Reprinted from

Eighth International Symposium

Machine Processing of

Remotely Sensed Data

with special emphasis on

Crop Inventory and Monitoring

July 7-9, 1982

Proceedings

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

AUTOMATED TERRAIN ANALYSIS

L.G. SAM THOMPSON

U.S. Military Academy/Department of Geography and Computer Science
West Point, New York

ABSTRACT

The standard rules for scene classification do not always apply when the analyst is searching for a single terrain feature. A comparison was made between the performance characteristics of a four-dimensional parallelepiped and those of the maximum likelihood decision strategy when discriminating unique features. Using Landsat and low-altitude, high-resolution multispectral data, a classification accuracy study was conducted with the ultimate goal being to assist in automating the terrain analysis procedure. This paper summarizes some significant traits of two decision strategies and presents the results of the classification accuracy study.

I. INTRODUCTION

The Computer Graphics Laboratory (CGL), Department of Geography and Computer Science (Headed by Colonel G.W. Kirby, Jr.), at the United States Military Academy has been conducting research in the area of automated terrain analysis as a part of a larger research effort for the Defense Mapping Agency and the Engineer Topographic Laboratories. The concept is to have the terrain analyst, rather than ponder over outdated maps, query the computer using state-of-the-art digital image processing techniques to quickly (eventually real time) arrive at sound conclusions concerning the type of terrain that lies within his area of concern.

Accuracy and speed are important; time consuming cluster analyses will be unacceptable. Therefore, the problem reduces to one of rapid, selective classification.

A pixel has an identity because of its associated measured brightness value in each band. Putting a pixel in a particular category is essentially a boundary problem, either strictly numerical size or probabilistic. A comparison, using Landsat data, was made between the performance characteristics of a four-dimensional parallelepiped (numerical boundary) and the maximum likelihood (probabilistic) decision strategies [Thompson].

The results of that comparison and of a preliminary test of the automated terrain analysis system, using both Landsat and low-altitude, high-resolution multispectral digital data, are presented in this paper.

II. CLASSIFICATION SYSTEM

Scenes are displayed on the CGL's DeAnza VC5000 image array processor which is driven by a VAX-11/780 minicomputer. Training samples may be gathered by recording the brightness values of all pixels inside a movable and variable size box cursor. Often the area from which the operator wishes to collect training samples is too small (particularly with Landsat data) to easily fit the box cursor in it. Therefore, the system permits an 8X magnification of the area and allows the operator to gather the training samples by placing a dot cursor within the now very large pixel and recording its brightness values.

Once the training samples have been collected the system provides the usual statistical analyses (mean, variance, highest and lowest values, scatter diagrams and histograms) to insure that a nonpolluted, homogeneous sample has been taken.

The system will then search for all similar terrain. An interesting feature is the ability of the operator to have the system classify just within a movable, variable size box cursor. This provides the opportunity to select features to be "compared" against the training sample, allows for flexibility and versatility, and greatly shortens the classification time. Computer time is not being wasted applying the decision algorithm to displayed pixels for which the analyst has no interest. All pixels which are considered to be of the same class as the training sample are displayed in a distinctive color.

III. DECISION STRATEGY COMPARISON

A Landsat scene of an area northeast of the Grand Canyon was displayed on the DeAnza. Two obvious and well-defined rivers were visible (Colorado and San Juan). Training samples were collected at various places in the rivers, the highest and lowest values in each band recorded, and all water classified according to a four-dimensional parallelepiped decision rule. Basically this is a large "IF" statement where each pixel band value is compared to the training sample boundary values. Over the test strip the rivers appeared to be correctly classified with 685 pixels categorized as water.

The same classification was attempted using the maximum likelihood decision strategy. Computing the probability density function for each pixel and each band will not result in a classification unless the technique of establishing a "threshold" is adopted [Swain, p. 157]. If the computed probability is less than the user-supplied threshold then the data point is considered to not belong to the population, i.e., it is rejected (thresholded) and not assigned to the class. [Thompson]

Unfortunately, the selection of a threshold introduces another variable whose value must be derived from trial and error and will vary with each scene and feature. Table 1 lists the threshold values tried and the number of pixels of water found in the test strip in each case.

Table 1. Threshold versus number of pixels categorized as water.

Threshold	No. of Pixels
0.0	all
0.00001	679
0.0001	679
0.0005	639
0.001	629
0.005	605
0.010	542
0.015	542
0.020	542
0.025	539
0.050	407
0.100	303

[Thompson]

It should be noted that when the same test was done for vegetation there was a 24% drop in the number of pixels categorized as vegetation when the threshold was changed from 0.00001 to 0.0001. Obviously the threshold is not only scene dependent but also feature dependent.

Although the number of pixels (685) selected by the parallelepiped cannot be considered as "absolute truth," the rivers appeared correctly classified when those pixels were made a distinctive color. When the larger threshold values were used and the classification program run, it was visually obvious that many water pixels were being incorrectly rejected. Therefore, a smaller threshold would be interactively inserted and the classification repeated. After several repetitions it became apparent that manipulation and testing of the threshold has the effect of iterating toward a duplication of the parallelepiped classifier.

While it is true that a carefully selected training sample must be gathered, this is not an indictment against the parallelepiped strategy. As Hoffer states, "If the training statistics are not representative, the classification results will not be satisfactory, no matter which algorithm is utilized." [Hoffer, p. 10]

This information, combined with the fact that the parallelepiped decision rule was found to be 26% faster than the maximum likelihood [Thompson], resulted in the parallelepiped rule being chosen for the automated terrain analysis system tests.

IV. AUTOMATED CLASSIFICATION TEST (Landsat)

The accuracy of any classification system can only be determined by comparing it to "truth" both quantitatively (total area) and qualitatively (location).

Using a combination of maps at various scales, CIR and black and white photographs, an existing land cover classification, detailed and recent orienteering maps and several hours of personal "ground truthing," land cover overlays were prepared of a selected region near West Point. Table 2 lists the classes and the number of distinguishable areas in each class. Naturally as the scale gets smaller, less lakes, swamps, etc., are plotted.

The area covered by each class could be measured and compared to the area located by using the landsat data and the automated system (number of pixels times the area of each pixel). The number and site of each feature was compared by making an overlay of the screen after each classification.

Table 2. Number of plotted terrain features at three scales in the ground truth area.

Feature	1:250,000	1:50,000	1:25,000
Water Body	23	60	68
Swamp	0	22	47
Impervious	5	19	56
Urban	5	10	21
Vegetation (nonforest)	15	23	28

It was hoped that the Landsat results would be more closely correlated to a specific map scale.

V. TEST RESULTS (Landsat)

Repeated tests under myraid conditions led to the same conclusion--Landsat data does not allow for accurate discrimination of the classes listed in Table 2 in the type of terrain found in the Hudson Highlands.

Although the Landsat classification located an average of 26 water bodies and 12 impervious (airports, CBD's, parking lots, etc.) areas, the number and area varied so widely the results were unacceptable. The other features varied tremendously in number, area and location.

The primary reason for the disappointing results is poor Landsat resolution resulting in pixel pollution or overlap. This is a particularly acute problem in a rugged nonhomogeneous area with small lakes, small swamps, heavy undergrowth, and frequent rocky terrain. An automated terrain analysis system <u>based on Landsat data as presently configured</u> is not possible in terrain of this type and probably not possible anywhere.

A search of the literature provides ample support for this rather severe statement.

Lulla, in 1980, stated that "The major limitation of Landsat data is the problem of resolution." [Lulla, p. 18]

As Billingsley elegantly said, if you want to see small things you need small pixels [Billingsley, p. 422]. Schreier, et al., noted that "Relatively few computer assisted land classification methods based on multispectral Landsat data have become operational ...." [Schreier, p. 112] The suggested reason was the limited ground resolution of the Landsat multispectral scanner [Schreier, p. 112].

Sharp, quoting from a senate hearing in 1977, commented that "... too much is being expected from the Landsat demonstration projects." [Sharp, p. 1487] Campbell speaks of the impossibility of identifying the sources of classification error [Campbell, p. 362] while Gordon discusses the substantial errors associated which his use of Landsat data in an experiment in Ohio [Gordon, p. 195]. Vogel, in 1977, completed a meticulous study in which Landsat data was examined to see if it could meet the needs of a large number of cartographic, mapping and terrain requirements. After comparing over 300 subcategories the requirements for only 2 could be met by Landsat. He concluded that Landsat data is inadequate for classifying most of the basic terrain elements [Vogel].

Concerning an automated classification system, based on data available today, the literature reveals comments such as, "... there are more cost effective ways of imaging the earth than Landsat-D," "infeasible," "unrealistic," "foolhearty," and "20 years in the future." [Colvocovesses, p. 69; Kanal, p. 2; Leighty, p. 260; Case, p. 340]

VI. AUTOMATED CLASSIFICATION TEST (High Resoltuion Data)

Tests are currently being conducted at the CGL using low-altitude, high-resolution multispectral digital data collected by Daedalus Enterprises Incorporated over an area in southeast Kansas. Pixel size is approximately 12 feet on the ground with data being gathered in 5 bands (blue, green, red, infrared, and thermal infrared). At the same time that the 5 band multispectral digital data was being gathered, overlapping color infrared and color photographs were taken. This data provides an excellent base on which to build an evaluation of an automated terrain analysis system.

At this time, although preliminary impressions are favorable, no substantive conclusions may be drawn. All roads and trails, buildings, small streams and lakes, individual trees, swamps, etc., are clearly visible. Using the technique of classifying only within the variable size, movable box cursor comparisons and classifications may be rapidly accomplished with experience being progressively accumulated.

Some of the rather formidable obstacles which lie ahead are provided below:

1. large volume of data,

2. image distortion (particularly on the periphery of the scan),

3. planimetric displacement (relief displacement and instrument errors),

4. complexity of digitally mosaicing the separately scanned data into one large data base, and

5. the limited information contained in the multispectral digital data.

The Defense Mapping Agency has rightfully committed itself to digital data [Williams, p. 488]. The future most certainly will see widespread usage of large digital data bases for every conceivable use. Rapid and accurate classification systems are but a research effort away.

VII. LIST OF REFERENCES

Billingsley, F. "Modeling Misregistration and Related Effects on Multispectral Classification." Photogrammetric Engineering and Remote Sensing. Vol. 48, no. 3, pp. 421-430, March 1982.

Campbell, J. "Spatial Correlation Effects Upon Accuracy of Supervised Classification of Land Cover." Photogrammetric Engineering and Remote Sensing. Vol. 47, no. 3, pp. 355-363, March 1981.

Case, J. "Automation in Photogrammetry." Photogrammetric Engineering and Remote Sensing. Vol. 47, no. 3, pp. 335-341, March 1981.

Colvocovesses, A. "Multispectral Linear Arrays as an Alternative to Landsat D." Photogrammetric Engineering and Remote Sensing. Vol. 45, no. 1, pp. 67-69, January 1979.

Gordon, S. "Utilizing Landsat Imagery to Monitor Land-Use Change: A Case Study in Ohio." Remote Sensing of Environment. Vol. 9, no. 3, pp. 189-196, May 1980.

Hoffer, R.M. "Computer-Aided Analysis Techniques for Mapping Earth Surface Features." Laboratory for Applications of Remote Sensing. Technical Report 020179, Purdue University, 1979.

Kanal, L.N. "Some Current Concepts and Problems in Pattern Clasification and Feature Extraction." Air Force Office of Scientific Research. Technical Report, TR-640. Laboratory for Pattern Analysis, University of Maryland, 1978.

Leighty, R.D. "Research for Information Extraction from Aerial Imagery." Proceedings Remote Sensing Symposium. Reston, VA, 29-31, October 1979.

Lulla, K. "Remote Sensing and Soil Studies: A Brief Review." Remote Sensing Quarterly. Vol. 2, no. 3, pp. 4-20, July 1980.

Schreier, H., Goodfellow, L.C., and Larkulich, L. M. "The Use of Digital Multidate Landsat Imagery in Terrain Classification." Photogrammetric Engineering and Remote Sensing. Vol. 48, no. 1, pp. 111-119, January 1982.

Sharp, J. "Demonstrating the Value of Landsat Data: A Case for Lowered Expectations." Photogrammetric Engineering and Remote Sensing. Vol. 45, no. 11, pp. 1487-1493, November 1979.

Swain, P.H. Remote Sensing: The Quantitative Approach. Edited by P. H. Swain, and S. Davis. McGraw-Hill Inc., NY, 1979.

Thompson, L.G. "A Comparison of the Four-Dimensional Parallelepiped and Maximum Likelihood Decision Strategies." Paper submitted for publication, Remote Sensing of Environment. February 1982.

Vogel, T. "An Analysis of Landsat System for Cartographic and Terrain Information." Engineer Topographic Laboratories. Report Number 9, 1977.

Williams, O. "Outlook on Future Mapping, Charting and, Geodesy Systems." Photogrammetric Engineering and Remote Sensing. Vol. 46, no. 4, pp. 487-490, April 1980.

L. G. Sam Thompson. Since earning his Ph.D. in Geodetic Science from the Ohio State University in 1972, Lieutenant Colonel Thompson (active duty Army) has had a variety of topographic engineering assignments to include the Defense Mapping School and the Engineer Topographic Laboratories. From 1976 to 1978, he served as the Defense Mapping Agency's Exchange Officer with the Royal Australian Survey Corps in Bendigo, Australia. After serving 3 years as an Associate Professor teaching Remote Sensing of the Environment and Astronomy at the United States Military Academy, West Point, New York, Lieutenant Colonel Thompson was chosen to be a Research Officer in the Department of Geography and Computer Science. He is currently conducting research in the area of automated terrain analysis at the USMA.