ABSTRACT

Lin, Keng-Fan Ph.D., Purdue University, May 2017. Hybrid Analysis for Synthetic Aperture Radar Data Stack. Major Professor: Daniele Perissin.

Demands for the Earth observation has risen in the past few decades. As technology advanced, remote sensing techniques have become progressively essential in various applications, such as landslide recognition, land use monitoring, ecological observation, etc. Among the existing techniques, synthetic aperture radar (SAR) has the advantage of making day-and-night acquisitions in any weather conditions. The characteristics secure the applicability of delivering reliable measurements over cloudy areas and performing measuring without the external energy source. However, SAR images suffer from lower spatial and spectral resolution compared to the optical ones. The coherent nature of radar signals also results in speckles which reduce the interpretability of the acquired datasets.

To overcome the aforementioned issues, one can consider analyzing a long series of observations over the same area. In that sense, spatial correlations of the image pixels can be studied based on similarity of temporal statistics. Adaptive image processing can thus be created. Such an adaptive procedure has been applied for movement detection based on SAR interferometry (InSAR) since the last few years; however, nothing more. For the first time, we propose a full framework that allows processing the SAR images with spatiotemporal adaptiveness without losing the original resolution. This framework, namely Hybrid Analysis for Synthetic Aperture Radar (HASAR), exploits information in single-polarized/multi-temporal data stacks and focuses on two applications–change detection and image classification. Three techniques are developed in this study. First, we derive a new hypothesis testing procedure to identify pixels behaving similarly over time. Compared with conventional

methods, the proposed test provides similarity measurements regardless of temporal variabilities and outliers. Its effectiveness paves the way for the following two techniques. Second, we develop an automatic change detection approach which utilizes spatiotemporal observations obtained by the first technique to locate abrupt changes in the imaged areas. Compared with existing methods, this approach does not require parameter-tuning procedures, giving a fully unsupervised solution for multi-temporal change analysis. Last, we deliver an efficient solution for classifying single-polarized datasets. A first-level classifier is implemented to analyze the spatiotemporal observations previously mentioned. Different from any other existing methods, the proposed method does not need polarimetric information for solving the multi-class problem. Its effectiveness greatly improves the added value of the single-polarization datasets.

Various experiments have been made to test the effectiveness of each proposed technique. First of all, the results from TerraSAR-X datasets in Los Angeles and Hong Kong signify that the proposed testing procedure is able to deliver effective extraction of statistically homogeneous pixels. Next, the detected changes from ERS-02 datasets in Taiwan show good matches with ground truth. Compared with conventional pairwise change analysis, the proposed multi-temporal change analysis provides much more extensive information related to the possible change instances. The detected changes can be better justified through the temporal statistics. Only historically significant changes will be considered as changes, which greatly reduces the false alarm rate. Finally, the results of multi-class classification from TanDEM-X and COSMO-SkyMed datasets in Los Angeles and Chicago, respectively, reveal high classification accuracies without complicated training procedures. It thus provides an entirely new solution for classifying the single-polarized datasets. By collectively utilizing different attributes (amplitude/coherence), dimensionalities (space/time), and processing approaches (pixel-based/object-based), the HASAR system significantly augments the information content of the SAR data stacks. It, therefore, reveals high potentials for continuous Earth monitoring.