

MAPPING THE DISTRIBUTION OF MATERIALS IN HYPERSPECTRAL DATA USING THE USGS MATERIAL IDENTIFICATION AND CHARACTERIZATION ALGORITHM (MICA)

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1. INTRODUCTION

Identifying materials by measuring and analyzing their reflectance spectra has been an important method in analytical chemistry for decades. Airborne and space-based imaging spectrometers allow scientists to detect materials and map their distributions across the landscape. With new satellite-borne hyperspectral sensors planned for the future, for example, HYSPIRI (HYPERspectral InfraRed Imager), robust methods are needed to fully exploit the information content of hyperspectral remote sensing data. A method of identifying and mapping materials using spectral-feature based analysis of reflectance data in an expert-system framework called MICA (Material Identification and Characterization Algorithm) is described in this paper. The core concepts and calculations of MICA are presented. A MICA command file has been developed and applied to map minerals in the full-country coverage of the 2007 Afghanistan HyMap hyperspectral data.

2. BACKGROUND AND KEY CONCEPTS OF MICA

MICA draws on the legacies of a variety of U.S Geological Survey (USGS) software that has been created to advance spectroscopy and spectroscopic remote sensing, including SPECPR [1] and Tetracorder [2]. MICA is written in IDL (Interactive Data Language) to run within ENVI (Environment for Visualizing Images). Maps created by MICA are easily integrated with the image processing and GIS (Geographic Information Systems) capabilities of ENVI. The MICA is one of four modules of PRISM (Processing Routines in IDL for Spectroscopic Measurements) which include: 1) ViewSPECPR; 2) spectral analysis routines; 3) image processing routines; and 4) MICA. MICA analyzes spectra by comparison to a spectral library and selects the best match to the entries in that library. The MICA process is illustrated in Figure 1 with a listing of the key inputs, analysis components, and outputs. The MICA command file contains the list of reference spectra and the analysis parameters used in conducting spectral comparisons.

The shape of a reflectance spectrum derives, in large part, from the material's chemical composition and physical structure [2]. Differences

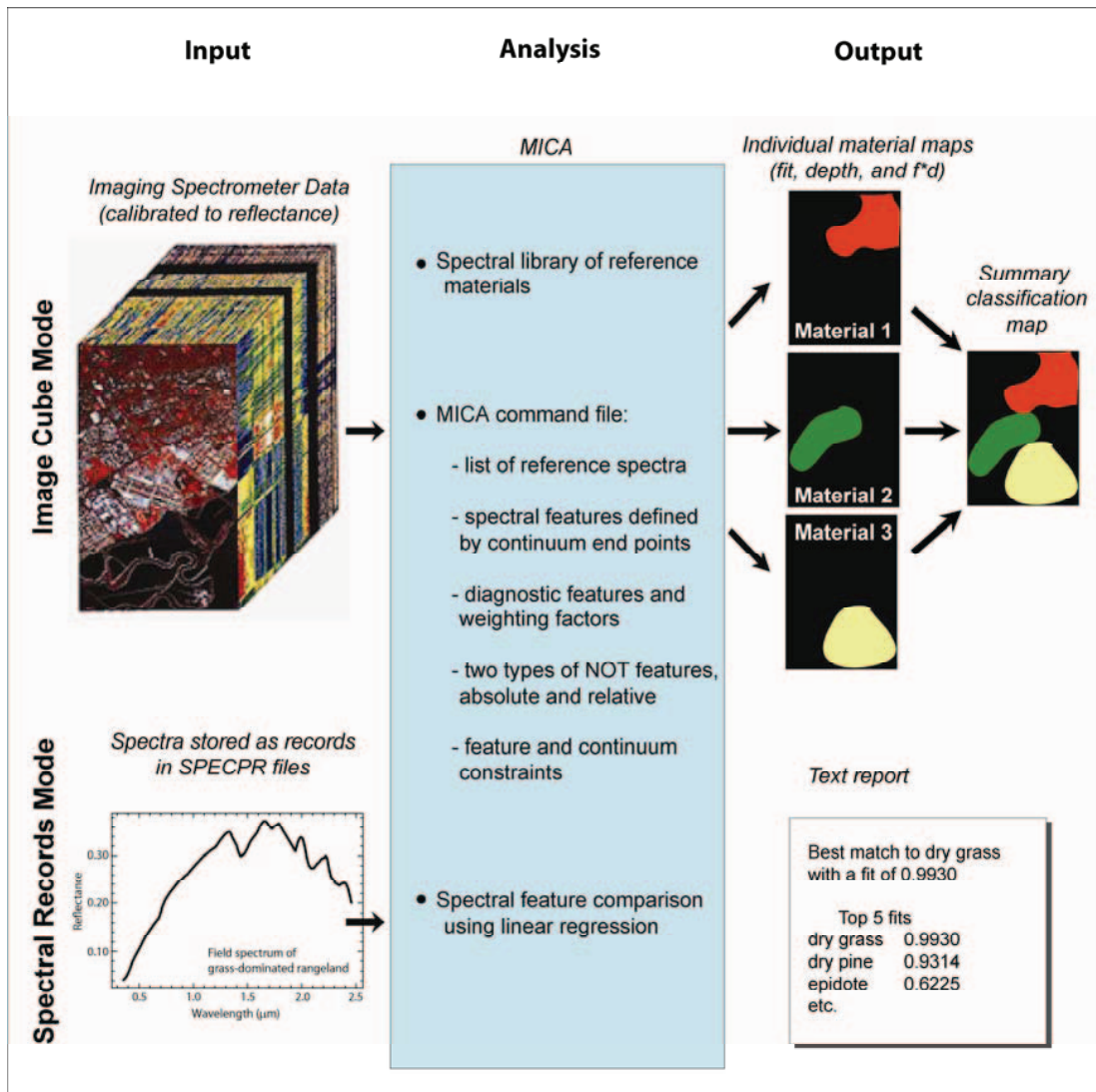


Fig. 1. Program flow and key algorithms of MICA module of PRISM.

in these properties lead to differences in spectral shapes for minerals [2] and vegetation [3]. The central function of the MICA algorithm is spectral feature comparison applied to continuum removed absorption features. The continuum removed values of the spectrum being analyzed are compared to the values of the continuum removed reflectance feature in reference spectra of known composition by linear regression, where the wavelength region for the

comparison is based on a diagnostic feature in the reference spectrum. Diagnostic features are strong and/or unique features arising from chemical bonds inherent in the reference material. The continuum removed values of the unknown and the reference are analyzed in linear regression. MICA uses the resultant coefficient of determination (r^2) as the “fit” value, that is, a measure of the agreement between the spectra. In contrast, Tetracorder uses the linear

correlation coefficient (r) as the fit value [2]. The r^2 fit value ranges from 0 to 1, with better matches indicated by high fit numbers. To illustrate the spectral feature comparison of a single feature, a field spectrum measured in a rangeland ecosystem

covered principally by dry grass (see fig. 2) is used as the spectrum of unknown composition and lab measurement of dry grass and dry pine as the reference spectra. The results show a higher fit to dry grass.

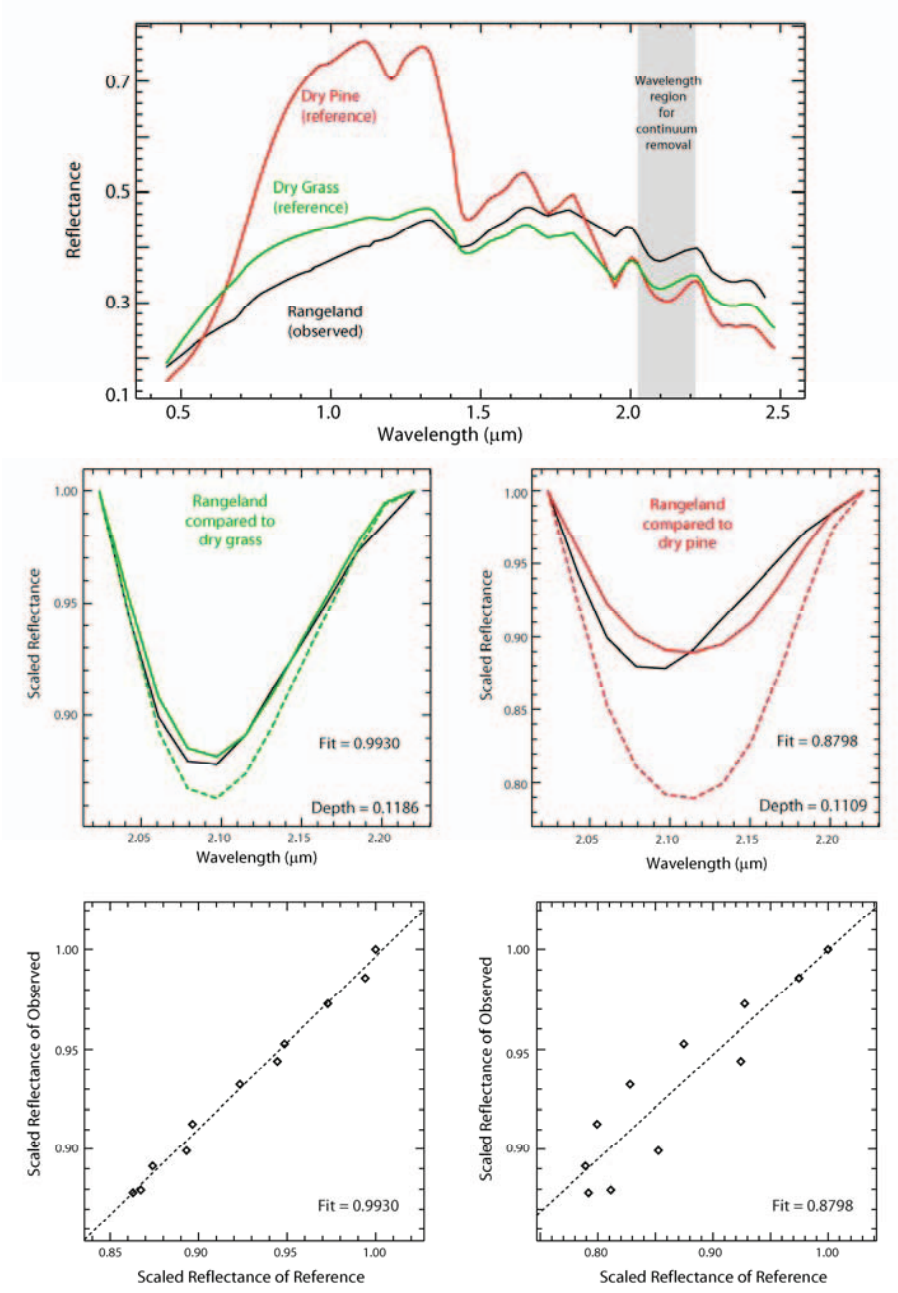


Fig. 2. Spectral comparison of a rangeland spectrum to spectral features of two reference materials.

MICA extends the spectral feature comparison concept to multiple features, allowing the user to define as many spectral features as desired for each reference spectrum listed in the command file and letting the user set the weighting factor for each feature. A single fit value, the “weighted fit”, is calculated by summing the products of the individual feature fits and their corresponding weighting factors. MICA arrives at an identification of the best match between the spectrum of an unknown material and the reference spectra in a MICA command file by selecting the material with the highest weighted fit value. Rather than relying solely on the fit values, MICA employs the concepts of feature and continuum constraints for each material in the command file in order to reduce false-positive identifications. In the command file, the user can define optional threshold values for each reference material for the minimum acceptable weighted fit value, allowable range of feature depth, fit*depth, reflectance levels at the midpoint and endpoints of the continuum line, and the ratio of the reflectance levels at the continuum endpoints. In order for its weighted fit value to be considered as the best match to the reference material, these values calculated from the spectrum being analyzed must meet any user-specified thresholds. To improve material identification, MICA employs the concept of NOT features. If any thresholds are violated or one or more of its listed NOT features are found, the weighted fit value for the material is zeroed out; that is, the material is removed from consideration as a match to the spectrum being analyzed. If all weighted fits to the reference spectra are zero, the

MICA result indicates no match was made to the analyzed spectrum. MICA is used to analyze hyperspectral data, where the MICA analysis is performed on the spectrum in each pixel.

The MICA command file is a user created/edited document listing the reference spectra and the spectral features to use in the analysis of spectra of unknown materials. A command file, containing reference spectra of 59 materials, was used to detect carbonates, phyllosilicates, sulfates, alteration-related minerals, and other materials absorbing in the 2 to 2.5 μm region, in the full-country coverage of HyMap data collected in 2007 over Afghanistan. Mineral maps for Afghanistan have been derived from the MICA results. This command file will be released to the general public by the USGS, along with the PRISM/MICA software.

3. REFERENCES

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