CHAPTER 7

SUMMARY, CONCLUSIONS AND FUTURE DIRECTIONS

Prelude: This chapter summarizes the overall observations and conclusions of the studies presented in the previous chapters, and important contributions of this thesis to the state-of-the art in hyperspectral image processing and analyses. Further, recommendations and directions of future research in this high impact area of remote sensing research are presented in this chapter.

This thesis has investigated some important issues involved in the application of a novel pattern recognition approach multiple classifier system for efficient hyperspectral image classification. In pursuance of the objectives of this thesis, we developed and implemented novel algorithmic schemes to make the multiple classifier system a reliable approach for hyperspectral image classification.

The main contributions of this thesis to the literature are: 1) an empirical analysis on the impact of dimensionality reduction methods on the classification performance of the multiple classifier system, 2) establishment of the existence of empirical relationships between classifier and dimensionality reduction method and between class, classifier and dimensionality reduction method within the framework of multiple classifier system, 3) demonstrated that transformed components from multiple dimensionality reduction methods can be used to sustain diversity in the functioning of base classifiers in the multiple classifier system, 4) a novel classifier system for automatically selecting input hyperspectral image adaptive classifiers and dimensionality reduction methods, 5) explored the potential of dynamic classifier selection approaches for hyperspectral image classification and developed two new dynamic classifier selection approaches for hyperspectral image classification. Of the two new approaches proposed, the first approach uses only spectral information, whereas the second approach is based on the spectral-spatial classification model to incorporate the spatial contextual information. These contributions will be valuable in devising efficient and generic methodologies.
for the analyses of various sources of hyperspectral images for applications in environmental monitoring, and the natural resource management.

The summary of thesis is presented below chapter wise.

• Chapter 3: The impact of different dimensionality reduction methods on the performance of the multiple classifier system was studied. This study was conducted to understand the potential of using multiple dimensionality reduction methods to create the essential performance variability required among the base classifiers in the MCS and to understand how this variability influences the performance of MCS. The empirical results show that there is a significant variability in the performance of the individual base classifiers in the MCS and the level of variability is a function of the dimensionality reduction method. This indicates the significance of adopting dimensionality reduction methods to create differential performance in the classifiers for the MCS classification. Further, the magnitude of classification improvement of the MCS has a significant bearing on the change in dimensionality reduction methods. The random choice of dimensionality reduction method could adversely affect the performance of MCS. Hence the choice-specific dimensionality reduction method has to be selected based on the information content of the hyperspectral image for exploiting the anticipated benefits of MCS. This study suggests the importance of domain adaptive knowledge and understanding the suitability of the dimensionality reduction methods in relation with the underlying hyperspectral image for successful hyperspectral image analysis.

• Chapter 4: With plethora of classifiers and dimensionality reduction methods available in literature, we assessed the relationship between classifier and dimensionality reduction method as well as information class, classifier and dimensionality reduction method for hyperspectral image classification. The results indicate that at overall image level, there are some empirical relationships indicating preferred pairs of classifiers and dimensionality reduction methods across the different hyperspectral images. At the land cover category level, different classes are best classified by different classifiers within each image and the existence of different preferred combinations of class, classifier, and dimensionality reduction method. These observations are found stable even at different spatial and
spectral resolutions as per our experiments on the synthetic hyperspectral images generated using original hyperspectral images. This remarkable observation puts forward the concept of information class specific methodologies for the analyses of hyperspectral images.

• Chapter 5: A novel classification approach named as dynamic classifier system was developed. This approach, functions within the MCS framework, dynamically identifies optimal pairs of classifiers and dimensionality reduction methods based on the input data dynamics and executes classification only with the identified pairs. The required optimal dimension of the dimensionality reduction methods is optimized by the classification accuracy and class separability of training samples. The identified pairs of classifiers and dimensionality reduction methods are combined with different non-trainable and trainable combination functions, and both of them showed significant increase in classification accuracy over the single best classifier. However, the magnitude of improvement is higher with trainable combination function. Moreover, the classification results are compared with that of MCS and SVM. The experimental results on five different hyperspectral images confirm the robustness of the proposed system to significantly increase the classification accuracy over the typical MCS and SVM.

• Chapter 6: We further improved our dynamic classifier system approach presented in the Chapter 5 to dynamic selection of classifier for identifying the best subset of classifiers relative to each image pixel. As part of this, we implemented some of the algorithms used in the pattern recognition methods (local accuracy based dynamic classifier selection and probabilistic based dynamic classifier selection) for testing their suitability for dynamic selection of classifiers with reference to image pixel for hyperspectral image classification context. Experimental results show significant improvement in the classification accuracy. However these approaches demand high computational time since it requires computing the distance between each image pixel and validation sample. To make the dynamic classifier selection accurate and computationally fast, we modelled the classifier selection problem as the classification problem and proposed a new dynamic classifier selection approach based on extreme learning machine regression framework. The proposed approach offers convincing results when compared to single best classifier and also to other dynamic classifier selection approaches. Fur-
ther, we proposed a new spectral-spatial classification model to incorporate spatial contextual information in the hyperspectral image classification framework. Classification results carried out on two different hyperspectral images demonstrate that the proposed spectral-spatial classification model yields a significant increase in accuracy when compared to the state-of-the-art approaches.

**Recommendations and future research**

The following are some important directions for future research to further enhance the scientific utility of the studies presented in this thesis. Our future works will include some of the following.

- The dimensionality reduction methods used to create diversity in this thesis can be further modified to work as feature selection methods. We believe that deployment of multiple feature selection methods with different complimentary characteristics could improve the classification performance of the MCS.

- Evaluation of the proposed dynamic classifier system to automatically select and combine the classifiers and dimensionality reduction methods based on each land cover class type. Moreover, the dynamic classifier system can be extended to incorporate spatial contextual information.

- Another interesting direction is optimizing the weights of the spectral-spatial classification model based on shape of the objects present in the image. This may improve the classification performance of small spatial structures. Moreover, devising a classifier competence strategy for hyperspectral image classification could also be of interest. Indeed, very limited studies are reported in this arena.

- The extension and investigation of the proposed techniques on the planetary hyperspectral images as well as on the other hyperspectral sensors should also be of interest.