CHAPTER 6

CONCLUSIONS

The main emphasis of this thesis is to design and develop new sensor independent algorithms for efficient classification of multispectral and hyperspectral remotely sensed images. The primary motivation of developing the proposed new algorithms encompass integrating band reduction, spatial and spectral information into image classification process to attain high classification accuracy without incurring significant computational cost overhead. The designed new algorithms have been implemented as one end-to-end software package with a GUI for operational use. The defined objectives in section 1.5 are successfully met through the developed new algorithms.

This chapter concludes the thesis by summarizing and discussing the results obtained in the development of considered research topics. The final section of this chapter gives an outlook on possible future research.

6.1 Summary and Conclusions

This thesis presented new algorithms and a system for effective and efficient classification of hyper- or multispectral RS images. It consisted of
developing a (i) a fast dimensionality reduction scheme, (ii) an elegant algorithm for segregating pixels in the image into mixed and pure pixel categories and (iii) an adaptive hybrid classification method that selectively applies the spatial information along with spectral information. For each of the above items detailed literature survey was carried out and the limitations of currently published methods were highlighted and new methods or algorithms were proposed. The new techniques were theoretically developed, implemented and applied on numerous real world remote sensing data sets to evaluate their effectiveness. Technical merits of the developed techniques are presented below.

(i) Processing of hyper- or multispectral data is complicated due to the heavy computational requirements, presence of redundant information and garbage features that compromise the modeling accuracy. In this thesis a new unsupervised method based on Hamming Distance metric is proposed. The strength of the proposed algorithm lies in its computational efficacy as only first order operations are required to identify the optimal band sub-set. As the unsupervised method does not require calculation of solving any complex optimization problem, extraction of costly entropy measures and does not require any prior knowledge of the underlying structure of data, it lends itself to be very suitable for applying to a wide variety of data sets. One other important benefit of the method is that it excludes formation of any new features and retains the original band information thus preserving the physical properties of the data. Evaluation of the proposed method indicated that application of the band reduction scheme resulted in significant computational savings in the later phases.
of the classification system without sacrificing the classification accuracies. Experimental results also revealed that the fast band reduction scheme performed at the same levels as the more expensive band elimination techniques.

(ii) The second main contribution of the work is the proposal of a novel algorithm for segregation of pixels in an image into mixed and pure pixel categories. The need for such a scheme is derived from the fact that most images are made up of a higher proportion of homogenous areas containing mostly pure pixels and only a small subset of heterogenous areas composed of mixed pixels and application of expensive spatial feature extraction techniques could be limited only to the mixed pixels. Extended Mathematical Morphological operations are used to identify the mixed pixels. The morphological methods have proven to be fast and require almost no input parameters enabling automatic detection of mixed pixels. Choice of D-ordering for performing primitive MM operations yielded good results. Experiments have revealed that the proposed technique, as it inherently uses the spatial structure, is more effective when the image contains classes with similar spectral responses and performs well even when the image is noisy. One drawback of the proposed method is the choice of appropriate structure element (SE) is not apparent without looking at a range of SEs. But, from the experiments it was seen that even with a fixed disk SE, classification of scenes even with large homogenous areas reported increased classification accuracies.
A hybrid adaptive pixel-wise classification method was proposed. The novel classification technique, based on SVM, exploits the contextual information only when required. By selectively applying the expensive spatial information only on the pixels categorized as mixed, this approach yields significant computational savings when compared to other methods that use a fusion of spectral and spatial information. When using spatial and spectral feature for classification of mixed pixels, the feature vector is built as a stacked vector made up of morphological profiles and neighborhood information that contains the spatial details and a vector of spectral values of all the bands. The hybrid SVM was built using a hybrid RBF kernel that uses both spectral and spatial information. After the pixel-wise classification of mixed pixels, a majority vote on the neighborhood is applied to make the final thematic map more homogenous and avoid salt-and-pepper effect. The use of SVMs provides a good solution to the problem of dimensionality, small training set size and robust to noise in the training set.

The proposed classification system was evaluated against the classical ML classifier, ECHO classifier that utilizes both spatial and spectral information, and a standard SVM based spectral classifier. From the classification results on multiple data sets presents in previous chapter following conclusion can be drawn.

- Proposed band reduction scheme greatly lowers the computational cost and also helps improve the classification accuracy by eliminating redundant bands.
• In most cases ECHO outperformed both ML and standard SVM, implying that the use of spatial information in general leads to improved results.

• Standard SVM classifier consistently outperforms ML, demonstrating that SVMs are better classifiers and are robust to a small training size.

• Application of mixed pixel segregation helps further lower the computation overhead by working as a specialized feature reduction method with sacrificing the accuracy.

• The hybrid SVM classifier significantly outperforms the ECHO classifier, indicating that adaptive application of spectro-spatial information is both economical and effective.

• Morphological profiles have demonstrated to have a good capability for extracting useful spatial information.

• Fusion of spectral information and morphological profiles in the feature vector performs better than using either of those alone.

• The proposed spectral-spatial classification scheme based on independent classification of pure and mixed pixels, followed by merging the independent thematic maps and a majority voting in the neighborhood of mixed pixels yields good classification results.

A hyper- or multispectral classification software package based on the proposed algorithms and techniques was developed. Each module in the software
is carefully designed for robustness, and ease of use. The software package was tested and evaluated against a number of data sets and should prove to be an effective tool for joint spatial and spectral classification of higher dimensional data sets.

The objective of this work was the need for incorporating spatial and spectral information in multi- or hyperspectral image classification process without incurring a huge overhead in terms of computational performance. The proposed methodology succeeds in satisfying this need by taking advantage of the fact that tradeoff between accuracy and computation cost is maximized by limiting the extraction and use of spatial features only for the subset pixels which mostly benefit by the use of this information in the classification process. Evaluation of the proposed techniques against existing methods has demonstrated that, on average, an increase of 5-10% overall accuracy has been observed with less than 40% computational cost increase.

6.2 Future Work

In this research, the designed and developed techniques and approaches can significantly improve the efficiency of classification of RS data. Several issues relating to dimensionality reduction, usage of contextual information, choice of proper classifier data model, fusion of spectral and spatial information were addressed. Following the direction of current research for effective handling of HS data, some of the issues that remain open and are conducive for further
research are identified. Application of a fast search based scheme to further optimize the proposed band reduction scheme might result in improved performance. As many of the tasks in the classification scheme lend themselves to be parallelizable both within and across modules, attempt at splitting and concurrent handling of these actions will result in reduction of overall classification time. Finally, enhancing the developed software to be more generic, with automatic tuning of parameters and capable of dealing with multiple image formats and adding additional image processing operations will further improve the utility of the package.