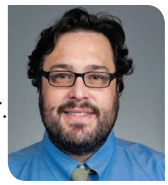
BY MARIO PARENTE, JOHN KEREKES, AND ROB HEYLEN



A Special Issue on Hyperspectral Imaging

Hyperspectral imaging (HSI) for geoscience remote sensing and Earth observation has been around since the mid-1980s. For many years, it was the purview of research laboratories and proof-of-concept satellite missions. Hundreds of research articles have been published exploring algorithms for analysis and demonstrating applications across many Earth observational fields of interest. Most have focused on a relatively small group of publicly available data sets due to the high cost of sensor operation and collection of ground reference data necessary for algorithm and product evaluation.

More recently, as the cost of focal planes and sensor technology has decreased, together with the emergence of inexpensive unmanned aerial vehicle (UAV) systems and CubeSats/smallSats in space access, the availability of hyperspectral imagery is poised to grow dramatically. Several airborne and spaceborne systems have been deployed or are being planned. Commercial remote sensing and image processing software systems provide more support and extended functionality for such data, while the practical use of hyperspectral data in both commercial and scientific applications has increased. The community now has access to relatively low-cost UAV systems and data and will soon see more routine availability of space-based HSI data.

THE EIGHT ARTICLES INCLUDED HERE REPRESENT A BROAD INTRODUCTION TO HSI FROM AN IMPRESSIVE SET OF LEADERS.

This special issue of *IEEE Geoscience and Remote Sensing Magazine* on HSI was put together based on the recognition that the field is on the cusp of expanded data availability. While formerly the domain of a relatively small group of specialists, it is anticipated HSI data will soon become available to a wider range of scientists and data users. This special issue was compiled to bring together a comprehensive look at the characteristics, phenomenology, algorithms, and applications as a resource for practitioners and students who wish to gain familiarity with the field. We have instructed authors to keep the language and the style of these tutorial amenable to a cross-disciplinary readership, as our main goal is to foster collaborations among the scientific, technological, and data-science communities within the remote sensing population.

The eight articles included here represent a broad introduction to HSI from an impressive set of leaders. The articles were selected through a two-step submission/review process.

We open the special issue with three articles focusing on foundational aspects of HSI that are not often understood by budding researchers. The first, "Spectral Variability of Remotely Sensed Target Materials," surveys the main causes of variability of spectral signatures: intrinsic (depending on the chemistry of a material), extrinsic (depending on the size of an object or concentration of a material), or environmental (due to illumination, atmospheric contribution, etc.) and describe some signal processing strategies to address this variability. The second article, "Atmospheric Compensation of Hyperspectral Data," provides a pedagogic illustration of hyperspectral atmospheric compensation. This tutorial leads the reader carefully through the modeling aspects of the atmospheric contribution to the optical radiation acquired by sensors and the necessary steps for analysis and mitigation to retrieve surface signals. The main objective of the third article, "Spectral Absorption Feature Analysis for Finding Ore," is to illustrate theoretical issues and methodologies related to mineral identification in geological remote sensing. In particular, the authors explain the variations in shape and wavelength position of spectral absorption features, which are diagnostic of

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changes in the chemistry of the minerals and rocks under investigation.

The next two articles consider aspects of HSI applications that have seen relatively little coverage in recent surveys. "Longwave Infrared Hyperspectral Imaging" explains the unique aspects of thermal infrared HSI. The phenomenology of spectral emission and the differences with respect to the reflective region of the spectrum are clearly demonstrated, from sensor design to data exploitation. "Hyperspectral Imaging for Military and Security Applications," reviews military and defense-driven applications of HSI. Its novelty lies in its comprehensive analysis and demonstration of currently available sensing technologies and advanced processing methodologies, such as subpixel target and anomaly detection, in the absence of prior information about the materials and the adversarial environment.

The final three articles focus on advanced processing techniques. Again, we investigate specific aspects that have not received attention in recent literature. "Hyperspectral Band Selection" reviews current hyperspectral band-selection methods and provides a precise taxonomy of the field. The authors also discuss the challenges and research directions of hyperspectral band selection. The contribution provides a tutorial on the advantages and drawbacks of different techniques and the tradeoffs involved when removing spectral redundancy and reducing computational costs while preserving significant spectral information of ground objects. The seventh article, "A Review of Change Detection in Multitemporal Hyperspectral Images," provides a comprehensive overview on change detection in hyperspectral images and surveys the main change detection techniques available for multitemporal hyperspectral images. The authors review both widely used methods and new techniques proposed in the recent literature, discussing and analyzing in detail the basic concepts, categories, open issues, and challenges. The final article, "Deep Learning for Classification of Hyperspectral Data," reviews various deep-learning approaches currently proposed for hyperspectral classification and identifies the problems and difficulties that arise when implementing deep neural networks for this task. In particular, the authors address issues of spatial and spectral resolution, data volume, and transfer of models from multimedia images to hyperspectral data. In addition, the authors have publicly released a software toolbox to allow practitioners to reproduce their comparative experiments.

These eight articles provide a sampling of the issues emerging in HSI. Compiling this collection highlighted in our minds the necessity for the remote sensing community to double its efforts toward facilitating integration among the scientific, technological, and data-analytic aspects of HSI. There is a great need for more initiatives not only to collect but also to calibrate and validate data from hyperspectral sensors. More interactions among application scientists, sensor experts, and data-processing practitioners would foster significantly enhanced mission returns from Earth and planetary, institutional, and commercial HSI projects.

WHILE FORMERLY THE DOMAIN OF A RELATIVELY SMALL GROUP OF SPECIALISTS, IT IS ANTICIPATED HSI DATA WILL SOON BECOME AVAILABLE TO A WIDER RANGE OF SCIENTISTS AND DATA USERS.

AUTHOR INFORMATION

Mario Parente (mparente@ecs.umass.edu) received his B.S. and M.S. (summa cum laude) degrees in telecommunication engineering from the University of Federico II, Naples, Italy, in 2003 and M.S. and Ph.D. degrees in electrical engineering from Stanford University, California, in 2005 and 2010, respectively. He is currently an associate professor in the Department of Electrical and Computer Engineering at the University of Massachusetts Amherst, where he is also founder and director of the Remote Hyperspectral Observers group. His research involves combining physical models and statistical techniques to address issues in remote sensing of Earth and planetary surfaces. He is a Senior Member of the IEEE.

John Kerekes (kerekes@cis.rit.edu) received his B.S., M.S., and Ph.D. degrees from Purdue University, West Lafayette, Indiana, in 1983, 1986, and 1989, respectively, all in electrical engineering. Since 2004, he has been with the Chester F. Carlson Center for Imaging Science, Rochester Institute of Technology (RIT), New York, first as associate professor and currently as professor. He also serves as Director of the Digital Imaging and Remote Sensing Laboratory at RIT. His research interests include the modeling and analysis of remote sensing system performance in pattern recognition and geophysical parameter retrieval applications. He is a Senior Member of the IEEE.

Rob Heylen (rob.heylen@uzleuven.be) received his M.S. degree in physics in 2003 from the Katholieke Universiteit Leuven, Belgium, and his Ph.D. degree in physics in 2008 from the Institute for Theoretical Physics, Katholieke Universiteit Leuven, with research on the statistical mechanics of spin systems and neural networks on random graphs. In 2009, he joined the Vision Laboratory, Department of Physics, University of Antwerp, Belgium, as a postdoctoral researcher, where he focused on hyperspectral image processing, specifically on the different steps involved in the hyperspectral unmixing processing chain. He is currently a postdoctoral researcher with the Medical Imaging Research Center, Department of Nuclear Medicine, Katholieke Universiteit Leuven.

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