INDEPENDENT COMPONENT ANALYSIS OF POLARIMETRIC SAR DATA FOR SEPARATING GROUND AND VEGETATION COMPONENTS

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1. INTRODUCTION

Synthetic Aperture Radar (SAR) interferometry is routinely used for obtaining Digital Elevation Maps (DEM) over terrain [1]. In conventional SAR interferometry, the DEM estimates are derived from the phase difference between two images generated from multiple, spatially-separated tracks of the SAR platform. It is assumed that the backscatter from a SAR pixel can be associated with a single scattering center at a fixed elevation relative to some reference elevation. However, when there are more than one scattering centers, each at a different elevation within a pixel, the phase difference between the images will be proportional to some weighted mean elevation of all scattering centers. This is especially true when estimating the elevation of terrain which is covered by vegetation.

In polarimetric SAR interferometry, fully-polarimetric measurements are obtained along multiple interferometric tracks and used to generate three-dimensional tomographic images of a scene [2-3]. The polarimetric diversity provides the means to separate multiple scattering centers, which may be located within a given SAR pixel. Chen and Kasilingam [4] have investigated the use of Vector Linear Prediction (VLP) for separating the ground and vegetation components in the composite radar echo. The VLP method uses multivariate data in the form of the polarimetric signature to separate components with discernible polarimetric signatures. Chen and Kasilingam [4] identified polarimetric signature as a means to separate independent signal components in a composite signal. Their study clearly established a critical need to understand the use of the polarimetric signature to separate different scattering components in a composite radar signal.

In this study, the use of Independent Component Analysis (ICA) with fully-polarimetric SAR data to identify and separate different scattering components from a composite radar signal is investigated. ICA is a statistical and computational technique for revealing hidden factors that underlie sets of random variables, measurements, or signals. ICA defines a generative model for the observed multivariate data. In this model, the data variables are assumed to be linear mixtures of some unknown latent variables, and the mixing system is also unknown. The latent variables are assumed non-Gaussian and mutually independent and they are called the independent components of the observed data.

2. ANALYTICAL APPROACH

In this study, the FastICA algorithm developed by Hyvärinen *et al* [5], is used to investigate the utility of existing ICA algorithms for separating the independent scattering components from the radar signal. The FastICA algorithm is a fast analysis technique, which is also easy to implement. It is widely used as a reference algorithm for comparing other more sophisticated algorithms.

In this study, fully-polarimetric ESAR data from the Glen Aftic region in Scotland is used for testing the analysis technique. The multivariate data samples are constructed by using a vector consisting of the HH and VV polarized measurements. The cross-polarized measurements are not used in this study. The results from the ICA analysis are compared with the results from the PolInSAR techniques presented by Chen and Kasilingam [6]. In the PolInSAR technique, measurements from two tracks of a polarimetric interferometer are used to estimate the interferometric phase of multiple scattering centers residing within an image pixel. A byproduct of the PolInSAR technique is that it also provides information about scattering signature of each scattering center. In ICA, each independent component would correspond to some discernible scattering center and in the case of two-dimensional multivariate, ESAR data from the Glen Afric region, they correspond to the ground scattering component and the vegetation scattering component.

In this study, each independent component is written as $e = \begin{bmatrix} h & v \end{bmatrix}^T = p\begin{bmatrix} \cos\alpha & \sin\alpha \exp(j\phi) \end{bmatrix}^T$, where α and ϕ represent the relative magnitudes of the **h** and **v** components and the phase difference between them, respectively. These two angles are used to parameterize the scattering components. For example, over water, the dominant scattering component is expected to have $\phi = 0°$, with a α value a little larger than 45°.

3. RESULTS AND CONCLUSIONS

Polarimetric measurements from the ESAR interferometer over the Glen Afric region are used in this study. Figures 1 and 2 show the cross-pol intensity image and the polarimetric coherence between HH and VV over this region. These images are used as 'ground truth' information. In figure 1, the lake and the terrain region are clearly visible. When one compares the cross-pol image with the coherence image in figure 2, the regions which are covered with vegetation are clearly discernible. These regions have high backscatter, which is reflected in the cross-pol image (figure 1) and low polarimetric coherence, which is reflected in the coherence map (figure 2). In this study, this information is used as a reference to discern vegetated areas from bare terrain.

The polarimetric data from this region is used to identify the dominant scattering mechanisms in the study area. Both the PolInSAR technique developed by Chen and Kasilingam [6] and the FastICA algorithm are used with the data to identify these components. The α and ϕ angles are calculated for each component, using both techniques. Figure 3 shows the α angle using the PolInSAR technique and figure 4 shows the same angle using the FastICA algorithm. The results agree well. Also both sets of results appear to be consistent with the polarimetric coherence shown in figure 2. Over bare terrain, the α angle is expected to be small because the scattering is dominated by ground scattering. Over vegetated areas, the α angle is significantly larger because the dominant scattering component is mostly depolarized vegetation scattering. Note the PolInSAR technique is expected to do better because it utilizes more data – polarimetric measurements from both tracks. The FastICA algorithm utilizes only polarimetric data from a single track. The motivation for this study is to identify a technique for estimating and separating different scattering components from a composite radar signal using only polarimetric measurements. The PolInSAR technique utilizes both polarimetric and interferometric data. The latter may not always be available for identifying and separating different scattering components.
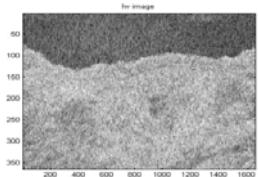

Fig 1 – HV intensity image of Glen Afric region.
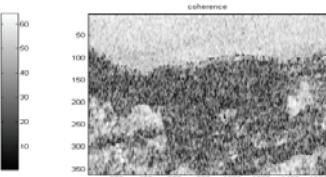
Fig 2 – HH/VV coherence of Glen Afric region.
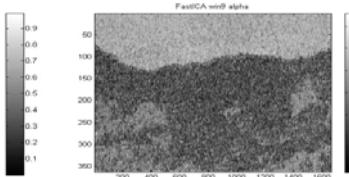
Fig 3 - α angle using PolInSAR method.
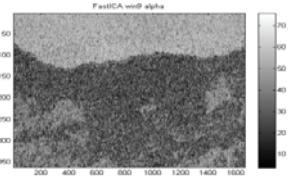
Fig 4 - α angle using FastICA algorithm.

4. REFERENCES

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