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A genetic algorithm for phase unwrapping errors correction

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Differential Synthetic Aperture Radar Interferometry (DInSAR) is a remote sensing technique that permits to study the temporal evolution of the detected displacements via the generation of deformation time-series. In this context, one of the most difficult task for the retrieval of displacement information is represented by the Phase Unwrapping (PhU) step.

We present an innovative technique to correct the phase unwrapping errors based on a guided scanning by means of a genetic algorithm (GA).

Once the unwrapped interferograms are inverted to generate the corresponding displacement time series, then the wrapped interferograms can be easily reconstructed from the time series itself. The phase difference between the wrapped interferograms and the reconstructed ones is higher for interferograms where a phase unwrapping error has occurred.

The presented algorithm considers a first inversion step based on the L1-norm minimization, which guarantees a more sharp and accurate identification of the interferograms that may need a correction. For every single considered pixel, an interferogram evaluated as containing a PhU error is considered as a gene of the GA chromosome.

A mechanism of evolution through mutations and crossing over, ranks every generation's chromosomes and saves only the best ones for the following generation until convergence.

The objective function for ranking chromosomes is the temporal coherence of the pixel, evaluated after the L2-norm inversion of the new unwrapped solution.

A pixel with a low value of temporal coherence, which entails an high presence of noise and PhU errors, is not so sensitive to be corrected, or, in a worse case, can be corrected by GA procedure toward an algebraic solution with no physical meaning. So we apply the GA only to pixel with a temporal coherence value higher than a fixed threshold.

In principles, the presented algorithm can be applied to more generic procedure of unwrapping, once the fitting function for the algorithm is identified.

In our case, we apply the correction technique to a solution obtained by the Small-Baseline Subset (SBAS) DInSAR.

The phase unwrapping is carried out through the well known EMCF (Extended Minimum Cost Flow) approach, based on a temporal and spatial phase unwrapping procedure. The above mentioned correction is applied at the end of the whole procedure.

The results show that in case of strong deformations the algorithm maximizes the temporal coherence, resulting in an increasing of the deformation dynamics, according with the known effect of underestimation risk for the phase unwrapping algorithms.

Another important result is given by the preservation of spatial consistence of the corrections, which is not intrinsically required by the GA procedure, but it emerges as a consequence.

The algorithm has been build up with a parallelization strategy characterized by a very high granularity level (pixel level) thus entailing an high scalability and a reduced processing time.