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

AN APPLICATION OF THE UNH DIGITAL IMAGE PROCESSING SYSTEM

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ABSTRACT

A digital image processing system developed for research and training purposes at the University of New Hampshire was tested on data from a subscene of coastal New Hampshire, scan digitized from high altitude infrared photography using an Optronics P-1700 microdensitometer. Spectral characteristics of nine cover types were first derived from three subscenes. Comparison to field data showed an overall 74 percent accuracy in classifying the pixels of a fourth test subscene.

INTRODUCTION

This paper describes an initial application of a software system for the digital enhancement and classification of multi-emulsion photographic data. It was developed starting in 1976 at the University of New Hampshire on the premise that locally developed software could make optimum use of on-site computer facilities (in this case, a DEC system-10) with potential for significant research in land classification methodology utilizing multispectral data from small scale infrared photography or LANDSAT data. Such work would enlarge paticipation in research, be of value for educational purposes, and could contribute to progress in applications despite the prior existence of sophisticated data analysis systems better suited for classification of large geographic areas.

Input for this application is from a May 9, 1975 flight (National Aeronautic and Space Administration (NASA) Mission 75-057) at a nominal scale of 1:120,000, utilizing Kodak Aerochrome 2447 Duplication film. A portion of frame 4264 on the 2447 film was scanned through the cooperation of Optronics International Inc. of Chelmsford, Mass. with an Optronics P-1700 scanning microdensitometer using three different narrow band pass filters centered at 0.45, 0.55 and 0.65 micrometers on the blue, green and red dye layers, respectively. A fourth data channel was acquired scanning the transparency with no filter. A 100 micron scan of the scene resulted in a ground resolution element or pixel approximately 40 feet square, or 1/27th of an acre in size. The result was a multispectral data set with a resolution the researchers expect will prove to be more effective than that of LANDSAT data for detailed cover type mapping of areas with the complexities of land cover apparent in coastal New England. Published work reporting on the use of photography and densitometric analysis are Steiner and Haefner (1965); Doverspike and Heller (1965); Coggeshall et al. (1973); Hoffer et al. (1971); Murtha (1973); Scarpace (1978); and Lillesand et al. (1978).

The digital values from the Optronics tape (on a scale of 0-255) were reformated for use on the DEC system and written to disk files for easy access. Software preprocessing methods which proved useful in enhancing the image data for the analyst included contrast stretching, edge enhancement, spatial filtering and band ratioing. Classification capabilities include an unsupervised algorithm based on Euclidean distance that incorporates a spatial mask for generating "seed cluster" centroids. Supervised classification can be done by Euclidean distance or Parallelpiped decision rules. Output products are classification summary statistics and line printer gray shade/character maps.

The test site selected for this study is in the Durham-Dover area of Strafford County in New Hampshire, an area with a relatively long and complex cultural history. It lies within the New England physiographic province and is typified by rolling topography containing marine clays, outwash plains and till deposits. The forest cover is white pine-hemlock-hardwood in pure and mixed stands (Lull, H.W. 1968).

COVER TYPES

Nine cover types were identified in fieldwork representing the predominant categories of vegetative cover and land use types in Strafford County. The descriptions below outline the major components of each class:

Hardwood: Comprises small stands of at least 75% hardwood species, usually dominated by one or more of the following: red oak (Quercus rubra), American beech (Fagus grandifolia), shagbark hickory (Carya ovata) and red maple (Acer rubrum). Secondary species commonly experienced in Northeastern hardwood stands include white oak (Quercus alba), birch (Betula spp.), American elm (Ulmus americana), poplar (Populus spp.) and cherry (prunus spp.).

Softwood: Including 75% or more composition of Southeastern New Hampshire conifers represented primarily by Eastern white pine (Pinus strobus) and Eastern hemlock (Tsuga canadensis) with minor appearances of red pine (Pinus resinosa), black spruce (Picea mariana) and Atlantic white cedar (Chamaecyparis thyoides).

Mixed Wood: This is a combination of the above two classes in which neither hardwood nor softwood species comprise more than 75% of the stand.

Brush: This is a vegetative type of shrub size widely varied in species composition and includes cultivated hedgerow species. The most common occurrences include alders (Alnus spp.), willows (Salix spp.) and American serviceberry (Amelanchier spp.).

Oldfield: Typically a transitional stage in the succession of abandoned agricultural land to mature forest. The majority of this class is comprised of grasses, sedges, and forbs with intermittent occurrences of brush species and intrusions of young intolerant hardwoods and softwoods.

Agricultural: Such lands are almost exclusively represented in this area of poor agricultural soils by active hayfields and pastureland. This cover type does not include plowed and exposed soils.

Exposed Soils: These areas include plowed and disturbed soils as well as gravel and sand excavations.

Highways: These are paved roads of less than interstate size, also including parking lots and other paved areas, but not dirt roads.

Water: Open surface waters as found in ponds, reservoirs, rivers and estuaries.

Other: This category encompasses all other land uses such as landfills, buildings and residential properties as well as areas of mixed resource composition which have not been successfully separated out from all others by the researchers to date.

METHODS

Spectral statistics were developed from the digitized photography to describe the spectral characteristics of the above field-identified cover types. An attempt to develop an additional class to include residential land use was abandoned early in the project. It was found that the reflectance patterns of different building and landscape materials varied too greatly at this level of detail to provide a reliable classification based on spectral patterns alone. For similar reasons no statistics were developed to correspond to other land use categories that comprise the "other" group.

Three training subscenes containing 4 data channels of 100 x 100 pixels (367 acres) were extracted from the entire image data set to allow for adequate sampling of all resources classes. (A fourth test window was extracted to assess the accuracy of the final classification.) The relatively small size of the subscene provide a convenient area for field sampling and the corresponding digital files are appropriately suited to the response time and on-line memory capacity of the UNH DECsystem-10.

Recent developments in digital image classification show a trend toward developing spectral statistics in an unsupervised manner (Fleming et al., 1975). Each training subscene was initially processed with an unsupervised clustering algorithm to differentiate the subscene into eight to ten spectral classes. The algorithm locates spectrally homogenious, spatially contiguous areas of user specified size. These initial "seed clusters" are the basis of an iterative minimum distance classification rule which completes the unsupervised classification of the selected subscene. In generating these "seed clusters" the algorithm utilizes the knowledge that image data is being classified and that the data is not simply a matrix of random events (Deigan et al., 1980). A practical advantage of this technique is to allow for spectrally homogenious areas to be readily identified prior to field work, thus eliminating considerable time and effort required to locate areas of suitable size and spectral similarity for field identifications.

Areas identified by this method were located in the field with the aid of compasses, ground measurement, 1974 ASCS photography (scale 1:20,000) and 800-micron photographic output of the digitized window (scale 1:15,000). Data were collected on a pixel by pixel basis including land use, vegetative cover, slope, aspect, and other relevant site variables. The areas to be used in the development of spectral statistics were selected to represent the natural variation occurring within a given class of interest. In general, homogeneous sample areas containing from 10 to 25 pixels were the basis for development of spectral statistics.

Each statistics file was screened in a multivariate test for outliers which identifies pixels that are spectrally anomolous. The BMD10M program (Dixon, 1976) was used to test the maximum Mahalanobis distance of each pixel to the mean of the others in the training sample and determine its probability against the F-distribution. Pixels with probabilities smaller than a user specified probability were considered anomolous and removed from the statistics file. Alphas varied from .05 to .20 depending upon the cover type, to account for differences in reflectance variability between cover types. For example, Hardwoods exhibit a moderate amount of spectral variation and the Hardwood statistics were screened at an alpha of .05. Because pixels comprising the Highway statistics file are more likely to be anomolous due to imprecise field location and the increased likelihood of mixed pixel situations, an alpha of .20 was more appropriate.

CLASSIFICATION

A fourth subscene was selected to examine the performance of the classification process. One hundred 3 x 3 pixel plots were randomly selected within the test subscene. The test plots were located in the field to within plus or minus one pixel of the computer coordinates. Each pixel within a plot was assigned its appropriate cover type and data were collected in a similar manner as described for the training samples.

A total of twelve plots were eventually rejected due to obvious gross changes in land use in the six year interval from the time the photography was taken and when plots were visited in the field. Seven of the plots were rejected due to housing developments and five were rejected due to extensive logging operations. The final total of 88 plots (792 pixels) represents a 7.9% random sample of the test subscene.

A variation of the minimum Euclidean distance criteria was used in the classification of the test subscene. Each pixel is assigned to the cover type for which the distance measure is minimized. The distances under consideration are those between the vector describing the spectral response of a pixel and the mean vector describing the spectral response of a pixel and the mean vector describing the spectral response of each cover type. Using this algorithm, each pixel is assigned to a cover type.

An accuracy assessment of this classification was calculated by overlaying the classification output with the field data, and allowing for an error in matching coordinates by plus or minus one pixel in either a north-south or east-west direction. The results comparing field and computer classification are illustrated in Table 1. Percent accuracies were calculated according to the formula:

$$\frac{\text{Number of Pixels Correct}}{\text{Total Number of Pixels}}$$

This results in an overall accuracy of computer classification of 74%. Without allowing for error in matching field and computer coordinates, accuracy was calculated at 516/792 = 65%.

DISCUSSION

An evaluation of the sources of classification error against actualities on the ground indicates that much of the difficulty lies in pixels that are not "pure" but contain portions of two or more cover types. The cumulative optical density resulting from two or more cover types may result in the pixel being classified as something entirely different. For example, the occurrence of hardwoods in an open wetland results in pixels that are more likely to be classified as softwood or mixed wood than either hardwood or water. The greater detail available from digitized high altitude photography apparently does not rectify this general problem which is also encountered in classification of LANDSAT data. However, it would appear that as long as there is greater detail to work with in photographic data, future direct comparisons with LANDSAT data using the same software systems and the same size areas might show greater potential for photographic systems in recognizing anomalous classifications.

The researchers believe that the full potential of a given software system comes in experience with and operator use of the system. This has not been achieved to date in use of the UNH system. As in the case of misclassification of hardwoods in open wetlands cited above, the most direct way of resolving the situation might be the development of a new class to include hardwood wetlands. In much the same way, the spectral statistics of the 54 "other" pixels in the test subscene may be separated out into other (new) cover types, and this will not all be counted as misclassified pixels as they are now.

However, a solution is not possible for all mixed pixel situations since the possible combinations of resource types and uses are many. The poor agreement of the Highway classification is illustrative. A 40 x 40 foot square pixel falling on a highway or county road more often than not also includes the spectral reflectance of a grassy shoulder, overhanging hardwoods and/or softwoods, roadside brush, a watery ditch, a traveling vehicle and so on.

Other difficulties in achieving proper classification from digitized photography are inherent in the physical structure of the optics or of the earth below. Steiner and Haefner (1965) recognized the problems of systematic variables inherent in photographic systems, including vignetting (a function of the physical transmission of light from a square image passing through a round lens). The spectral characteristics of light reaching the lens is affected by the slope and aspect of the ground surface, as well as its moisture content. Data enhancement techniques, such as normalization and ratioing, are helpful in dealing with ground conditions (General Electric Space Div., 1975; Smith and Baker, 1975). Although incorporated into the UNH software, the potential of these powers has not been fully applied as yet. Ratioing combines information from two spectral channels to produce another channel with reduced atmospheric and topographic effects. Normalization can also be used for both enhancement and classification purposes. The technique expresses one data channel as a percentage of the sum of all data channels.

Preliminary work in tree species discrimination at UNH suggests that the level of precision necessary to accomplish this goal requires further understanding and refinements, incorporating the above mentioned techniques. Developing useful spectral statistics for all possible ground cover may not be feasible nor desirable. For some, such as highways, other methods of recognizing cover type, such as spatial pattern recognition, may be necessary.

The six year interval between photographic acquisition and field sampling is thought to account in part for many disagreements between field and computer classifications. For example, the Oldfield classification is by and large made up of abandoned hayfields reverting to forest land. In early successional stages these lands are easily reclaimed for agricultural use. This reasoning suggests a possible explanation for the large percentage of Agricultural cover being classified as Oldfield. A possible solution might be to redefine the cover types or to utilize more current photography.

CONCLUSIONS

Digital classification of high altitude color and color infrared photography has potential for providing a rapid and accurate means of mapping land cover types in detail. The continuing availability of this type of photography through agencies such as the National Aeronautics and Space Administration will provide photographic materials needed by users generally in monitoring land use change, environmental assessment and in resource inventory. Such applications result in geo-based information systems and the use of multi-stage sampling designs.

The performance of the UNH digital image processing system is consistent with similar systems. Sources of error considered in the discussion include the occurrence of "mixed" pixels, the time interval between photo and field samplings and radiometric and geometric distortions. Further experience with applications and system refinements should lead to an overall improvement in the results of future applications.

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Field Identification	Softwood	Mixed Wood	Hardwood	Brush	Old Field	Agricultural	Water	Highway	Bare Soil	Total Pixels	% Accuracy
	Computer Classification										
Softwood	120	7	4							131	92
Mixed Wood	12	93	17							122	76
Hardwood	7	14	110	4	3					138	80
Brush				6	5	3	2	2		16	37
Old Field	1		4		189	3		3	1	201	94
Agricultural			1		51	62				114	54
Water							0			0	--
Highway			1	1		2		3		7	43
Bare Soil						2			7	9	78
Unclassified	4	1	4	2	23	18		1	1	54	--
Total										792	74.49

Table 1. Comparison of field identification to computer classification of digitized aerial photograpy for the North Dover Point Window.

Figure 2. Hardcopy output of digitized aerial photography for the red dye layer. The area represented is the North Dover Point Test Window.

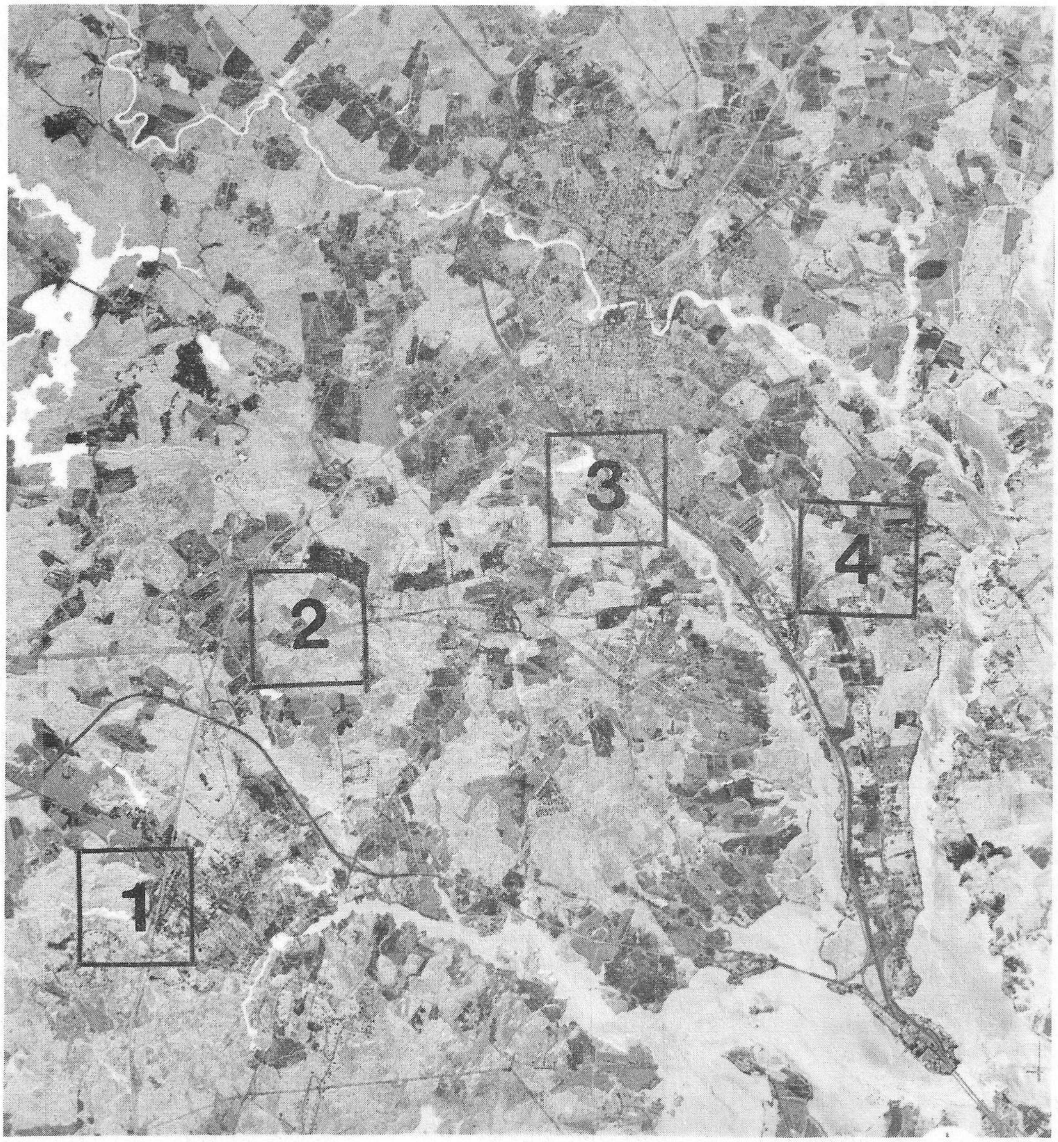

Figure 1. A black and white copy of a portion of the aerial photograph used in the study. The boxed areas to the left (1, 2 and 3) are the training subscenes used to develop spectral statistics. The test subscene (4) is at the far right.