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14. ABSTRACT
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Terrain Categorization using a Background Spectral Library

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Abstract-We describe development of a background spectral library for northeastern Virginia, USA, based on hyperspectral images and an extensive land cover database. The library consists of mean spectra and standard deviations measured in 14 areas of uniform land cover. Terrain categorization products include classification maps and fractional abundance maps determined by linear mixture analysis. There is excellent qualitative agreement between the linear unmixing results and the known land covers.

I. Introduction

Terrain categorization, determining land cover type from multispectral or hyperspectral images, is a key function of remote sensing for both the military and civilian communities. In this paper, we describe our development of a background spectral library appropriate for the mixed pine and deciduous forest of northeastern Virginia, USA. We use Advanced Visible and Infrared Imaging Spectrometer (AVIRIS) hyperspectral images along with an extensive ground truth data base at Fort A. P. Hill, Virginia, to develop the spectral library. Ground truth consists of a qualitative description of land cover types organized in a geographical information system (GIS). The library was built by using the ground truth data to identify large areas of uniform land cover type, and consists of 14 spectra covering a range of natural and man-made land covers.

The purpose of the library is terrain categorization, so testing the library centers on how well it performs this task. We use the library in two related ways: image categorization in which each pixel is assigned to a single land cover type, and image unmixing in which the library spectra are used as the end members of a linear unmixing algorithm. The result of unmixing is an estimate of the proportions of each library spectra that make up the pixels in the image. We test the library by comparing the image categorization and unmixing maps to the known land cover types represented in the database.

II. Data and Methods

The two basic types of data used in this study are hyperspectral images and ground truth information. We use AVIRIS hyperspectral images along with an extensive ground truth data base at Fort A. P. Hill, Virginia, to develop the spectral library. The AVIRIS images were collected during low-altitude operations in November, 1999 and September, 2001 at a ground sample distance of ~3.5 m [1]. The calibrated radiance data were corrected to reflectance using the Fast Line of Sight Analysis of Atmospheric Spectral Hypercubes (FLAASH) code [2]. A representative AVIRIS scene from the September, 2001 collect is shown in Figure 1. Ground truth consists of a qualitative description of land cover types organized in a geographical information system (GIS).

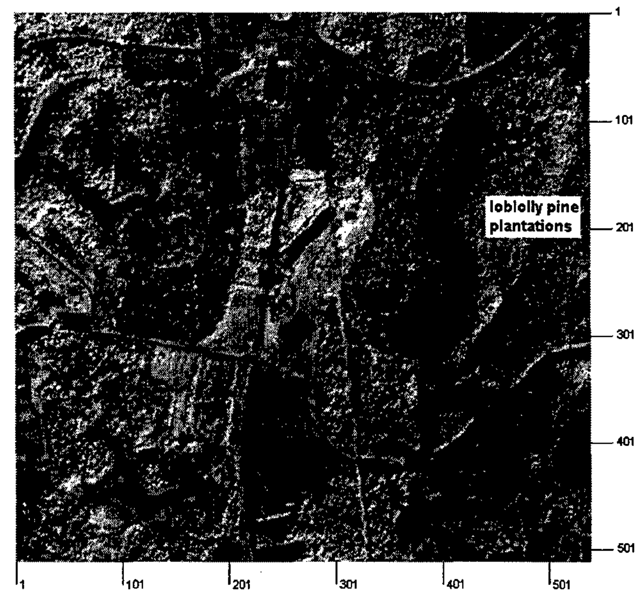

Fig. 1. AVIRIS reflectance image (channel 55, 865 nm) for a portion of Fort A. P. Hill, Virginia.

Our method is essentially a modern version of supervised classification. The ground truth database is used to identify regions of interest (ROI) of uniform land cover type. Next, distinct spectra within the region of interest are identified. This algorithm starts by setting the first pixel spectrum as the first element in the set of distinct spectra. Each pixel in the image is compared to the set of distinct spectra using a metric such as spectral angle or Euclidean distance. If the metric for a given pixel exceeds a pre-determined threshold, the pixel spectrum is added to the set of distinct spectra. These distinct spectra are used as seed spectra for a migrating means cluster analysis, which calculates the mean spectrum and standard deviation. We apply this technique to relatively small ROIs that encompass nearly homogeneous land covers, and it is easy to determine the spectrum for the land cover by inspection. A background spectral library for northeastern Virginia has been developed in this way and is illustrated in Figure 2. We define spectra for 14 land cover types: summer deciduous forest, loblolly

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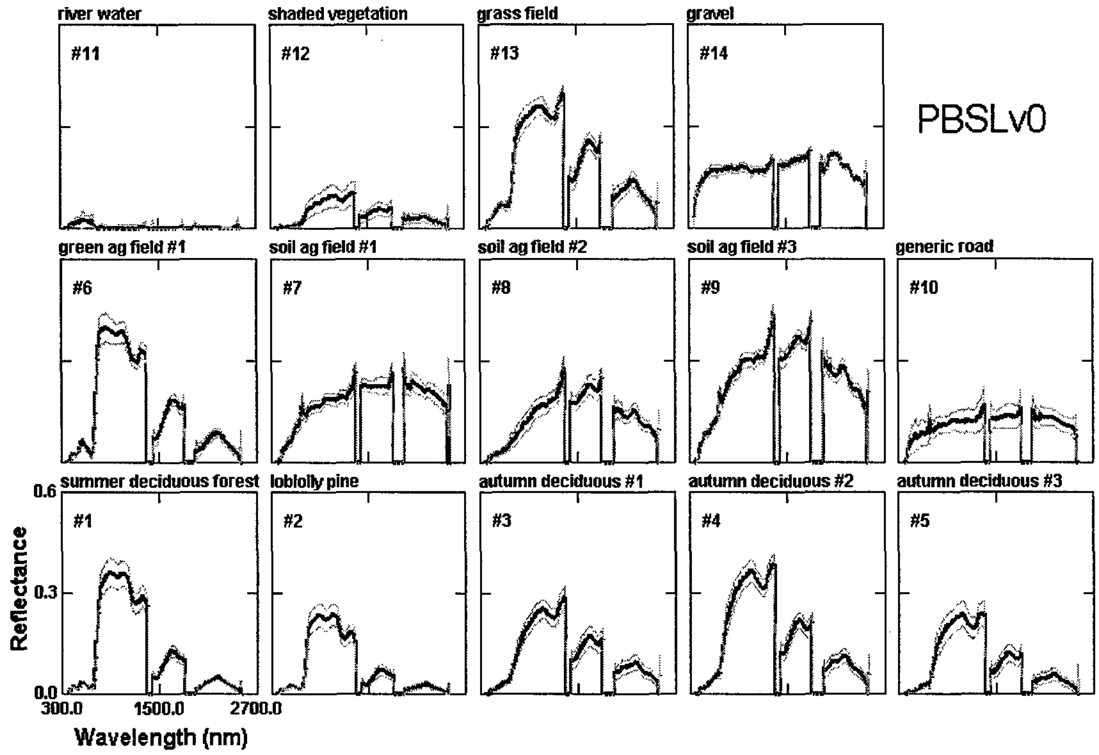

Fig. 2. Preliminary background spectral library for Fort A. P. Hill, Virginia.

pine, three examples of autumn deciduous forest, green agricultural fields, three types of soil agricultural fields, generic road, river water, shaded vegetation, grass field, and gravel. Note that these distinct spectra are not 'end members' in the sense that they are not necessarily extremal spectra, however in accordance with common practice, we will use that term as a shorthand for these library spectra.

III. Classification and Unmixing

We use this library to produce two terrain categorization products: (1) a classification map of the land covers present in the image; and (2) an unmixing analysis of the image that estimates the abundance of each land cover at each pixel. Classification is particularly simple. Each pixel is classified based on which land cover spectrum produces the minimum distance between pixel spectra and land cover spectra. In this paper, we use Euclidean distance as the metric, however spectral angle can be used and has the advantage of being insensitive to absolute brightness. Experience with the Fort AP Hill AVIRIS data indicate that some land covers, mostly notably loblolly pine and summer deciduous trees, have similar spectral angles and are distinguished mostly on the basis of Euclidean distance, i.e., on brightness level. We have also found that spectral angles are unreliable in areas of low signal such as water and shade.

The other product is an unmixing analysis resulting in estimates of end member abundances. In this paper, the linear mixture model [3,4] is used to determine the fractional

Fig. 3. Fractional abundance map for loblolly pine for the AVIRIS image shown in Fig. 1. Shading indicates relative abundance of loblolly pine in each pixel. Hatchured areas outlined in white are loblolly pine plantations; areas outlined in black are mixed coniferous forests.

abundances of the end members. The unmixing result is illustrated in Figure 3 which shows the abundance plane for loblolly pine along with the ground truth information for pine plantation (white outline) and mixed pine (black outline) land cover types. Fort A. P. Hill has a number of loblolly pine plantations in which the trees are planted in a regular, dense pattern to maximize forest yield. These plantations stand out in the hyperspectral imagery as spectrally and spatially uniform (see Figure 1). Note that the loblolly plantation land cover type (white outline) is nearly coincident with the dark areas (high percentage of loblolly pine) in the abundance image. The mixed pine areas (black outline) are somewhat lighter indicating a smaller proportion of loblolly pine. White areas in Figure 3 are areas with zero fraction of loblolly pine. Comparing to Figure 1, we see that these are mostly fields and built-up areas. Overall, we feel that there is excellent qualitative agreement between the abundance estimates and the observed land cover types.

IV. Conclusions

We have developed a background spectral library for northeastern Virginia based on an extensive land cover database and AVIRIS hyperspectral imagery. The database was used to identify areas of uniform land cover type. Spectra for each land cover were extracted from the hyperspectral data using an algorithm to identify distinct spectra followed by a migrating means cluster analysis to estimate the mean and standard deviation. Use of the library was illustrated by classifying and unmixing a typical AVIRIS scene. We obtain good qualitative agreement between the unmixing abundance planes and the observed land cover types.

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