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Retrieving 3-D Surface Deformations from Multiple InSAR Measurements Based on Strain Model and Variance Component Estimation

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Interferometric synthetic aperture radar (InSAR) technique has been confirmed to be useful in determining spatial-continuously 3-D surface deformation by combining line-of-sight (LOS) measurements from differential InSAR (DInSAR) technique and azimuth (AZI) measurements from multiple-aperture InSAR (MAI) or Pixel Offset-Tracking (POT) techniques. However, the exact priori variances of different types of InSAR measurements (i.e. measurements derived from different platforms or techniques) are quite difficult to obtain, resulting in inaccurate weighting factors in the fusing model and unstable 3-D deformations. In addition, 3-D deformations are generally resolved on a pixel-by-pixel basis. As a result, the relationship between the deformations of the adjacent ground points cannot be considered in the existed research.

On the purpose of defeating above-mentioned shortcomings, this paper presents a novel method to retrieve 3-D deformations from multiple InSAR measurements based on Strain Model (SM) and Variance Component Estimation (VCE). In this method, SM is employed to construct a new observation model, which can establish not only the relationship between the multiple InSAR measurements and 3-D deformations, but also the relationship among the adjacent ground points' deformations. In such case, a large amount of observations can be provided for each interested ground point. Sequentially, VCE algorithm is exploited to extract accurate weighting factors for different types of InSAR measurements based on the observation redundancy, yielding accurate 3-D deformation estimations.

The proposed method was firstly validated by a simulated experiment and then applied to reconstruct the 3-D deformation fields associated with the 2007 eruption of Kilauea volcano in Hawaii, USA. Both the simulated and real data experiments show that the novel method is superior to the traditional method, i.e. Weighted Least Squares (WLS) method. The estimated 3-D deformation fields of the 2007 Kilauea volcano are consistent well with the observations of 25 GPS stations. The root mean square errors (RMSEs) of the 3-D deformations derived by the new method are 2.0 cm, 6.8 cm and 4.2 cm for the east, north and up components, respectively, exhibiting the improvements of about 53.7%, 8.2%, and 17.9% with respect to the traditional WLS method.