Abstract

Hyperspectral remote sensing images are acquired in hundreds of contiguous spectral bands in a narrow spectrum interval. Hyperspectral technology is well-suited for many remote sensing applications since the substances on earth can be easily differentiated based on their spectral signature. At the same time, analysis of hyperspectral images (HSIs) has to face challenges due to their huge data volume and the limited availability of labelled samples. Moreover, the recent research demonstrates that the integration of the spatial information obtained from the neighbourhood with the spectral information improves the analysis results. This thesis is focused on developing some robust techniques for effective analysis of of HSIs using spectral-spatial information obtained by exploiting mathematical morphology.

The first contribution of the thesis presents a novel spectral-spatial active learning technique for classification of hyperspectral images having limited labeled samples. Several AL techniques are existing in the HSI literature however, only a few of them are presented in the spectral-spatial domain which are mostly computationally demanding. In the first contribution of this thesis, a novel computationally efficient spectral-spatial multi-criteria AL technique is presented that exploits the properties of extended morphological profiles to integrate spectral-spatial information and defines a novel query function for incorporating uncertainty, diversity and cluster assumption criteria by exploiting the properties of support vector machines, k-means clustering and K-nearest neighbors algorithm. Finally, GAs are exploited to optimize these three criteria for selecting batch of most informative samples for labelling.

The second contribution of the thesis presents a novel unsupervised feature selection technique to select an optimal subset of features from a large dimensional multi-attribute profile. Morphological attribute profiles (APs) are generalization of morphological profiles (used in first contribution) since the image filtering is based on attribute values computed on connected components of image. To fuse the spectral and spatial information of HSI, an entire extended multi attribute profile (EEMAP) is constructed for the HSI considering filter parameter values

sampled in very small interval from a wide range. Although, the large EEMAP contain variety of spatial information, it has very high dimensionality with ample redundancy that increases the computational cost and also may introduce curse of dimensionality problem. To mitigate these problems, the only method existing in the literature that selects subset of features from the constructed EEMAP is highly computational demanding and supervised in nature. In the second contribution of this thesis, a novel computationally efficient unsupervised feature selection technique is presented that selects an optimal subset of features from the constructed EEMAP for spectral-spatial classification of HSI. The proposed technique exploits the properties of mutual information and genetic algorithms with the definition of a novel objective function. The two important advantages of the proposed technique are 1) it is unsupervised in nature; and 2) it has low computational burden.

The final contribution of the thesis presents a compact threshold-free attribute profile for spectral-spatial classification of HSI. The construction of an AP using threshold values (selected manually or automatically) is a time-consuming task and may result in a large number of features that may introduce *curse of dimensionality* problem. To the best of our knowledge, no method exists in the HSI literature that generates APs without employing threshold values. In this thesis, a novel approach is presented that generates the filtered images for constructing APs without using the threshold values. These APs are compact in size and incorporate sufficient amount of spatial information. The proposed method has several advantages: 1) it generates filtered images without using any threshold value; 2) it is fully automatic and independent on the image content; 3) a small number of filtered images generated by this method are capable to capture a large amount of spatial information; 4) it is more robust to handle curse of dimensionality problem; and 5) it generates the profiles in a much faster way.

Keywords: Hyperspectral image, Spectral-spatial classification, Dimensionality reduction, Mathematical morphology, Morphological profile, Active learning, Attribute profile, Feature selection, Threshold-free attribute filtering, Threshold-free attribute profile.