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LANDSAT IMAGE INTERPRETATION AIDS

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ABSTRACT

In the Large Area Crop Inventory Experiment, image interpretation aids were produced to assist in selecting and/or identifying representative samples of signatures in a given Landsat scene. The three methods employed are based on clustering techniques, information extraction, and aggregation of like spectral information on a two-dimensional spectral plot.

1. INTRODUCTION

Image interpretation is an important method for acquiring training data for classification of Landsat images in the Large Area Crop Inventory Experiment (LACIE [1]). Interpreting a scene for classification requires that training fields containing statistically representative samples of all spectral signatures in the given scene be selected and correctly labeled. This becomes especially difficult when multiple passes over a scene are to be interpreted. The variation of the spectral signatures, in a multitemporal sense, makes it difficult to select and identify all of the variety of signatures in a scene. To address these problems, three image interpretation aids were developed.

The first and the second image interpretation aids were obtained by applying nonsupervised pattern recognition techniques (clustering) and data compression. The clustering method identifies the inherent classes in the scene. Color film is generated from the cluster image, with each cluster having a distinct color – the color corresponding to the value of the cluster mean [2]. In interpreting multipass data, a principal component (PCOMP) transformation technique is applied to the cluster image. This compresses or summarizes the multitemporal spectral variation of the scene into a three-dimensional image which can be displayed as a color image. In order for the analyst to view the structure of the Landsat data in spectral space, a two-dimensional spectral plot of the data was developed as the third aid. The spectral plot [2] takes advantage of the inherent two-dimensionality of Landsat data [3]. The plots are constructed to assist in relating picture elements (pixels) in the scene to their locations on the spectral plot.

2. CLUSTER IMAGE

A cluster image is generated first by clustering the data in the scene and then by replacing each data sample according to the cluster mean to which it belongs. Color infrared (CIR) film of the cluster image can be generated by a production film converter (PFC). One of the main features of the cluster image is that two spectrally similar clusters are shown by the film product to have similar colors. This feature easily could be lost when an arbitrary color assignment is used to generate a film product from the one-dimensional cluster map. A CIR film product of the cluster image normally is generated using the same gain and bias as that used to produce the original CIR image. This results in a CIR film product of the cluster image that resembles the standard CIR film product.

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A color key of the clusters is generated also by assigning a square of 100 samples (pixels) to each cluster. Each pixel in the square is equal to the cluster mean it represents. The color keys are then ordered according to the Kauth greenness number [3].

It was discovered from observing cluster images on CIR film that they can be used as aids in defining spectral classes and helping to standardize the image interpretation procedure. In addition, an increase in the contrast of adjacent fields is apparent, which assists in the delination of training fields.

3. PCOMP CLUSTER IMAGE

A PCOMP cluster image of a scene is generated by applying the PCOMP transformation to the cluster image described in section 2. Ready and Wintz [4] have shown that the PCOMP transformation applied to airborne and satellite-gathered multispectral data is very useful for information extraction, since the first few PCOMP images contain essentially all the information present in the original spectral bands. Additional analyses of PCOMP transformed Landsat data are available [5].

The PCOMP transformation is

$$\underline{Y} = M\underline{X} \tag{1}$$

where

$\underline{X}$ = a vector of n spectral intensities associated with each pixel.

M = an n-by-n unitary matrix derived from the mixture covariance matrix Σ_X of the spectral bands such that the rows of M are the normalized eigenvectors of Σ_X.

$\underline{Y}$ = a vector of n PCOMP's.

The covariance matrix of the PCOMP transformed data then becomes

$$\Sigma_Y = M\Sigma_X M^T = \begin{bmatrix} \lambda_1 & & & 0 \\ & \lambda_2 & & \\ & & \ddots & \\ 0 & & & \lambda_n \end{bmatrix} \tag{2}$$

where $\lambda_1, \lambda_2, \cdots, \lambda_n$ (the variances of the PCOMP's) are the eigenvalues of Σ_X ordered so that $\lambda_1 > \lambda_2 > \cdots \lambda_n$ and M^T is the transpose of M.

Since M is a unitary matrix, the PCOMP transformation preserves the total data variance; i.e.,

$$\sum_{i=1}^{n} \sigma_{x_i}^2 = \sum_{i=1}^{n} \lambda_i \tag{3}$$

where the values for $\sigma_{x_i}^2$ are the variances of the original spectral bands. Note that in the PCOMP transformation most of the data variance is concentrated in the first few PCOMP's. It was observed that, for Landsat data in four channels, $\lambda_1 + \lambda_2$ contained approximately 96 percent of the total data variance. In eight channels of Landsat data, $\lambda_1 + \lambda_2 + \lambda_3$ contained approximately 91 percent of the total data variance. For 16-channel Landsat data, $\lambda_1 + \lambda_2 + \lambda_3$ contained approximately 82 percent of the total data variance. The interest in the first three PCOMP's of Landsat data arises from processing color film products. A PFC generating a color product of Landsat data uses three channels, with each channel assigned to the blue, green, or red color film gun. Since the first three PCOMP's contain most of the data variance, the PCOMP transformation, which uses the first three PCOMP's, seems to be a good method of reducing multitemporal data.

Once the PCOMP transformation is applied to both the cluster image and the color keys, the transformed data are rescaled to lie between 0 and 255 to allow storage of the image in a standard image format.

4. SPECTRAL PLOT

A spectral plot of a Landsat scene is a graph of one channel of the data versus that of another. The spectral plot relates the image space (i.e., the spatial domain) of the PFC product to the spectral space of the classifier. A schematic diagram showing the relationship between image space and spectral space is shown in figure 1. The spectral plot uses the inherent two-dimensionality of Landsat data where most of the spectral class separability exists [3]. For example, overlaying the spectral plot of training field means over the spectral plot of the scene provides a quick view of missing signatures and of the corrections to subclass assignments.

The axes used for generating a spectral plot may be two selected Landsat channels or two linear combinations of channels; i.e.,

$$\underline{Z} = B\underline{X} + \underline{e} \tag{4}$$

where

B = a two-by-n transformation matrix of rank 2.

$\underline{e}$ = a two-by-one bias vector.

$\underline{Z}$ = a two-by-one vector of the channels to be plotted.

The transformation matrix B might be formed from the first two rows of the Kauth transformation, the first two rows of M in equation (1), or from a linear-combination feature-selection algorithm [6]. If B is obtained from the Kauth transformation, then the dimension of the data n must be four since the Kauth transformation is a four-by-four matrix.

A color-coded spectral plot contains the locations of the pixels and the channels to be used for coloring them on the spectral plot. The location of each pixel on the spectral plot is computed using the radiance values (or linear combinations of radiance values) of the pixel. Multiple pixel occurrences at the same location on the spectral plot are shown to be the color of the pixel corresponding to the first occurrence. To illustrate what is meant by a color-coded spectral plot, assume that a given pixel on the Landsat image has radiance values of 28, 30, and 50 on channels 1, 2, and 4, respectively, as shown in figure 2. Also, let channel 4 be plotted versus channel 2. The color-coded spectral plot is created by assigning the values of 28, 30, and 50, respectively, to the point (30,50) on channels 1, 2, and 3 of the spectral image. By maintaining the same gains and biases, the color-coded spectral image can be displayed in the same color as the original Landsat image. With such a spectral plot, the full effect of color-shaded aggregation can be observed.

The color of the pixel on the spectral plot is optional. It can be colored according to its original radiance value or the mean of the class, cluster, or field from which it was extracted. Naturally, the location of the pixel on the spectral plot can be displayed in the PCOMP colors.

Color-coded spectral plots can be used to observe the partitioning of spectral space imposed by clustering or by maximum likelihood classification. It can be used also to view the spectral locations of training samples. A partition of the two-dimensional spectral space by the maximum likelihood classification rule is depicted on the color-coded spectral plot by assigning a color to the pixel on the plot according to the mean of the subclass to which it was classified. A change in the color or its intensity on such a plot determines the maximum likelihood decision boundary.

When multiregistered Landsat images are available over a scene, the location of the pixels to be plotted can be selected from two channels of one pass, whereas another pass would be used for color definition. Such a color-coded spectral plot is especially useful for the analysis of multitemporal Landsat data. Through spatial correlation of this color-coded spectral plot and the Landsat image from which the plotting axes are selected, areas where temporal change because of factors such as growth, disease, severe weather conditions, and harvest can be delineated.

A typical application of the color-coded spectral plot, which is currently being considered for applications in the LACIE, is to use the plot as an aid in labeling the training samples. This is done by providing a spatial correlation between the spectral plot and the original Landsat image.

5. CONCLUSION

To aid in interpreting the Landsat image, three color image display techniques were presented. These interpretation aids are the cluster image, the PCOMP cluster image, and the color-coded spectral plot. From the results of preliminary experimentation, the three displayed techniques have been shown to be useful in selecting training data from Landsat images. The developed interpretation aids are being considered for implementation in the LACIE.

6. REFERENCES

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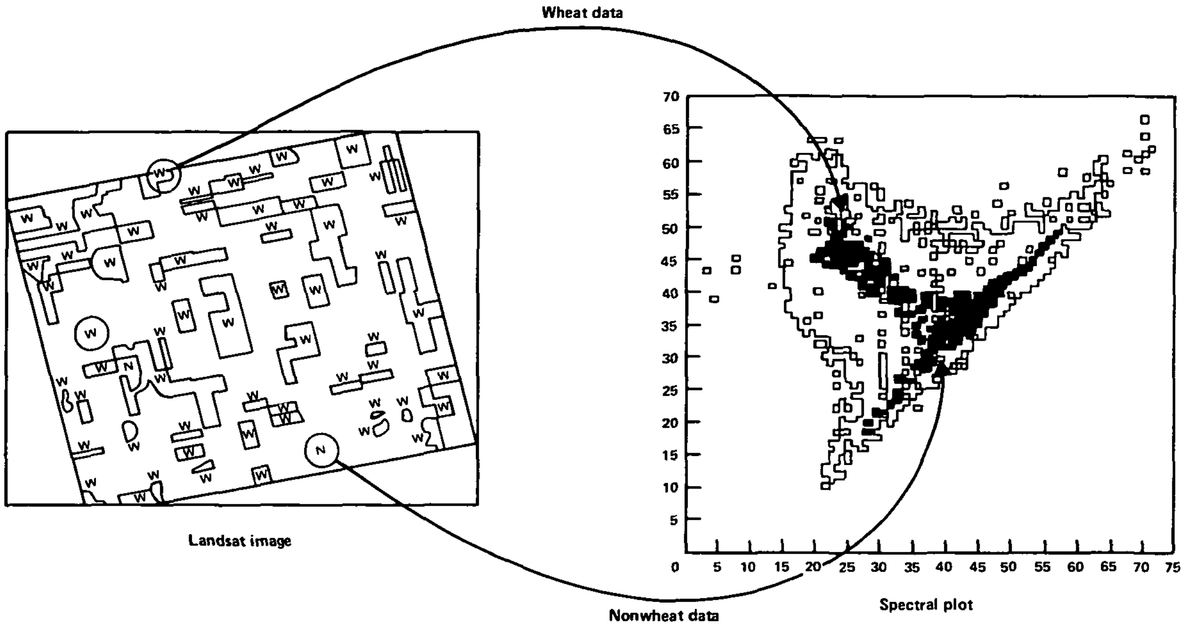

FIGURE 1. IMAGE AND SPECTRAL SPACE. A schematic diagram showing the relationship between image space and spectral space.

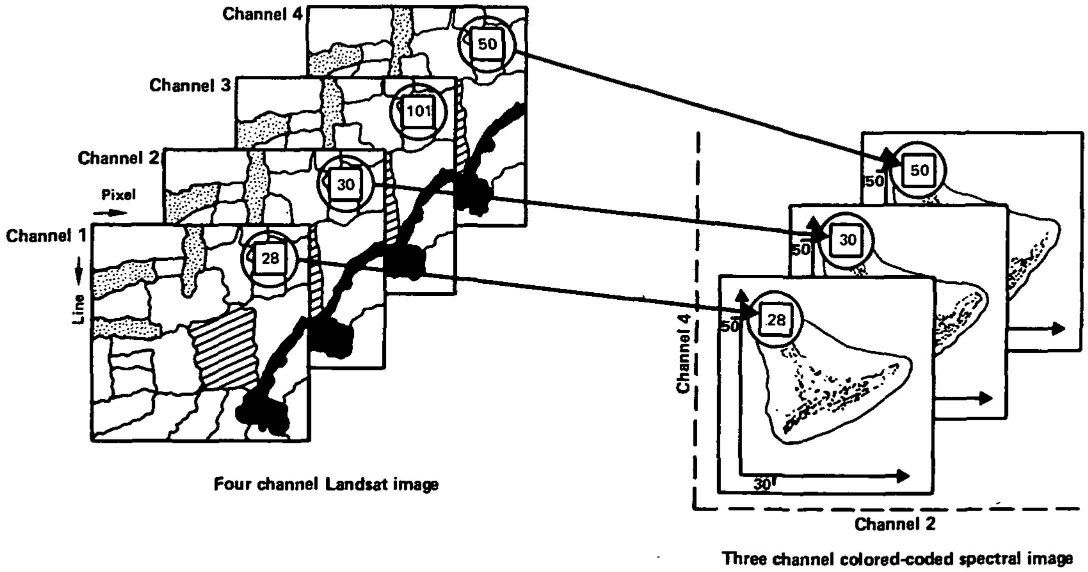

FIGURE 2. STRUCTURE OF COLOR-CODED SPECTRAL PLOT. A diagram showing how Landsat radiance values are plotted on the color-coded spectral image.