthquake, 2015. In doing so, conventional InSAR procedures are implemented to two repeat passes of Sentinel-1A satellite 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 the 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 earthquake deformation because of reducing the length of the branch cuts and improving the quality edge of phase unwrapping.

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