Liguo Wang · Chunhui Zhao

Hyperspectral Image Processing

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Hyperspectral Image Processing

Preface

With the rapid development of the modern science and technology, the hyperspectral remote sensing science, as a comprehensive high and new technology, has gained the extensive as well as considerable development in the theory, technology, and application. The hyperspectral remote sensing will acquire the land object information by utilizing the space image and spectral features, to achieve the unity of image and spectrum and provide the powerful technical support for the humans to learn the world and change the world. At present, the hyperspectral remote sensing has been widely applied to the fields such as military affairs, agriculture, forest, meadow, ocean, geology, and ecology. In recent years, the quantity of the remote sensing SCI periodicals and the impact factors have been increased internationally, and the international academic conference specially aiming at the hyperspectrum is gradually developed and continues to mature.

The development degree of the hyperspectral image processing technique directly determines the information acquisition and utilization degree. Our country attaches importance to the development of this technique. The supporting strength of the fields involving 863, 973, and Natural Science Foundation of China is bigger and bigger, and the human powers input by various national colleges and universities and the scientific research institutions are more and more, with more and more abundant achievements. However, this current situation still cannot meet the demands of the scholars on the breadth and depth of the technique. In combination with the research of the author engaging in the related technique for many years, this book carries out the systematic classification and elaborate interpretation for the main processing techniques of hyperspectral remote sensing, i.e., classification, endmember extraction, spectral unmixing, sub-pixel mapping, super-resolution reconstruction, anomaly detection, dimensionality reduction, and the newer research results, for the purpose of contributing the small gains for the readers to understand, learn, and research the hyperspectral image processing technique.

The whole book is composed of nine chapters. Chapters 2–6 are mainly written by the first author Liguo Wang, involving classification, endmember selection, spectral unmixing, sub-pixel mapping, super-resolution reconstruction, and other hyperspectral image processing techniques, which are the research results gained by

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this author for many years, in the hope that these contents can provide some references or enlightenments for the readers in the thought or method. Chapters 1 and 7–9 are mainly written by the second author Chunhui Zhao. Chapters 7 and 8 are the innovative achievements gained by this author in recent years. In order to facilitate the reader to have a comprehensive understandings on the principles, current situation and main processing technique of the hyperspectral image, this book especially add the contents of Chaps. 1 and 9. Chapter 1 firstly makes the simple introduction to the basic theory of the hyperspectral remote sensing and mainly refers to the related works of Qingxi Tong, Jiabing Sun, and other persons. Then, it makes the systematic introduction to various typical and mainstream processing techniques of hyperspectrum and mainly refers to a lot of domestic and overseas academic literatures. Chapter 9 makes brief introductions to the application of the hyperspectral remote sensing technique. These contents mainly refer to the published articles of the domestic scholars in this field. It is important to note that the main body of this book, namely Chaps. 2–8, regards the creative contents of the author as the textual basis, so the current situation and review of the relevant technique are mainly introduced in Chap. 1. On the other hand, the sequencing determination of various knowledge points takes consideration into their inclusion relations front and back, rather than designing in accordance with the sequence relations from the perspective of the image processing.

A part of job for the contents in Chaps. 2–4 is finished by the first author during studying as a PhD candidate in Harbin Institute of Technology under the guidance of Professor Ye Zhang; therefore, this author especially thanks to his own old school and tutor. At the same time, the contents of Chap. 4 are finished in cooperation with Doctor Xiuping Jia in University of New South Wales. Here, we express the sincere gratitude and respect for her industrious work and rigorous academic spirit. The contents of Chap. 5 are finished by the first author together with his graduate students. The contents of Chaps. 7 and 8 are finished by the second author together with his graduate students. Many graduate students of the authors participate in the research or classification work of some contents, mainly involving Danfeng Liu, Qunming Wang (gainer of outstanding master's thesis of Heilongjiang Province), Chunhong Liu, Feng Mei, Jia You, Lingyan Zhang, Jing Zhang (gainer of outstanding master's thesis of Heilongjiang Province), Yaxin Ji, Chunmei Hu, Luqun Deng (gainer of outstanding master's thesis of Harbin Engineering University), Yan Zhao, Lijuan Sun, Wensheng Zhang, Guofeng Wu, Fangjie Wei, Qian Xiao, Yao Shi, Zhengyan Wang, Jian Tan, Qiong Wang, Liang Zhao, Jinghui Yang, Siyuan Hao, Fanwang Meng, and Jie Sun. Here, we express the gratitude to them. Here, we express the sincere thanks to the authors of references by this book, and especially thank to all authors with the key references in this book. The first author includes Qingxi Tong, Ruiliang Pu, Jiabing Sun, Ersen Li, Chunhong Liu, Wu Ren, Feng Ling, Jianwei Wan, Anguo Teng, Bingxiang Tan, Lei Zhou, Quansheng Lou, Chengkai Pei, Yanjie Yang, Chaoyang Zhang, and numerous experts and scholars in the related fields internationally. Their outstanding achievements provide the favorable materials for the compilation of the summary and introduction of this book. For the above-referenced literatures, due to

huge numbers and limited space, this book does not make the further comments. Here, we express the apology to the relevant authors.

On account of the limited ability of the author, the large time span of the research contents, big differences of the programming software and hardware conditions, many involved researchers and other practical problems, the main technical contents of Chaps. 2–8 inevitably have the problems in various levels. The contents of Chaps. 1 and 9 are difficult to make the most reasonable and scientific arrangement for the mainstream technique and typical application, and the comments made can only stand for the statements of a school. We sincerely hope that the readers criticize, correct, and grant instructions. We will further perfect in the subsequent work.

January 2015

Liguo Wang
Chunhui Zhao

Symbols and Abbreviations

Symbols

ND	The number of features/dimensionalities
Nd	The number of reduced features/dimensionalities
Np, Ntr and Nte	The number of pixels, trainning pixels, and testing pixels
p and P	Pixel and the matrix formed by pixels
Nc and Ne	The number of classes and endmembers
e, E	Endmember and the matrix formed by endmembers
v, V	Endmember difference vector, and the matrix formed by endmember difference vectors
x or s_0	Sample
F	Fractional abundance
Vol	Volume
Dist	Distance

Abbreviations

ASVDD	Adaptive kernel parameter estimation-based support vector data description
FCLS	Fully constrained least squares
HSI	Hyperspectral imagery
LS	Least squares
LSMA	Linear spectral mixing analysis
LSMM	Linear spectral mixing modeling
LSSVM	Least squares support vector machine
LSVM	Linear support vector machine
MAP	Maximum a posterior probability
MPS	Modified pixel swapping algorithm
MRF	Markov random field

MSAM	Mixed spatial attraction model
MSPSAM	Sub-pixel/pixel spatial attraction model
POCS	Projection onto convex sets
PSA	Pixel swapping algorithm
SPSAM	Modified sub-pixel/pixel spatial attraction model
SSRSI	Sub-pixel shifted remote sensing images
SVDD	Support vector data description
SVM	Support vector machine

Abstract

The whole book is composed of nine chapters. To cater to different readers with different requirements, in the first and last chapters, basic theory on hyperspectral remote sensing, development trend of some important techniques for hyperspectral remote sensing, and application of hyperspectral remote sensing are briefly introduced. Chapters 2–8 mainly consists of the authors' research achievements on hyperspectral imagery in recent years, including classification, endmember extraction, spectral unmixing, sub-pixel mapping, super-resolution reconstruction, anomaly detection, and dimensionality reduction. All these techniques are introduced in detail to offer readers complete framework of the mentioned novel knowledge on hyperspectral imagery.

This book can be used for undergraduates and graduates in different domains, including remote sensing, surveying and mapping and geoscience and information system. It can also provide some reference information for researchers at different levels.

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Chapter 1
Basic Theory and Main Processing Techniques of Hyperspectral Remote Sensing

In order to enable the readers to have a better understanding of the main body contents of this book, this chapter firstly introduces the basic theory of the hyperspectral remote-sensing technique, involving the electromagnetic wave, solar radiation, imaging spectrometer and spectral imaging modes etc. Then, it introduces the development status of the main technique, involving classification, endmember extraction, spectral unmixing, sub-pixel mapping, super-resolution processing, anomaly detection, dimensionality reduction and compression, etc.

1.1 Basic Theory of Hyperspectral Remote Sensing

Basic theory of hyperspectral remote sensing mainly includes the theoretical basis of electromagnetic wave, interaction of solar radiation and materials, imaging spectrometer and spectral imaging modes, and imaging characteristics of HIS etc. (Tong et al. 2006).

1.1.1 Theory of Remote Electromagnetic Wave

Remote sensing means a technique of the long-range detection and perception for the target or the natural phenomenon without the direct contact (Sun 2003). Remote sensing can judge the land object target and the natural phenomenon in accordance with the collected electromagnetic wave, because all objects possess entirely different electromagnetic wave reflection or emitted radiation features due to different categories, features, and environmental conditions. The remote-sensing technique is mainly established on the principle of the object reflection or electromagnetic wave emission.

The varying electric field can cause the varying magnetic field all round, and the varying magnetic field causes the new varying electric field in further region, and causes the new varying magnetic field in the farther region. The varying electric field and magnetic field are alternated, and the process of transmission in the space

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