N95- 33742

Mapping Minerals, Amorphous Materials, Environmental Materials, Vegetation, Water, Ice and Snow, and Other Materials: The USGS Tricorder Algorithm

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Introduction

One of the challenges of Imaging Spectroscopy is the identification, mapping and abundance determination of materials, whether mineral, vegetable, or liquid, given enough spectral range, spectral resolution, signal to noise, and spatial resolution. Many materials show diagnostic absorption features in the visual and near infrared region (0.4 to 2.5 μm) of the spectrum. This region is covered by modern imaging spectrometers such as AVIRIS. The challenge is to identify the materials from absorption bands in their spectra, and determine what specific analyses must be done to derive particular parameters of interest, ranging from simply identifying its presence to deriving its abundance, or determining specific chemistry of the material.

Recently, a new analysis algorithm was developed that uses a digital spectral library of known materials and a fast, modified-least-squares method of determining if a single spectral feature for a given material is present (Clark *et al.*, 1990). Clark *et al.* (1991) made a another advance in the mapping algorithm: simultaneously mapping multiple minerals using multiple spectral features. This was done by a modified-least-squares fit of spectral features, from data in a digital spectral library, to corresponding spectral features in the image data. This version has now been superseded by a more comprehensive spectral analysis system called Tricorder.

Tricorder: New Features

The mapping of materials now includes a) pre-processing, b) specific algorithm selection, c) case-specific analyses, d) "not" features, e) spectral thresholding operations, and f) band constraints:

Preprocessing steps within Tricorder can include conversion of radiance data to reflectance data on the fly, ratioing to ground calibration target spectra or other reference spectra, and uncompressing data. The ability to correct the imaging data within Tricorder saves both time and disk space while eliminating the need for time-consuming manual file management.

The Tricorder concept is a simulation of the scientist's spectroscopic analysis method: it does the same operations you would do to analyze a spectrum. After preprocessing, Tricorder offers a selection of the algorithms that allow analysis of special cases. For instance, the first step in your analysis would be to decide which spectral features are present. Say, for example, that you determine there are both chlorophyll absorptions and clay mineral absorptions in a spectrum. Your next step might be to determine the relative areal coverage of the plants, and then to determine the water content of the plant leaves, remove this component and calculate the lignin/nitrogen ratio. You could also analyze the chlorophyll absorption for stress-induced red edge shift, and determine the plant species. Once the plant component is removed you could use the resulting unmixed soil spectrum to search for additional minerals that might have been concealed by the vegetation's spectral features.

Tricorder has the capability to analyze spectra stepwise, making specific decisions on what to do first, then based on the result, what to do next. This is achieved with a case sequence. For instance, if material "A" is found, do case 3, and when case 3 is complete, use the resulting answer to derive parameter "B," etc.

The new "not" feature is used for distinguishing between materials that have identical dominant spectral features but diagnostic subordinate features. The spectra of montmorillonite and muscovite are good examples. Both have nearly identical absorption features near 2.2 μm. However, muscovite has additional, weaker absorptions at longer wavelengths (near 2.3 μm). To be certain that montmorillonite is identified correctly, the 2.3-μm muscovite bands must not be present. The "not" features allows tricorder to distinguish between materials like montmorillonite and muscovite.

Other new concepts include fit, band depth, and continuum thresholding. For example, fit thresholding evaluates the value of the correlation coefficient from the least squares analysis. If the fit is too low to reasonably identify any of a given set of materials, the pixel can be rejected from further analysis. Band depth thresholding works in a similar fashion. Continuum thresholding prevents material identifications in pixels with very low continuum levels where noise could resemble weak absorptions. In addition, by knowing the continuum value, you can often determine if the spectrum represents an area in a shaded region, over water, or in a region covered by a cloud.

Some materials have less-intense subordinate absorptions in addition to strong diagnostic absorptions. While the diagnostic absorptions may be detectable if abundance is high enough, the subordinate absorptions might be concealed by absorptions from other materials or might be too weak to be detected. Tricorder now uses diagnostic and optional absorption band assignments for each material which allow for the concealment or absence of these weaker absorptions during the fitting process. This band constraint feature has proven especially useful for mapping pixels containing mixed materials.

Use and Availability

We have developed Tricorder command files that are now analyzing for over 120 materials (including minerals, amorphous materials like weathering products, environmental materials like mine waste, vegetation, ice and snow, mineral mixtures, etc.). As the Tricorder code is refined, and as the number of spectra in our libraries increase, we will map for hundreds to thousands of materials at a time. Tricorder can now analyze individual laboratory spectra, field spectrometer data, as well as imaging spectrometer data like that from AVIRIS or other imaging spectrometers.

Because of the complexity involved in spectroscopic analysis, and therefore the necessary sophistication of Tricorder, having expert knowledge of spectroscopy is important to successfully use this algorithm. In addition, users must be knowledgeable with the Specpr software package (Clark, 1993). The user's guide for Tricorder is currently being written, and as soon as it is complete, the user's guide and the Tricorder code will be released. We anticipate that this release will occur in the first half of 1995, pending funding to complete the project. The capabilities of Tricorder, and examples of Tricorder products will be shown at the workshop.

References

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