Comparison of Three Methods for Materials Identification and Mapping with Imaging Spectroscopy

Roger N. Clark[1], Gregg Swayze[1, 3], Joe Boardman[2], and Fred Kruse[2, 3]

[1]U.S. Geological Survey
MS 964 Box 25046 Federal Ctn., Denver, CO 80225

[2]Center for the Study of Earth from Space (CSES)
Cooperative Institute for Research in Environmental Sciences (CIRES)
University of Colorado, Boulder, CO 80309-0449

[3]Department of Geological Sciences, University of Colorado, Boulder 80309

We are comparing three methods of mapping analysis tools for imaging spectroscopy data. The purpose of this comparison is to understand the advantages and disadvantages of each algorithm so others would be better able to choose the best algorithm or combinations of algorithms for a particular problem. The 3 algorithms are:

1) The spectral feature modified least squares mapping algorithm of Clark et al (1990, 1991): programs mbandmap and tricorder.

2) The Spectral Angle Mapper Algorithm (Boardman, 1993) found in the CU CSES SIPS package,

3) The Expert System of Kruse et al. (1993 and references therein).

The comparison uses a ground-calibrated 1990 AVIRIS scene of 400 by 410 pixels over Cuprite, Nevada. Along with the test data set is a spectral library of 38 minerals. Each algorithm is tested with the same AVIRIS data set and spectral library. The minerals tested are shown in Table 1. Field work has confirmed the presence of many of these minerals in the AVIRIS scene (Swayze et al. 1992).

The spectral feature modified least squares mapping algorithm removes a continuum from spectral features in reference library spectra as well as from each spectrum in an imaging spectrometer data set. The continuum-removed spectra are compared to the continuum-removed reference spectra and a modified least squares fit is performed. The correlation coefficients from the fits are compared and the best fitting material for that spectral feature (or group of features is selected). The algorithm has an advantage in that the complete shape of a particular absorption band is tested. This tends to reduce the noise sensitivity. It is also insensitive to topographic effects or to errors in the derived reflectance level. The algorithm can also be used as a general shape algorithm (for example, an entire spectrum could be tested

for shape, as well as specific absorption bands). Multiple spectral features in a material are weighted in the proportions of the feature area (under its continuum) in the library reference spectrum.

The Spectral Angle Mapper (SAM) algorithm was designed to measure the spectral similarity between unknown and reference spectra. It is designed to be easy to use and sensitive to unknown illumination differences introduced by topographic effects. It assumes the data have been reduced to apparent reflectance, so the data origin corresponds with a "pure black" spectrum. SAM calculates the angle between the observed and reference spectra, treating them as vectors in *n*-dimensional space, where *n* is the number of bands used. This angle value is the arc-cosine of the dot product of the two spectra, after they have been normalized to unit length. Small angles indicate high similarity. By doing this on a pixel-by-pixel basis, with a series of reference spectra, maps of spectral similarity, nearly uneffected by topographic effects, are produced.

The Expert System algorithm has an advantage in that relationships between the features of a particular material can be included in the identification process. This can include a more sophisticated knowledge of spectral features than in the above systems. First a generalized algorithm for extraction of absorption features from digital spectral libraries automatically produces "fact tables" characterizing the individual absorption features. An "expert" (knowledgeable user) then interactively analyzes these library results to determine key absorption features for mineral identification. These key features are in turn used in simple rules to examine each picture element (pixel) in an imaging spectrometer data set. An information data cube is produced that contains measurements of the certainty of occurrence of specific materials in the library at each pixel. An image map is also produced showing the best mineral match for each pixel. The major drawback of this system is that it is particularly sensitive to low signal-to-noise data. It is primarily designed as a "first" cut analysis tool to help assign names to image spectra and map their general spatial distribution.

Results of the comparison will be presented at the workshop.

Table 1
Minerals used in Comparison

Ammonium Smectite	Halloysite
Alunite (K)	Hematite 2wt% + quartz
Natroalunite 65mol% Na	Illite
Natroalunite 80mol% Na	NH4 Illite/Smectite
Ammonioalunite	Jarosite
Ammoniojarosite	Kaolinite (wxl)
Analcime	Kaolinite (pxyl)
Buddingtonite	Lepidochrosite
Calcite	Mesolite
Carphosiderite (Na-Jarosite)	Montmorillonite (Ca)
Chlorite (Fe)	Montmorillonite (Na)
Chlorite (Mg)	Muscovite
Diaspore	Natrolite
Dickite	Nontronite
Dolomite	Paragonite
Epidote	Pyrophyllite
Ferrihydrite	Scolecite
Goethite	Silic Rhyolite Tuff
Gypsum	Zoisite

References

Boardman, J.: Spectral Angle Mapper: A tool for measuring Spectral Similarity. In preparation.

Clark, R.N., A.J. Gallagher, and G.A. Swayze: Material Absorption Band Depth Mapping of Imaging Spectrometer Data Using a Complete Band Shape Least-Squares Fit with Library Reference Spectra, .I Proceedings of the Second Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) Workshop. JPL Publication 90-54, 176-186, 1990.

Clark, R.N., G.A. Swayze, A. Gallagher, N. Gorelick, and F. Kruse: Mapping with Imaging Spectrometer Data Using the Complete Band Shape Least-Squares Algorithm Simultaneously Fit to Multiple Spectral Features from Multiple Materials, *Proceedings of the Third Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) Workshop*, JPL Publication 91-28, 2-3, 1991.

Kruse, F.A., Lefkoff, A.B., and Dietz, J. B., 1993: Expert System-Based Mineral Mapping in Northern Death Valley, California/Nevada using the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS): *Remote Sensing of Environment* Special issue on AVIRIS, May-June, 309-336.

Swayze, G.A. R.N. Clark, S. Sutley, and A Gallagher, Ground-Truthing AVIRIS Mineral Mapping at Cuprite, Nevada, *Summaries of the Third Annual JPL Airborne Geosciences Workshop, Volume 1: AVIRIS Workshop*. JPL Publication 92-14, 47-49, 1992.