# Preface

Hyperspectral signal and image processing has witnessed a quantum leap due to recent advances of hyperspectral imaging sensors or spectrometers which use hundreds of contiguous spectral channels for data acquisition and collection. A clear indication is evidence that hyperspectral signal processing was not designated as a topic area in the *IEEE Transaction on Geoscience and Remote Sensing* until 2001. So far, this journal probably is still the only one with such designation among all IEEE transaction journals. With availability of very high spectral resolution provided by hyeprspectral imagery many subtle information and signal sources can now be uncovered and revealed unknowingly. On many occasions, a piece of information is considered to be crucial if it cannot be obtained *a priori* or it cannot be identified by visual assessment, for example, rare minerals in geology, special species in agriculture and ecology, waste in environmental monitoring, drug trafficking in law enforcement, combat vehicles in battlefield etc. When such targets occur, they appear either at subpixel scale or in a mixed form. In addressing these issues statistical signal processing-based spectral (non-literal) approaches are generally more effective than traditional visual-based spatial domain (literal) analysis. My recent book, *Hyperspectral Imaging: Spectral Techniques for Detection and Classification* published in 2003 by Kluwer/Plenum Academic Publishers (now is part of Springer-Verlag Publishers) has documented statistical signal processing techniques developed by the Remote Sensing signal Processing Laboratory (RSSIPL) at the University of Maryland, Baltimore County (UMBC) to investigate issues of subpixel detection and mixed pixel classification. Since it was published in 2003, many new results have been reported in the literature or various conferences in many venues. In order to keep up this trend, this book is edited with two goals in mind. One is to provide with readers most recent research conducted in the RSSIPL at UMBC which is not included in my 2003 book. A second goal is to invite experts in this particular field to share readers with their most recent research findings. Accordingly, a total of 16 chapters are included in this book and divided into two categories, Part I consisting of 6 chapters (Chapter 1-Chapter 6) contributed by my current students and me in the RSSIPL at the UMBC and Part II comprising 10 chapters (Chapter 7-Chapter 16) contributed by researchers from other organizations.

The topics covered in Part I start with Chapter 1 on a new recently developed concept, Virtual Dimensionality (VD) with its applications in hyperspectral data exploitation. It is then followed by Chapter 2 and Chapter 3 on endmember extraction, Chapter 4 on unsupervised classification, Chapter 5 on background suppression for unsupervised target detection and Chapter 6 on hyperspectral signature analysis. More specifically,

Chapter 1: Virtual Dimensionality and Its Applications in Hyperspectral Data Exploitation by Chang explores a concept, called Virtual Dimensionality (VD) first coined in my 2003 book and investigates its utility in several fundamental issues: how to estimate number of classes to be classified, number of components needed to be remained after dimensionality reduction, number of bands required for band selection and number of endmembers. The VD was originally developed to estimate the number of spectrally distinct signatures in the data and will be shown in this chapter to be very useful in versatile applications (see Chapters 2-5, 7).

Chapter 2: Pixel Purity Index-Based Algorithms for Endmember Extraction from Hyperspectral Imagery by Chaudhry et al. investigates a popular endmember extraction algorithm in the ENVI software, called Pixel Purity Index (PPI) and its variants. Since the details of implementing the PPI are not available in the literature, this chapter provides its step-by-step MATLAB-based implementation and also several improved versions of the PPI. In particular, the VD is used to estimate the number of endmembers required for the PPI to generate. This chapter provides readers with a complete treatment of the PPI and a valuable guideline of how to implement the PPI.

Chapter 3: Principal Components Analysis-Based Endmember Extraction by Ji and Chang develops a new Principal Components Analysis (PCA)-based endmember extraction algorithm that can be shown to perform at least as well as the PPI does in Chapter 2 where once again the VD is used for estimation of number of endmembers. It shows how a commonly used and well known technique, PCA can be modified for endmember extraction.

Chapter 4: A Comprehensive Experimental Study on Purdue's Indian Pines Test Site by Liu et al. investigates issues in classification of Purdue's Indian Pine test site, which is one of most well-known hyperspectral image scenes. This chapter demonstrates how heavily pixels in the image scene are mixed and how difficult to classify this image scene supervisedly and uunsupervisedly where the VD is again used to estimate the number of classes for unsupervised classification. It is believed that this chapter is probably the first work reported in the literature for such a thorough and comprehensive study and analysis on this particular scene, specifically unsupervised classification.

Chapter 5: A Low Probability Detection for Unsupervised Background Suppression, Target Detection and Classification for Hyperspectral Imagery by Jing Wang and Chang looks into the issue of background suppression in unsupervised target detection where a low probability detection (LPD) approach is investigated. The idea of the LPD was originally developed in Harsanyi's dissertation in 1993 and later detailed in my 2003 book. Unfortunately its application in background suppression has yet to be explored. This chapter offers a new look at the LPD implemented in conjunction with the concept of the VD.

Chapter 6: Kalman Filter-Based Approaches to Hyperspectral Signal Similarity and Discrimination by Su Wang and Chang reinvents the wheel for the Kalman filter-based linear unmixing to provide new insights into hyperspectral signature analysis.

The topics covered in Part II follow very closely the same logic approach presented in Part I. It also starts with endmember extraction (Chapter 7 and Chapter 8) followed by transform methods (Chapter 8 and Chapter 9), data compression (Chapter 9 and Chapter 10), target detection (Chapters 11 and Chapter 12), classification and feature extraction (Chapter 13, Chapter 14 and Chapter 15) and culminates in information mining for remote sensing imagery (Chapter 16). In what follows, brief descriptions of each of 10 chapters in Part II are provided.

Chapter 7: Applications of Morphological Processing to Endmember Extraction by Plaza extends classic morphological image processing to extraction of endmembers from hyperspectral imagery. Unlike most endmember extraction algorithms including those in Chapter 2 and Chapter 3 which are pixel-based non-literal techniques, it is one of very few endmember extraction techniques which make use of both spatial and spectral properties to find endmembers.

Chapter 8: Transform Methods in Hyperspectral Imaging by Ifarraguerri describes three families of transforms for hyperspectral image analysis. One of them is called endmember transform and can be considered as a technique for endmember extraction in Chapters 2-3 and 7.

Another is the Maximum Noise Fraction (MNF), also known as Noise Adjusted Principal Component (NAPC) transform which is also discussed in Chapters 2, 3 and 9.

Chapter 9: Noise-Adjusted Principal Component Transform and Its Applications to Hyperspectral Image Analysis by Du provides insights into the NAPC transform and further explores its utility in hyperspectral data compression.

Chapter 10: Near Lossless Data Compression Techniques and Their Evaluation Using Remote Sensing Applications by Qian reviews near lossless and lossy hyperspectral data compression techniques and performance evaluation criteria where two specific compression algorithms, Successive Approximation Muti-stage Vector Quantization (SAMVQ) and Hierarchical Self-Organizing Cluster Vector Quantization (HSOCVQ) are developed for applications.

Chapter 11: A Maximum Spectral Screening (MSS) Algorithm for Target Detection by Robila develops a spectral measure-based target detection method, referred to as Maximum Spectral Screening Algorithm which reduces high dimensional data to representative subsets of spectra from which the measure of spectral dissimilarity can be used for unsupervised target detection.

Chapter 12: Anomaly Detection in Hyperspectral Imagery: Second Order and High Order Statistics-Based Algorithms by Ren considers an high-order statistics-based approach to anomaly detection where two specific $3^{rd}$-order and $4^{th}$-order statistics-based techniques are derived and compared to the commonly used $2^{nd}$ order statistics-based RX detector.

Chapter 13: Applying the Support Vector Machine to Classification of Hyperspectral Data by Gualtieri reviews a very promising supervised classification technique, the Support Vector Machine (SVM) which has recently found success in hypespectral image classification.

Chapter 14: Decision Boundary Feature Extraction for Hyperspectral Image Classification by Lee et al. presents a decision boundary-based feature extraction method for hyperspectral image classification.

Chapter 15: Greedy Modular Eigenspace Method for Hyperspectral Image Classification by Yang-Lang Chang develops a Greedy Modular Eigenspace (GME) approach to explore band-to-band correlation so as to achieve data dimensionality reduction for feature extraction in hyperspectral image classification.

Chapter 16: Integrated Information Mining and Image Retrieval in Remote Sensing by Jiang and Narayanan explores a new area in information retrieval and data mining for remote sensing image analysis where it take advantage of data mining techniques along with advanced database technologies to retrieve spatial and spectral information from remote sensing images.

It is my great hope that the chapters presented in this book can offer readers with a broad view of hyperspectral signal and image processing. In particular, this book can be found very useful for practitioners and engineers who work in this area and may be greatly benefited if this book is used in conjunction with my 2003 book which provides many basic techniques available and published in the literature.

Last but not least, I would like to thank all the contributors for their participation in this book to provide and share their experience with readers. This book cannot be completed without their contributions.

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