Hyperspectral microscopy for enhanced characterization of ground-truth spectral signatures

Abstract: Hyperspectral imagery (HSI) microscopy allows for vegetation and geologic material to be examined at the sub-centimeter spatial scale. NIST has developed a laboratory dedicated to measuring the optical properties of materials through the use of commercial and custom hyperspectral imagers. The custom built hyperspectral imaging microscope covers the 400 nm to 2500 nm spectral range. This system provides a means to collect >10,000s of spectra from both pure substances and mixtures. The large abundance of spectra allows for a more detailed understanding of the distribution and variability of spectra. This additional information may aid in understanding the variability observed in ground truth spectra collected from portable spectrometers. Additionally, the databases collected can serve as proxies for airborne and spaceborne collected datasets for test and evaluation purposes.

STARR Facility

STARR is the national reference facility for scales of refection

The scales of refection can be transferred through PTFE refection plaques with uncertainties of 0.2 % \pm 2

Direct traceability to national scales minimizes measurement uncertainty

Tunable Laser Basen Hyperspectral Microscopy

Broad spectral coverage: 405 nm to 2500 nm

High spectral resolution: typ. < 0.3 nm

1 cm sample area ~ 7 \mu m resolution

Apox. 80,000 spectra in SWIR

COTS Hyperspectral Microscopy

Several hyperspectral imagers provide spectral coverage from 1 \mu m to up to cm spatial scales in order to bridge the gap between the microscopic realm and common remote sensing GSDs

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 1

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 2

Case Study: Spectral signatures of NIST Gaithersburg Campus

ARCHER Airborne Real-Time Cued Hyperspectral Enhanced Reconnaissance. RGB composite (right) from HSI database. VNIR, 1 m GSD, atmospherically corrected

Examination of granite slab in SWIR (900 nm to 2500 nm)

Granite slab, 4 cm by 5 cm, images (above left) show spatial heterogeneity based on composition. The slab was measured using the OPO-based hyperspectral microscope over the 900 nm to 2500 nm spectral range at every 5 nm. The illumination/observation geometry was 45\(^\circ\)/0\(^\circ\). The spatial resolution was approximately 200 \mu m per pixel. RGB color composites from principal component analysis (PCA) and minimum noise fraction (MNF) are shown. Spectra from discrete regions were matched to the USGS spectral library (above right)

Microscope Composition

The microscope allows for the rapid production of hyperspectral data sets that may be used in test and evaluation of hyperspectral imaging systems and applications. Ref 3

References:

1) Ronald G. Reven 

2) Ronald G. Reven; Robert S. Rand; David W. Allen; Christopher J. Deloye; Jeffrey R. Stevens; A hyperspectral approach to the evaluation of hyperspectral system performance. Proc. SPIE 8747, Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XX, (May 2014)

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