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Thesis Title: Graph based Machine Learning Techniques for Classification of Hyperspectral Images

Abstract

Hyperspectral imaging technique captures a detailed contiguous spectrum of the received light in each spatial position in the image. Since different substances exhibit different spectral signatures, hyperspectral imagery is a well-suited technology for accurate image classification, which is an important task in many application domains. However, the high dimensionality of the data presents challenges for image analysis. While most of the previously proposed classification techniques process each pixel independently without considering information about spatial structures, recent research in image processing has highlighted the importance of the incorporation of spatial context in a classifier.

The goal of this thesis is to address the issues that arise prior and during the hyperspectral image classification; therefore this thesis mainly focuses on the feature reduction and classification task of the hyperspectral images. Notably, the primary focus of this thesis is to work on both linear and nonlinear feature reduction as well as feature extraction with application to the classification of the hyperspectral data. In this work, we develop some advanced graph based feature reduction techniques for better classification of hyperspectral data by using both the spectral and spatial domain information.

Majority of the algorithms assume that the data is in linear Euclidean space and perform the task without considering the data geometry, which degrades the performance. To address that issue, in the first objective, we developed a geometry aware mapping technique that maps the hyperspectral data to a new discriminative space for better classification performance. We observed that most of the feature reduction techniques are based on L2-norm, which is very sensitive to noises and outliers. To tackle that problem, in our second objective, we developed a new graph based L1 norm scaling cut (L1-SC) method. Although the L1-SC handles the noise and outliers issue, it ignores the correlation property of the data. Hence, again we extended that work with a newly developed regularizer "Trace lasso" and proposed Trace lasso regularized L1 norm graph cut (TL-L1GC) for handling the sparsity and correlation adaptively. The TL-L1GC considers all the samples of the class and spectral information of the data. To make it more robust and computationally inexpensive, we reformulate it to the spatial spectral Trace lasso regularized L1 norm local graph cut (TL-L1LGC) method.

Then in the third objective, we proposed a graph based spatial spectral regularized local scaling cut (SSRLSC) feature reduction technique to handle the data singularity and the small sample size (SSS) problem. However, the SSRLSC ignores the data nonlinearity and limited training sample problem. Hence, in the fourth objective, we proposed a semi-supervised manifold learning technique semi-supervised spatial spectral regularized manifold local scaling cut (S3RMLSC). The S3RMLSC not only takes care of the nonlinearity issue but also solves the limited training sample problem by its semi-supervised approach. Furthermore, in the final objective, a spectral graph based deep neural network classifier has been investigated for better classification performance. This deep graph based classifier use the geometrical structure of the data. The new techniques, developed in this thesis, improve classification results, when compared to previously proposed methods, and thus show great potential for various image analysis scenarios.

Keywords: Dimensionality reduction, graph cut, graph convolution neural network, hyperspectral image, local scaling cut, manifold, spatial-spectral, semi-supervised, scaling cut, trace lasso.