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Cost Effective Computer Processing of Airborne Scanner Data for Regional Level Mapping

The use of four channels gave results comparable to those for 11 channels but with much reduced computer time.

ABSTRACT: *Resource surveys through the use of an aircraft-based scanner involve the generation of enormous quantities of spectral data in numerical format, requiring machine processing for expeditious information extraction. Computer analysis of the airborne 11-channel multispectral scanner data, to be cost effective, requires that a minimum number of channels of data be used commensurate with information requirements. The results of an investigation carried out on the Multispectral Data Analysis System (MDAS), an interactive computer, towards reduction of computer time through the use of fewer spectral channels, but without decreasing categorization accuracy, are described.*

The results of categorization of a test area of 15 km by 5 km indicate that, for a typical MDAS analysis with 36 land cover/use groups, there can be a reduction of about 130 minutes in CPU time when four channels are used compared to that involving all 11 bands. This constitutes a saving of as much as 20 to 25 percent of the total analysis time. The disk memory space for four channels is only about 50 percent of that needed for 11-channel data. The categorization accuracy is comparable, even when only four channels, instead of all the 11 channels, are used. Furthermore, the uncategorized area was 15.7 percent with 11 channels of data compared to 1.14 percent of the area when only four channels are used. Hence, in this regional level categorization, use of four channels could give comparable results with much reduced computer time.

INTRODUCTION

RESOURCE SENSING from space and aircraft altitudes is being increasingly adopted to supplement the inadequate ground based data collection methods. The use of the 11 channel airborne multispectral scanner for land use mapping over large areas results in the generation of vast quantities of digital spectral data which requires computer processing for expeditious extraction of information (Table 1). Operational use of computer techniques for reduction of spectral data into resources information would, however, depend on its cost-effectiveness.

Optimum computer analysis of the airborne 11 channel scanner data requires that the minimum number of channels of data be used commensurate with information requirements. It may not be always necessary to use all the 11 channels of data since the marginal increase in information generated may not warrant the more than proportionate increase in computer time. For instance, one water quality study indicated that only three channels (bands 2, 6, and 8) of data need to be used to produce comparable classification accuracy (Johnson, 1977). Another investigation demonstrated the feasibility of using just four out of 11 bands to ensure effective separation of water from other categories (Ayyangar and Bhan, 1978). The impetus towards the present investigation on optimizing computer analysis of multispectral data was given by the recent airborne scanner survey over an area of approximately 750 sq km in the northeastern part of India. The survey was conducted to obtain information with regard to flood inundation along a selected reach of a major river system. Digital analysis was performed on the interactive Multispectral Data Analysis System

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TABLE 1. AIRBORNE MULTISPECTRAL SCANNER CHANNEL ALLOCATIONS

Channel	Wave length band (micrometre)
1	0.38– 0.44
2	0.44– 0.49
3	0.49– 0.54
4	0.54– 0.58
5	0.58– 0.62
6	0.62– 0.66
7	0.66– 0.70
8	0.70– 0.74
9	0.77– 0.86
10	0.97– 1.06
11	9.75–12.25

(MDAS), operated at the National Remote Sensing Agency (NRSA) facility at Hyderabad.

BASIC DATA

The airborne survey involved the use of an 11-channel scanner mounted on a DC-3 Dakota aircraft to collect multispectral data from an altitude of about 7500 ft above ground level. The scanner survey was conducted along 18 flight lines with an average 7200 scan lines each.

MULTISPECTRAL DATA ANALYSIS SYSTEM

The analysis was performed on the Multispectral Data Analysis System (MDAS), an interactive computer designed to use data from satellite and airborne multispectral scanners to produce accurate results in quantity (Bendix, 1976). Operating on the basis that all objects have identifiable spectral signatures, the MDAS is interactively trained by the investigator to derive a set of optimum processing coefficients to be used by a multivariate normal algorithm to process the data into categorized results. This is performed by a series of built-in programs for conversion of high density digital tape (HDDT) to computer compatible tape (CCT) format, tape display on TV screen, categorical analysis, generation of categorical table, categorical processing, and filming. The system essentially consists of the computer subsystem in which a DEC PDP 11/35 performs MDAS control, a disc memory to store software programs and problem data, and dual magnetic tape units to input unprocessed computer compatible tape data and to output categorized data. A color TV monitor presents a movable color coded image display of the tape data. The operator interactive panel enables the system analyst to interact with MDAS by moving the display field, changing the image scale, and positioning and shaping the cursor to select, enter, and modify training set data. A precision Optronics drum film recorder/digitizer provides the capability to produce annotated, corrected, and categorized film output products, as well as to input aerial imagery, radar imagery, or any data on film. The multivariate categorical processor is a hardware unit for highspeed multispectral data categorization. The high density digital tape unit provides the capability to input the 11-channel airborne scan data. A Data Grid digitizer enables corrections of satellite data to be made to conform to base maps. Initiation and termination of built-in programs, output of statistical data, and other interaction is made possible through a Decwriter.

STUDY BACKGROUND

The analysis effort in this survey was made extremely difficult because of

- The change in the setting of the scanner made along a line to avoid saturation of spectral data,
- Nonuniform illumination conditions along a flight line and between lines, and
- Specular reflection from water surfaces.

The second difficulty arose as a result of the necessity to fly over the area to cover high flood flow conditions even though the season was unfavorable for aerial surveys, with unacceptable cloud cover, haze, and other meteorological conditions. Though normally flying time would be restricted to avoid sunglint problems, the limited sunshine hours available in this season made it necessary to take this risk. These constraints meant that a single set of statistical coefficients for categorical processing did not hold good along the entire line or for adjacent lines. Even along a line, depending on degree of non-uniformity of illumination conditions, more than one analysis had to be performed and sets of processing coefficients generated. For instance, while the entire line No. 13 could be analyzed once, lines 11, 7, and 5 needed two sets of coefficients to suit the two different illumination conditions prevailing along the lines. Furthermore, extrapolation of categorization statistics between lines was impossible.

The increase in the total analysis effort necessitated development of a strategy to reduce the computer time per analysis so that the analysis cost would be acceptable to the user.

After experimentation, it was found that comparable categorization results could be obtained by considering just four channels as would be obtained from all the 11 channels. This paper describes the results of the cost reduction study undertaken as part of the operational scanner survey project.

ANALYSIS METHODOLOGY

Airborne multispectral data originally recorded on HDDT was converted to CCT's prior to categorization. Though a CCT can contain a maximum of 4000 scan lines, it was felt advantageous to cut for

TABLE 2. FLOOD PLAIN LAND-USE CLASSIFICATION SCHEME

1. Water
2. Wetlands/Water logged or Flooded Areas
3. Channel bar—sandy
4. Fallow Fields
5. Cropland
6. Forest land
7. Scrub land
8. Barren land/Pasture

only 2400 scan lines since filming in the Optronics P-1700 film recorder/digitizer is limited to 2400 scan lines. Otherwise, for a flight line of average 7200 lines length, two CCT's of 4000 lines data would have involved filming in four parts with a consequent increase in filming time. Incidentally, an increase in color composing time and difficulties in printing efforts would have also resulted in ensuring color uniformity between adjacent pieces to facilitate mosaicking.

A test CCT convering an area of 15 km by 5 km was then analysed on MDAS to generate regional flood plain land use information (Table 2). The 'ground truth' was provided by aerial photographs acquired simultaneously with the scanner data. Post-classification check regarding categorization accuracy was also based on simultaneous photography.

Previous experience had shown that the use of all the 11 bands involves large amounts of computer time, which may be unacceptable to the user. Since regional level land-use classification has been successfully attempted from satellite data in four spectral bands, it was decided to explore the possibility of using just four out of the 11 M²S bands for this purpose. Since the review of the spectral signatures of specified categories in the 11 bands did not indicate any definite criteria for selection, the four spectral bands for inclusion in the analysis were selected heuristically. Though a trial and error procedure may seem time consuming at first, in practice a few trial analyses with different combinations sufficed to reach the final selection of bands 5, 7, 8, and 9. The results of categorization of the sample area into 36 land-use groups indicate a significant reduction in computer time when only four channels are used (Table 3).

CATEGORICAL ANALYSIS

The categorical analysis (CA) program in MDAS performs the categorical analysis of operator supplied training and produces coefficients to allow categorization of different surface features based on their multispectral response. When four out of 11 channels were used, in each CA operation with 36 groups there was a decrease in time of 19 minutes. Typically, ten CA operations are performed per analysis, with about six in the initial stages with an average reduction of 9 minutes, and four operations in the latter stages with an average reduction of 19 minutes, resulting in a total reduction of 130 minutes per analysis. This can be as much as 20 to 25 percent of the total analysis time. Since generation of the land-use information for the entire project area consisted of 17 analyses, the use of four-channel data in the CA program alone would have decreased the computer time by as much as 37 hours.

TABLE 3. COMPARISON OF CPU TIME

Program	Time taken in seconds	
	4 channel	11 channel
Categorical Analysis (CA)	647.86	1779.06
Categorical Table (CT)	476.70	543.28
Categorical Process (CP) (for 500 lines)	540.6	560.64

DISK MEMORY

Typically with 36 groups, the CA result with four-channel data is stored in 120 blocks in the disk, while the use of 11 channels involves 253 blocks, resulting in fewer analyses per disk. When all the 11-channel data are used, perhaps not more than three to four analyses could be performed with one disk. Furthermore one should have a minimum of 300 free blocks before starting the CA programme, because otherwise the program stops midway due to storage space constraints.

CATEGORICAL TABLE (CT) AND PROCESSING (CP)

The categorical processing and categorization table programs do not show appreciable difference of time whether 4- or 11-channel data are used.

TABLE 4. TRAINING SET CATEGORIZATION TABLE
REJECTION LEVEL: 8 STANDARD DEVIATIONS
NUMBER OF GROUPS: 36

Category	Sample area in hectares	Accuracy level in percent	
		4 channel data	11 channel data
Water	9.84	98	96
Wetland	1.72	99	90
Sand	0.47	100	100
Crop	0.58	96	81
Fallow land	0.58	99	95
Barren	0.26	99	93
Forest	0.29	100	92
Scrub	0.16	67	71
Average Accuracy Level		95	90

Categorization Accuracy

The results of categorization of the training sets shows that use of four-channel data could result in comparable accuracy levels (Table 4).

Though scrub has been categorized correctly only at 67 percent, a review of statistics indicate that the misclassification is only between scrub and forest categories. Overall classification accuracy over the entire strip was checked through direct comparison with simultaneously acquired aerial photographs at a few selected points and found to be acceptable.

An additional advantage of using fewer channels was the reduction in area left uncategorized after categorized processing. For instance, on the test site, the uncategorized area was 15.7 percent with 11-channel data compared to 1.14 percent when only four channels are used. 11-channel classification would require enormous ground truth for reduction of the percent area uncategorized to acceptably low levels, due to the increased spatial and spectral resolution of airborne scanner, and would not be cost-effective when only a broad first level land-use classification is required. In contrast, while four channels are used, almost the entire area is generalized into the specified major land-use categories as a result of a less complicated feature space and, thus, a regional thematic map is obtained cost-effectively.

Conclusions

Computer analysis of 11-channel airborne scanner data can be made cost effective by the use of fewer channels and without sacrificing classification accuracy, when regional selection of level information is to be obtained. Selection of channels for analysis can be made, depending on the type of resource information to be generated, through a few trial and error iterations.

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