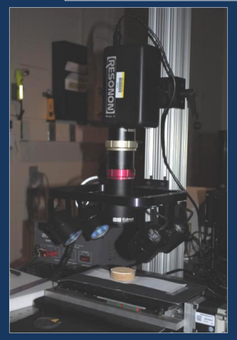
Title: Hyperspectral microscopy in support of robust spectral signature development

David W. Allen
100 Bureau Drive
Gaithersburg, MD 20899
dwallen@nist.gov

Abstract: Hyperspectral imagery (HSI) microscopy provides a means for grain-scale measurements of geological materials such as soils and of individual crystals in thin-sections (or slabs) of rocks. The additional information measurements at this scale provides can play a key role in explaining spectral signature variability; it also generates more detailed metadata and sample descriptions to help explain differences between ground truth spectra and spectra from remotely sensed imagery. HSI microscopy complements 'traditional' spectral signature measurements made with laboratory (and field-portable) point spectrometers. Additionally, the hyperspectral imagery collected at close range can be used as a rich source of scene data ('microscenes') for testing algorithms. NIST has developed a laboratory dedicated to measuring the optical properties of materials through the use of commercial and custom hyperspectral imagers. A description of the instruments, measurement methods, and example applications will be provided.

COTS Hyperspectral Microscopy

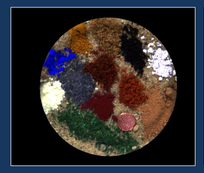


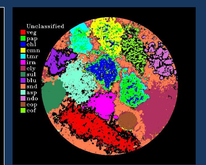
Commercial hyperspectral imagers used in combination with magnification can provide hyperspectral imagery with spatial resolution (GSD) on the order of 0.7 µm to mm scales.

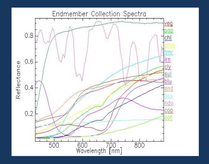
Most common imagers cover the 400 nm to 1000 nm spectral range; imagers going out to 1700 nm are becoming more prevalent.

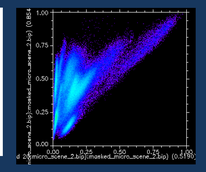
Sand grains on the order of 100 µm. Each grain may provide 100s of spectra.

Microscene Composition



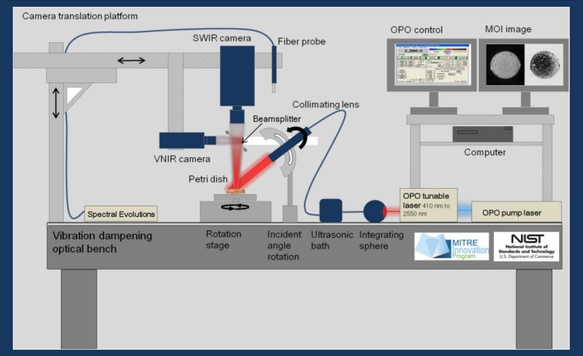


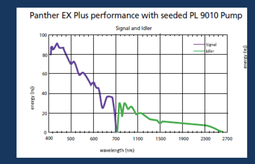




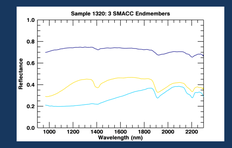
The microscene allows for the rapid production of hyperspectral data sets that may be used in test and evaluation of hyperspectral imaging systems and applications . Ref 1

Tunable Laser Baser Hyperspectral Microscopy



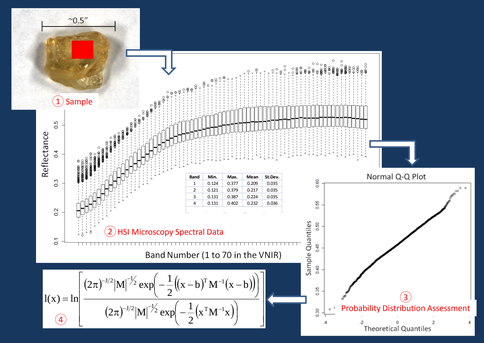


Broad spectral coverage: 405 nm to 2500 nm
High spectral resolution: typ. < 2 nm
1 cm sample area ~ 7 µm resolution
Aprox. 80,000 spectra in SWIR
Direct NIST traceability



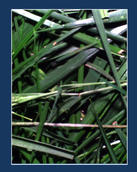
Courtesy: Jason G. Zeibel, US NVL

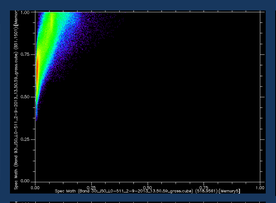
Statistical Distribution of Spectra

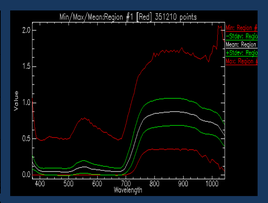


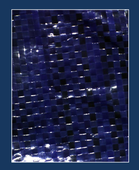
A large number of spectra of a material allows for the evaluation of the parameters of the probability distribution (PD) that describes the data (i.e., density estimation); estimates of the multivariate PD are then compared to a multivariate normal PD. The PDs are used to build algorithms. Ref 2

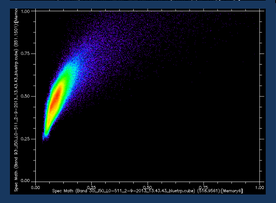
Spectral variability from ~350,000 Spectra

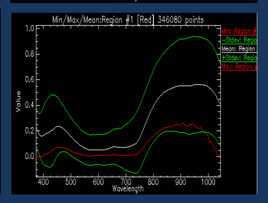


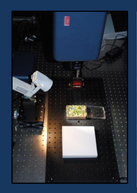


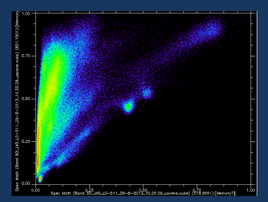








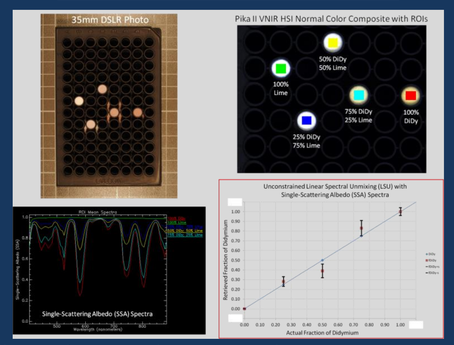




Spectral variability may be attributed to:

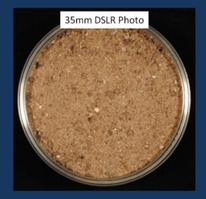
- Inhomogeneity of the sample
- Illumination/observation geometry
- Surface and volume scattering
- Adjacency effects

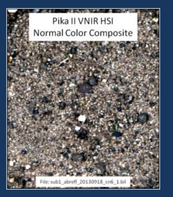
Non-Linear Spectral Mixing

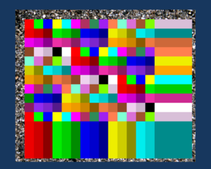


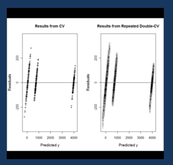
Mixtures of pure materials can be examined and used to study non-linear mixing. The resulting data set can then be used to develop predictive models. Ref 3

HSI Signature Determination of Soil Contaminants









Spectral determination of soil contaminate concentration (e.g. Pb/ soil mixtures):

Microscene provides a large training data set for evaluating latent variable data analysis methods (e.g. partial least squares regression)

References:
1) David W. Allen ; Ronald G. Resmini ; Christopher J. Deloye ; Jeffrey R. Stevens; A microscene approach to the evaluation of hyperspectral system level performance . Proc. SPIE 8743, Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XIX, 87431M (May 18, 2013)

2) Ronald G. Resmini ; Christopher J. Deloye ; David W. Allen; An analysis of the probability distribution of spectral angle and Euclidean distance in hyperspectral remote sensing using microspectroscopy. Proc. SPIE 8743, Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XIX, 87431I (May 18, 2013)

3) Ronald G. Resmini; Robert S. Rand; David W. Allen; Christopher J. Deloye; An analysis of the nonlinear spectral mixing of didymium and soda-lime glass beads using hyperspectral imagery (HSI) microscopy. Proc. SPIE, Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XX, (May 2014)

Acknowledgements: In collaboration with Ronald Resmini, MITRE Corp. and Terry Slonecker, USGS

NIST National Institute of Standards and Technology U.S. Department of Commerce

Physical Measurement Laboratory