Analysis of Lithology - Vegetation Mixes in Multispectral Images

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Abstract

Discrimination and identification of lithologies from multispectral images become more challenging with increasing density of vegetative cover. Although hyperarid areas such as parts of the Sahara have virtually no vegetation a greater part of the earth's surface, including much of the Western U.S., shows reflectance from some mixture of rock/soil and vegetation. Rock/soil identification can be facilitated by removing the component of the signal in the images that is contributed by the vegetation. Conversely, in some studies it is desirable to isolate the vegetation signal and to suppress the rock/soil signal. Work to date suggests that at least for some areas unmixing techniques provide unique and useful information.

Our approach relies heavily on the results of laboratory studies of the spectral reflectance of minerals, rocks, weathering products, soils, and vegetation. We have developed mixing models to predict the spectra of combinations of pure end members, and have tested and refined those models using laboratory measurements of real mixtures. Models in use include a simple linear (checkerboard) mix, granular mixing, semi-transparent coatings, and combinations of the above.

We also rely on interactive computer techniques that allow quick comparison of the "spectrum" of a pixel stack (in a multiband set) with laboratory spectra. To make these comparisons we recalculate the laboratory spectra to the values that would be expected if the sample were being viewed by the imaging device. Solar, atmospheric, and instrumental corrections are applied. This approach has

been used successfully to identify lithologies in Viking Lander and Orbiter images, and using LANDSAT images.

There are two main objectives of the pixel-by-pixel spectral analysis. First a rapid check can be made of the laboratory spectra for correspondence with pure materials or mixtures; and their distribution can be displayed on the image by alarming like pixels. Second, whether or not there is correspondence with any laboratory spectra, the "pixel spectra" can be analyzed and classified according to their ranking as end members or as part of a mixture of end members. Displayed on the image these data show unique units (rock, soil, vegetation, mixes, etc.), and the mixing relations between units. In ideal cases where a continuous gradation exists between end members A and B, the proportions of the mixtures of A and B can be contoured on the image. We have studied a LANDSAT image of part of the Western Desert of Egypt where there is continuous spectral mixing between dark lag chert and lighter drifting sand. Pixels that fall on the mixing line between A and B can with some confidence be assigned the percentages of spectra of the two contributing components (chert and sand) even though neither component is spatially resolved by LANDSAT.

The spectral response of green vegetation is more complex. There are, of course, important differences between species in both pigmental and leaf/stem surface characteristics. In addition the architecture of the plant (arrangement of leaves, stems, etc.) and the multi-layered nature of a plant community introduce factors of shading and shadow which when coupled with the reflectance of detrital components, often make the signatures of plant assemblages difficult to interpret.

Working with field and laboratory vegetation data and LANDSAT MSS images in two semi-arid areas, Arizona (Tucson Mtns.) and Hawaii (Mauna Kea-Mauna Loa saddle), we find little evidence of simple mixing of vegetation and the rock/soil substrate. That is, changes in vegetation density do not usually involve simple changes in the proportions of spectral components A and B (vegetation and rock/soil) seen in the images. Instead image analysis, confirmed by field work, typically defines several vegetation and rock/soil zones that are spectral end members. These do not mix appreciably with one another, even though the type of rock/soil is constant throughout the image. These observations are consistent with ecological theory. For example, plant density changes which often follow altitudinal or moisture gradients typically are accompanied by changed in numbers of species or in the relative proportions of those species.

To isolate (and possibly remove) the spectral signature of vegetation requires an understanding of the types of vegetation present in an area, as well as an estimate of the percent cover. This may be a difficult task, depending on how much is known about the area in the image that is being studied. Given some knowledge of the likely vegetation types and their distribution in an area we can isolate the vegetation signal after working through an interative process that progressively narrows the model (species and percent cover) for a vegetation zone. The steps are: first, to define the zone (spectrally unique end member that does not mix with other zones); second, to model in the computer the composite spectral signature of the vegetation (which does involve mixtures of the spectra of the vegetation species within the zone); third, to model the percent cover of the vegetation. With field data and laboratory spectra on the main kinds of vegetation that occur in altitudinal zones in the Tucson Mtns. and on Mauna Loa we can reconstruct the complex vegetation signal. In these areas a limited field traverse provides data that allows correct analysis of large surrounding areas. With proper modeling of the complex vegetation signal we can then isolate the component from the rock/soil and more readily map lithologies.

The techniques described here have been developed using LANDSAT MSS data. We conclude that future advanced multispectral imaging systems with many band-passes will greatly facilitate identification of rock/soil and vegetation, and will substantially improve the reliability of mixing models. At the same time the increased data load will force the use of selective strategies for discriminating, identifying and mapping, and will make less attractive "brute force" approaches for classifying. We propose that spectral mixing techniques will become increasingly useful as the instrument technology advances.