Reprinted from

Tenth International Symposium

Machine Processing of

Remotely Sensed Data

with special emphasis on

Thematic Mapper Data and

Geographic Information Systems

June 12 - 14, 1984

Proceedings

Purdue University
The Laboratory for Applications of Remote Sensing
West Lafayette, Indiana 47907 USA

SPICE - SCATTERPLOT PARTITIONING FOR IMAGE CLASSIFICATION AND EVALUATION

L.R. TINNEY, S.B. BREWSTER

EG&G Energy Measurements, Inc.
Las Vegas, Nevada

ABSTRACT

A highly interactive multispectral classification and analysis procedure has been developed and implemented. This procedure, termed SPICE, allows rapid switching between image (geographic) and spectral (measurement) vector space. Emphasis has been placed upon graphical representations of spectral data; to date we have used site specific brightness and greenness transformations. Decision boundaries can be established by an analyst using either non-parametric or parametric techniques. A high degree of analyst interaction flexibility is built into the procedure. The classifier is computationally very fast because it is based upon a simple table look-up procedure.

The main purpose of using this approach is to encourage better analyst understanding of the spectral data being precessed. Improved understanding should lead to higher accuracies and more repeatable classification results. Initial results have shown accuracies comparable to or better than conventional classifiers.

I. INTRODUCTION

Accuracy and repeatability are two of the most significant problems encountered when attempting digital multispectral classification. Most conventional classification procedures have inherent limitations and several methods have been explored to improve them. Among these are:

- Better representations of the multispectral data, such as transforms (e.g. Kauth-Thomas) and spectral-temporal plots
- The use of more "optimal" clustering or supervised classification algorithms and implementation procedures
- Incorporation of pertinent collateral data such as terrain features, into the classification process
- Use of higher order image elements, such as texture, size and shape
- Application of more sophisticated decision logics, which has been encouraged by the availability of georeferenced data bases and is leading towards artificial intelligence techniques.

This paper addresses an application of the first two methods for improving classification performance. More specifically, we shall discuss the use of location specific brightness and greenness transforms and the development and application of an image structured table look-up classification procedure we have termed SPICE, an acronym for Scatterplot Partitioning for Image Classification and Evaluation. Together these two techniques can lead to better analyst understanding of the multispectral data being processed.

The table look-up procedure used in SPICE is most applicable to two dimensional data, although a sequential or layered application of SPICE can be used for higher dimensioned data. In some cases two raw spectral channels can provide adequate discrimination between information classes of interest. In many situations, however, analysts prefer to reduce the dimensionality of multispectral data using transformations such as principal components or canonical analysis.

The brightness and greenness indices proposed by Kauth and Thomas (1976) have proven quite useful for presenting and analyzing Landsat multispectral data. The indices are products of what Kauth and Thomas call the "tasselled cap" transformation. Brightness is similar to albedo while greenness is related to plant phytomass. The indices are not precisely defined in a physical or biological sense but they do convey useful concepts that are readily understood by multispectral data analysts.

The development of site specific brightness and greenness indices is discussed by Jackson (1984), who also provides a procedure for extending the concept beyond the four Landsat multispectral bands. An image processing example of the procedure is provided by Ezra et al. (1984).

Table look-up procedures can dramatically improve the speed of classification algorithms

(Eppler et al., 1971). To accomplish this, each unique vector to be classified is stored in conjunction with it's corresponding output class. This allows a simple indexing operation to be used in place of repetitious calculations which results in significant improvements in speed.

The SPICE procedure makes use of a two-dimensional table look-up that is based upon analyst defined partitions of a scatterplot. The table is stored in it's complete form, which means that even those vectors not represented by any image pixels are stored. By using a standard image format for storing the scatterplot it is possible to use existing image processing programs to display, partition, and label regions of interest. The large size of the table (64K for a 256x256 byte-scaled scatterplot) is balanced against conceptual simplicity, speed, and a modular structure that will allow simple modifications of the procedure.

It has been noted in previous studies that different classification procedures, based on quite different assumptions and algorithms, can provide very similar multispectral classification results (Tinney et al., 1979). It has been our observation that classification performance usually is more a product of available imagery and field data, analyst expertise, and the amount of effort devoted to a particular classification, rather than any specific algorithm characteristic. With this in mind, the SPICE procedure emphasizes graphical aids for the analyst (primarily scatterplots), interactive processing, and iterative refinement of classification products.

A preliminary version of SPICE was first implemented in a batch version of VICAR at the University of California at Santa Barbara. A more refined interactive version was subsequently installed on an ESL IDIMS minicomputer system based on an HP-3000 Series II processor and a DeAnza display subsystem. The following section discusses the IDIMS version of SPICE.

II. SPICE PROCEDURE

The processing sequence involved in the SPICE procedure is a set of modular stages that can be individually improved for a specific task. The steps include the following:

1. Creating a scatterplot image.
2. Interactive partitioning.
3. Table look-up classification.
4. Spectral class labeling.

These steps will now be individually discussed.

A. CREATING A SCATTERPLOT IMAGE

A two-dimensional scatterplot of measurement vector space, or some transformation thereof (e.g. Kauth-Thomas brightness and greenness), is first created and displayed as an image. Although initially calculated using real numbers, the scatterplot image is usually converted to byte format (256 levels) to facilitate rapid display on the image processing system. We have found a logarithmic scaling useful for presenting low frequency values while still preserving patterns in areas of higher pixel counts. In the scatterplot presentation of brightness and greenness, the X- and Y-axis represent brightness and greenness values, respectively, while the Z value is indicative of frequency of occurrence (see Figure 1).

The most standard scatterplot used is that of the entire scene to be processed, or some systematic sampling of the scene. Scatterplots of this type assist the analyst in better understanding the full scene patterns and variance to be encountered. Because the scatterplot is in a conventional image format, it is possible to use a variety of image processing techniques to interactively enhance the scatterplot. Another useful scatterplot can be generated if ground areas of known labels are available. Individual scatterplots can be created for each area or ground cover type of interest and these individual scatterplots can be combined with the full scene scatterplot to indicate relative class positions in measurement vector space. In this type of scatterplot, it is useful to color-code individual cover types. Once again, the flexibility of standard image processing routines allows several methods for combining and displaying the scatterplot images.

B. INTERACTIVE PARTITIONING

Either a supervised or an unsupervised approach can be used in partitioning the scatterplot image. The real advantage of the SPICE procedure is most evident when the analyst actively participates in the partitioning process. Partitioning is accomplished using graphic overlay capabilities common to most image processing systems. Partitions are initially defined by lines representing decision borders. In subsequent processing stages the partition overlay is converted to a byte (256 level) image where the partition regions are filled and assigned spectral class numbers.

In the unsupervised mode of operation, the SPICE procedure usually begins with a coarse partitioning of measurement space. To facilitate this approach, various display aids have been implemented to assist the analyst in viewing the data and rapidly accomplishing the partitioning task. A systematic grid can be applied over any portion of the image, or even the entire image, and partition region numbers (somewhat analogous to arbitrary cluster numbers) automatically assigned (see Figure 2). Specific regions can be partitioned at different grid spacings, allowing greater attention to be placed upon those areas where confusion is anticipated. As an alternative to systematic grids, the analyst can use polygonal regions. With a polygonal approach, however, the analyst currently must individually define each of the partitions. After information class labeling is accomplished (discussed in Step D), the analyst can easily iterate the process and more finely partition any regions where confusion persists.

When training data is available the analyst can examine how conventional classification algorithms would partition the scatterplot. It is sometimes difficult to refine the supervised classification process with conventional techniques (which emphasize training set editing). However, using the SPICE procedure, the analyst can directly focus attention upon decision border regions and in those areas of measurement vector space where confusions are occurring the analyst can intervene. Several options are available to the analyst at this point. If the scatterplot and partitioning are well enough understood, decision borders can easily be moved in the desired direction. Alternatively, the analyst can finely partition the problem area(s) into smaller regions that can be individually labeled using the labeling techniques discussed in Step D.

C. TABLE LOOK-UP CLASSIFICATION

The look-up table used for classification purposes is based upon the partition overlay. Once converted into an image format, where pixel values correspond to partition region numbers, the partition image can be considered a complete table of all input value combinations. Simple XY indexing outputs the partition region number. This operation is extremely fast when compared to standard classification algorithms and even outperforms most other table look-up procedures that are more storage efficient (since only represented vectors or decision borders are saved) but require additional indexing and comparison steps.

Brightness/greenness scenes of 2000x800 (1.6MB) pixels can be classified in approximately five minutes using the SPICE procedure with the HP-3000 Series II version of IDIMS. If modified to make use of an array or video processor, the process could be made nearly instantaneous. The procedure appears well suited for even microcomputer implementation if adequate random access memory is available.

D. SPECTRAL CLASS LABELING

The labeling of spectral classes (analogous to cluster labeling) is required whenever ground data has not been used to establish partition region labels. The analyst uses both partition location in measurement vector space and flagged pixel locations in image or geographic space to determine best class labels. The flagging of pixel locations is accomplished using graphic overlay capabilities of the image processing system. A color composite image, typically in a standard color infrared presentation, is displayed on the monitor as a base for labeling. The classified image to be labeled is also stored in image memory but not directly displayed. From it, individual or groups of spectral classes are highlighted using a graphics plane of the display system. By flickering the graphics overlay, the analyst can examine both spectral and spatial cues to assign an information class type.

Since the original classification table is stored in an image format it is possible to color-code both the classified image and the table image in the same manner. This allows possibly erroneous partition labels to be noted based upon their "improper" location in measurement vector space. It also greatly increases the analyst's understanding of the multispectral data.

A key feature of the SPICE procedure is it's suitability for iterative refinement. Initial labelings are usually done in a conservative manner, whereby partitioned areas with any significant level of confusion are left unlabeled on the first round. The areas of confusion are noted and more finely partitioned, as discussed in Step B. In contrast to conventional cluster labeling, those areas that are well defined need not be relabeled on successive iterations. Since the whole process is fairly rapid, it is possible to iterate several times until either satisfactory results are obtained or no further improvements are possible with single pixel spectral techniques.

III. DISCUSSION AND SUMMARY

Rigorous comparisons of SPICE to other classification procedures have not been completed. Fundamental differences between various procedures makes it difficult to devise fair comparisons. As an example, SPICE classifications can presently handle up to 256 spectral classes and process typical scenes in about five minutes; a comparison run of an ISOCLASS algorithm with 64 classes had to be aborted after 23 hours of computing. Various options were available to speed up the ISOCLASS program (such as sampling the scene) but the more such options are exercised the less comparable the results become.

In one initial comparison the SPICE procedure did outperform an ISOCLASS program with accuracies of 92% versus 86%, respectively, for a wetlands classification of land cover types. The data involved was aircraft multispectral imagery. We believe that the real value of SPICE, however, lies mainly in it's ability to enhance analyst understanding of the data. This better understanding should be expressed in terms of both higher accuracies and more repeatable results.

IV. REFERENCES

Eppler, W.G., C.A. Helmke and R.H. Evans, 1971. "Table Look-Up Approach to Pattern Recognition", Proceedings of the 7th International Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor, pp. 1415-1425.

Ezra, C.E., L.R. Tinney and R.D. Jackson, 1984. "Considerations for Implementing Vegetation Indices for Agricultural Applications," Proceedings of the 1984 Annual ASP/ACSM Conference, Washington D.C.

Jackson, R.D., 1983. "Spectral Indices in N-Space" Remote Sensing of Environment, Vol. 13, pp. 409-421.

Tinney, L.R., D. Stow, and J.E. Estes, 1979. "Conceptual Design and Preliminary Demonstration of a Prime Agricultural Land Component of an Integrated Remote Sensing System," Final Report.

BIOGRAPHICAL DATA

Larry R. Tinney is a Remote Sensing Specialist with the Aerial Measurement Operations of EG&G Energy Measurements, Inc. His primary interests are the integration of image processing and geographic information systems and the development of advanced information extraction techniques. Mr. Tinney received his B.A. and M.A. degrees from the University of California at Santa Barbara, where he was previously employed by the Geography Remote Sensing Unit.

Stanley B. Brewster, Jr. is a multispectral data analyst with the Aerial Measurement Operations of EG&G Energy Measurements, Inc. His emphasis has centered on the remote sensing and digital image processing of vegetation as well as image classification techniques. Mr. Brewster received his B.A. in Geography from the University of California at Santa Barbara andis currently progressing toward an M.S. in Computer Science at the University of Nevada at Las Vegas.

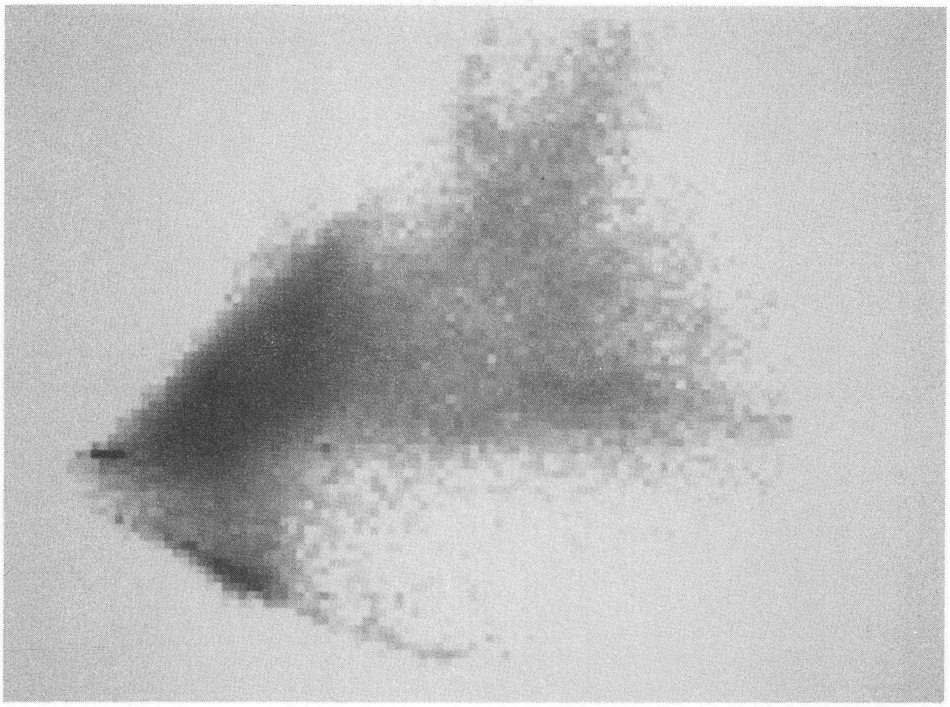

Figure 1. Scatterplot image of brightness (x axis) and greenness (y axis) values obtained from aircraft multispectral scanner imagery. Dark tones indicate high counts and light tones low counts. The original data is from a wetlands site in southeastern United States.

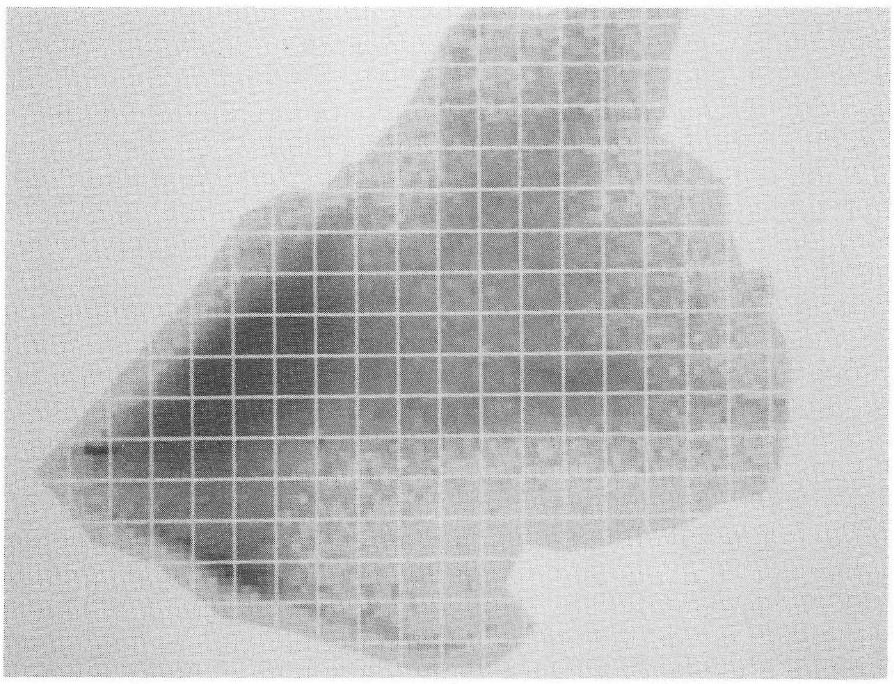

Figure 2. Systematic gridding of above scatterplot image. This coarse gridding represents over 200 spectral classes to be used in the initial class labeling.