A COMBINATION OF PARTICLE FILTER, MATRIX PENCIL AND REGION GROWING TECHNIQUES FOR PHASE UNWRAPPING IN SAR INTERFEROMETRY

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1. INTRODUCTION

This work presents an improved InSAR phase unwrapping (PU) method based on a combination of a particle filter, a matrix pencil based local slope estimator and a region growing technique. The better performance of this new solution when compared against some representative traditional methods and the previous particle filter PU approaches is justified and illustrated with results obtained from synthetic and real data.

2. CONCEPT DESCRIPTION

A traditional and extended practice in InSAR applications when dealing with phase unwrapping consists in filtering of the phase signal as a previous step. However, if a pre-filtering stage is applied, some useful information contained in noisy pixels could be lost and never recovered. Thus, filtering and phase unwrapping should not be considered as independent events and an ideal solution should perform both processes simultaneously. In this sense, an EKF based solution, which pursues our same objective, was introduced in [1]. However, due to the non-Gaussian nature of the noise, this solution can not guarantee always a correct solution. In previous works, the authors of the present abstract introduced solutions based on a Grid based Filter and a Particle Filter in [2] and [3], respectively, which are able to consider the Wishart nature of the noise. In addition, as a result of the combination of a particle filter, an improved omni-directional version of the phase slope estimator presented in [1] and a path following strategy, the 2PFPU algorithm was presented in [3]. This 2PFPU solution was shown to provide higher robustness than other conventional techniques and excellent results when dealing with zones containing high density of residues, as well as a simultaneous filtering capability.

In spite of those excellent results, there exist two areas which are subject of improvement: the election of the local slope estimator and the path following technique. Concerning the first, the precision of the local phase slope estimator based on the mode of the power spectral density (introduced in [1] and improved in [3] by means of its omni-directional version) is limited. This precision depends on the size of the window employed for the spectral (FFT) estimation, which defines the sampling in the slope spectrum. The matrix pencil technique introduced in [4] and [5] does not suffer from this limitation and will provide the PU algorithm with local phase slope estimations of a better precision, thus obtaining a higher performance. In addition, a matrix pencil technique was shown to be computationally more efficient than traditional methods [4]. The method we will use in this work will be an improved omni-directional version of the algorithm presented in [5].

Concerning the path following technique used by the authors so far, it grows from a single seed or starting point in the full interferogram. Sometimes there will be no other chance than crossing an area with high density of residues, existing the risk of introducing mistakes which could be propagated to the rest of the interferogram. Contrarily, the more the number of seeds, the less the probability of error propagation, obtaining more accurate results than any mono-seed methods. The region growing technique introduced in [6] starts from different seeds, growing the corresponding areas simultaneously by following a pattern of thresholds. At every iteration, growth rings are defined and every candidate following the threshold criteria will grow. When a growth iteration fails to unwrap any pixels, then the thresholds are relaxed and the process continues. As a result of the threshold scheme, this method is affected by two important drawbacks. The first one is that it does not guarantee an optimal solution. The second one, it is computationally inefficient. The improved region growing method we present in this work makes use of cost functions. In this way, it can guarantee that only the best pixel among all regions (the pixel whose cost function is the best) will be unwrapped at every iteration, providing an optimal solution. On the other hand, it is computationally efficient since it guarantees the unwrapping of one pixel per iteration.

In summary, the solution presented in this work combines a particle filter with a local phase slope estimator based on matrix pencil techniques [4]-[5] and the improved version of the region growing technique presented in [6]. From the synergy obtained as a result of the combination of these three techniques, an improved and more robust phase filtering and unwrapping algorithm is obtained.

3. RESULTS AND CONCLUSIONS

It will be shown with examples the better performance of our new solution when compared against some representative traditional methods and the previous so named 2PFPU method [3]. These algorithms were applied to some illustrative synthetic examples, as well as, to some areas extracted from real interferograms obtained by the ERS1&2 satellites in tandem configuration over the province of Alicante in Spain. Filtering ability when compared to the traditional non- filtering methods will also be shown.

4. REFERENCES

[1] O. Loffeld, H. Nies, S. Knedlik and W. Yu, "Phase Unwrapping for SAR Interferometry – A Data Fusion Approach by Kalman Filtering", *IEEE Transactions on Geoscience and Remote Sensing*. Vol. 46, No. 1, pp. 47-58. January 2008.

[2] J. J. Martinez-Espla, T. Martinez-Marin, and J. M. Lopez-Sanchez. "Using a Grid-based Filter to Solve InSAR Phase Unwrapping". *IEEE Geoscience and Remote Sensing Letters*. Vol. 5, No. 2, pp. 147-151. April 2008.

[3] J. J. Martinez-Espla, T. Martinez-Marin, and J. M. Lopez-Sanchez. "A particle filter approach for InSAR phase filtering and unwrapping". *IEEE Transactions on Geoscience and Remote Sensing.* 2009. In press.

[4] G. Nico and J. Fortuny. "Using the Matrix Pencil Method to Solve Phase Unwrapping", *IEEE Transactions on Signal Processing*. Vol. 51, No. 3, pp. 886-880. March 2003.

[5]Y. Hua. "Estimating Two-Dimensional Frequencies by Matrix Enhancement and Matrix Pencil", *IEEE Transactions on Signal Processing*. Vol. 40, No. 9, pp. 2267-2280. Sept. 1992.

[6] W. Xu and I. Cumming. "A Region-Growing Algorithm for InSAR Phase Unwrapping". *IEEE Transactions on Geoscience and Remote Sensing*. Vol. 37, No. 1, pp. 124-134. January 1999.