LARS Contract Report 033080

A QUANTITATIVE APPLICATIONS-ORIENTED EVALUATION OF THEMATIC MAPPER DESIGN SPECIFICATIONS:

INTERIM REPORT FOR THE PERIOD

October 1, 1979 to March 31, 1980

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OVERVIEW

We describe in this report our activity for the six-month period October 1, 1979 - March 31, 1980 related to "A Quantitative Applications-Oriented Evaluation of Thematic Mapper Design Specifications." Our activity for the period October 1, 1979 - December 31, 1979 was reported in our letter of January 11, 1980 (attached). This report emphasizes our activity for the period January 1, 1980 - March 31, 1980.

Two major tasks have been addressed during the first half of the study. First, a literature search, discussed in our letter of January 11, was initiated to compile and understand available information relevant to evaluating the Thematic Mapper specifications. Second, a project implementation plan was prepared for determining the effects of system noise on classification accuracy and this work was initiated.

Our activity for the period January 1, 1980 - March 31, 1980 has included (1) initiating the implementation plan reported January 11, 1980, (2) determining that the plan as described was unsatisfactory, (3) investigating and documenting the deficiencies, (4) revising the implementation plan, and (5) initiating the revised plan (see Figure 1). Additionally, reviews of two reports were written.

While the detailed features of several sections of the plan have been significantly changed, the major topics remain unchanged: (1) Degradation of the spatial resolution of the aircraft scanner data (5 meters) to the resolution specified for the Thematic Mapper (30 meters), (2) use of LARSYS processors to obtain the statistics of each information class in each scene, (3) addition of noise, and (4) estimation of the resultant classification accuracy.

Figure 1 lists the computer programs and steps necessary for investigating the effects on classification accuracy of both the addition of noise to the data and the band-to-band misregistration of the data. As discussed in the letter of January 11, 1980, data acquired during the Corn Blight Watch Experiment (Table 1) are being used for the purposes of this study.

RATIONALE FOR REVISED PLAN

The details of the implementation plan are substantially changed from the originally proposed implementation plan. The changes result from our decision not to use in the project the Unified Scanner Analysis Package of computer programs. One primary and several secondary considerations precipitated this decision.

The primary reason for the decision not to use the scanner analysis package was that the spatial correlation of the aircraft scanner data from the Corn Blight Watch Experiment could not be correctly modeled by the computer algorithms in these programs. In an analysis involving the scanner analysis package, the spatial correlation of the data must be determined because the spatial resolution of the aircraft scanner data (5 meters) must be degraded to the spatial resolution of the Thematic Mapper (30 meters). The algorithms in the scanner analysis package assume that the spatial correlation of the data can be described approximately by an exponential decrease with ground distance. The Corn Blight data do not always satisfy this condition, one obvious reason being that many of the fields contained seed corn planted with different varieties in alternating multiple row strips. In the data from many of these fields, the strips manifest a Moiré pattern and a periodic, non-exponential spatial correlation function violating the exponential assumption required for use of the scanner analysis package.

To further investigate and document the spatial correlation properties of the data and the ability of the scanner analysis package to model these properties, seven fields (three corn fields, three soybean fields, and one woods) were selected for intensive study. As a basis for selection, each field appeared to have a spatially uniform spectral response, containing no Moiré pattern, as determined by gray-scale computer printouts. Using the scanner analysis package, the spatial autocorrelations and spatial cross-correlations were computed for each pair of simulated Thematic Mapper spectral bands. (Simulation of the Thematic Mapper spectral bands is discussed below.) Only for one field was the exponential model adequate for describing the spatial correlation properties of the data for all combinations of pairs of bands. For all other fields, the spatial correlation properties of one or

more pairwise combinations of bands did not fit the exponential model. Because each of the seven fields was selected for its apparently uniform spatial response, devoid of a Moiré pattern, it was concluded that the scanner analysis package was not able to adequately model the spatial properties of the data, even under the best of circumstances. This conclusion rendered pointless further work with the Unified Scanner Analysis Package on this project.

Several secondary considerations support the decision not to use the scanner analysis package. First, an analysis involving these programs would be based entirely on "pure pixels," each representing only one ground cover type, failing to account for the likely presence of mixed pixels containing an average of the responses from two or more ground cover types. Yet if fields are small, the results of several studies (references 4, 16, 20 in the January progress letter) suggest that mixed pixels have significant impact on classification performance. Second, the Hughes Aircraft Company monthly reports show that noise dependent on signal amplitude, "shot"noise, is expected to be present in the Thematic Mapper data in addition to white, Gaussian noise. Yet only white Gaussian noise is added by the scanner analysis package programs to simulate the effects of noise in the data. Third, programs do not include computer programs necessary for determining the effects on classification accuracy of band-to-band misregistration, an important part of this study. If the scanner analysis package were to be used in this study, the needed algorithms would in any case have to be developed and the appropriate programs modified in the scanner analysis package.

The Unified Scanner Analysis Package was chosen originally as the analysis vehicle because it appeared to represent a suitable and inexpensive approach to analyzing, using actual data, the properties of a hypothetical scanner system. However, due to its limitations which have now become apparent, the applicability of this software package for meeting the project objectives has proved ephemeral. Modification and further development of the package to overcome these limitations would require significant resources and time that we feel are better allocated elsewhere, as indicated by the revised implementation plan.

REVISED IMPLEMENTATION PLAN

The revised implementation plan, as shown in Figure 1, involves extensive use of LARSYS computer programs which are widely used and well documented. Two steps in the plan require programs not in LARSYS and three steps require modifications to existing LARSYS programs.

The first step in the revised implementation plan involves normalizing each column of data in a flight line to obtain a response which on the average is constant as a function of scan angle (view angle) across the flight line. Scanner response variations with scan angle are due fundamentally to the properties of both the atmosphere and the scene. For example, the ratio of the amount of shadowed to illuminated foliage in the instantaneous field of view of the scanner may change significantly with scan angle, even becoming zero in the anti-solar direction of the "hot spot." The normalization process represents the best available procedure for reducing the effects of these variations upon the classification process. The computer program required for this step, MANREA, originally was developed in support of the Thematic Mapper simulation project at LARS. No additional programming is required to apply MANREA to the data of this project.

In step 2 of the revised implementation plan, data for the Thematic Mapper channels are simulated by appropriately selecting and averaging data from the aircraft scanner channels (Table 2). The computer program DUPRUN in LARSYSDV is used without modification.

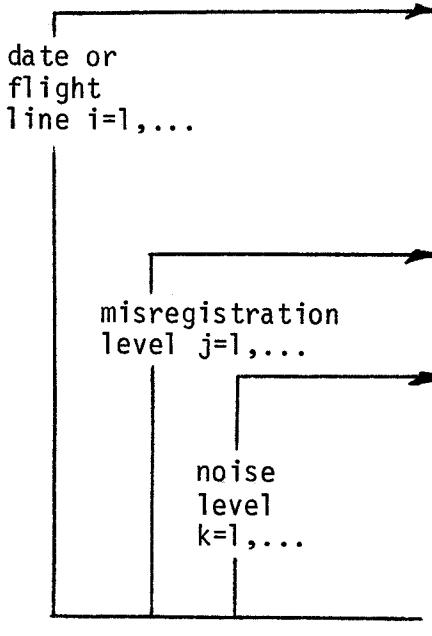
Step 3 involves resampling the data in each scan line to obtain standard-sized pixels in the across-track direction. The resampling process, accomplished using a nearest-neighbor algorithm, compensates for the variation in the ground size of the instantaneous field of view of the aircraft scanner as a function of scan angle. The effective ground size of the resampled pixels, three meters, will facilitate later degradation of the spatial resolution to 30 meters. One computer program, RESAMP, has been written and DUPRUN has been modified in support of this step.

Work is in progress on steps 4, 5, and 6, entailing further modification of the DUPRUN program. These steps involve band-to-band misregistration, degradation of the spatial resolution, and addition of noise.

Steps 7 - 11 require use of the standard LARSYS programs to determine classification accuracy.

REVISED SCHEDULE

Due to the unforeseen developments described above concerning the usefulness of the Unified Scanner Analysis Package, it was not possible to complete the noise sensitivity portion of the study by March 31, 1980, as previously planned. As of this writing, however, software development for the revised approach is well along. The compatibility of this software with the requirements of the registration sensitivity study may enable us to make up the lost time during the next quarter.



Step	Description	Computer Program
1	Radiometric adjustment for view angle	MANREA
2	Combine aircraft spectral bands to simulate TM spectral bands	DUPRUN (LARSYSDV)
3	Resample to obtain standard-size pixels across track	RESAMP and modified version of DUPRUN
4	Misregister bands	
5	Degrade spatial resolution of each band	Modification of DUPRUN (LARSYS)
6	Add noise	
7	Compute statistics	STATISTICS (LARSYS)
8	Compute separability	SEPARABILITY (LARSYS)
9	Merge statistics	MERGESTATISTICS (LARSYS)
10	Classify	CLASSIFYPOINTS (LARSYS)
11	Determine classification accuracy	PRINTRESULTS (LARSYS)

Figure 1. Revised Implementation Plan

Table 1. Data in runtable at LARS from the 1971 Corn Blight Watch Experiment

	Dates of Flights									
Flightline	May 17-22	June 28-30	July 12-21	July 27-31	Aug 12-17	Aug 28-29	Sept 14-15	Sept 24	Oct 5	TOTAL
206					X	X	X			3
207					X	X	X			3
208	X	X	X	X	X	X	X	X		8
209					X	X	X			3
210		X	X		X		X			4
212					X					1
218					X					1
219			X							1
221			X		X					2
223	X	X	X	X	X	X	X		X	8
225				X	X					2
230			X		X	X				3
Number of flightlines with data available	2	3	6	3	11	6	6	1	1	39

Table 2. Simulation of Thematic Mapper wavelength bands using aircraft bands

Wavelength Limits of Aircraft Bands	Aircraft Bands Used to Simulate Thematic Mapper Bands	Wavelength Limits of Thematic Mapper Bands
0.46 - 0.49	(0.46-0.49)+(0.48-0.51)	0.45 - 0.52
0.48 - 0.51		
0.50 - 0.54	(0.52-0.57)+(0.54-0.60)	0.52 - 0.60
0.52 - 0.57		
0.54 - 0.60		
0.58 - 0.65		
0.61 - 0.70	0.61 - 0.70	0.63 - 0.69
0.72 - 0.92	0.72 - 0.92	0.76 - 0.90
1.00 - 1.40		
1.50 - 1.80	1.50 - 1.80	1.55 - 1.75
2.00 - 2.60	2.00 - 2.60	2.08 - 2.35
9.30 - 11.70	9.30 -11.70	10.40 -12.50

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January 11, 1980

Mr. Frederick Gordon
Code 902
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Ref: NASA Research Grant NSG 5414

Dear Mr. Gordon:

We describe briefly in this letter our activity related to "A Quantitative Applications-Oriented Evaluation of Thematic Mapper Design Specifications" for the period October 1, 1979 - December 31, 1979.

Two major tasks were addressed during the first three months of the study. First, a literature search was initiated to compile and understand information relevant to evaluating the Thematic Mapper specifications. Second, an implementation plan was prepared for addressing the first part of this study, determining the effects of system noise on classification accuracy.

Several references (annotated with an '*' in the enclosed bibliography of information acquired to date) bear directly on the goals of this study.

ERIM publications consider the theoretical and practical aspects of misregistration (4,16), and the spatial, radiometric and spectral resolution of the Thematic Mapper (20). LARS conducted an empirical study (14) of the Thematic Mapper scanner parameters. One LARS publication (29) examines in detail the addition of white Gaussian noise to one run of scanner data. Several LARS publications (13,18,19,30) provide both the theory and documentation necessary to understand and use the Unified Scanner Analysis Package (USAP), a set of computer programs available at LARS for performing simulation and parameter studies of multispectral scanners. The USAP programs will be used in this project.

The remaining references in the bibliography provide more general information, several discussing the spectral properties of scanner data. The potential importance to economic geology of using the two Thematic Mapper bands in the middle infrared for mapping hydrothermally altered land areas is discussed (1). Many references (8,9,10,22,23,27) consider the spectral properties of soils and healthy and stressed vegetation. Several references (6,7,11, 15,24,25,28,34) consider the hardware and engineering aspects of the design of the Thematic Mapper and other satellites, while other references (2,3,12, 17,21,31) discuss preprocessing techniques.

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Implementation of the plan for determining the effects of system noise on classification accuracy will involve analysis of data taken during the 1971 Corn Blight Watch Experiment. Data set selection was based on (1) the wavelength range and number of channels of the data available, (2) apparent lack of noise in data, (3) availability of ground reference data ("ground truth"), and (4) diversity in data set (i.e., does the data set adequately represent large/small fields, early/middle/late time periods in the crop calendar of several economically important crops, and other important information classes such as water and forests). Measured by criteria 1 and 2, the quality of the Corn Blight Watch data, acquired with the multispectral line scanner in the instrumented C-47 aircraft from the University of Michigan's Willow Run Laboratories (the predecessor facility to ERIM), is remarkably good. Considering criteria 3 and 4, there are 39 runs from 12 different Corn Blight Watch flightlines available at LARS. The data were taken throughout the 1971 corn growing season in the western one-third of Indiana and represent some variety of field sizes and cultural practices from the northern to the southern part of the state. Data from another potential source, the two multispectral scanners used in the Large Area Crop Inventory Experiment (LACIE), sometimes appear noisy and do not always contain the requisite 7 spectral channels in the proper wavelength regions.

The implementation plan to determine the effects of system noise on classification accuracy consists of four parts: (1) Degradation of the spatial resolution of the aircraft scanner data (5 meters) to the resolution specified for the Thematic Mapper (30 meters) (2) use of LARSYS processors to obtain the statistics of each information class in each scene, (3) addition of noise, and (4) estimation of the resultant classification accuracy. If possible, the data used for analysis will be taken from the center portion of each scan line, obviating the need to apply the radiometric and spatial corrections to the data. Corrections usually must be applied to data taken at large scan angles and adjusted for the varying light scattering properties of vegetative canopies and atmosphere and the ground spot size of the scanner instantaneous field of view (IFOV), each a function of scan angle.

The spatial resolution of the data will be degraded to 30 meters in both the across-track and down-track directions, using a Gaussian weighting window.

To select training fields and generate statistics, the training procedures developed for the Corn Blight Watch will be used whenever appropriate. Available ground reference data tabulate the crop planted by field.

The addition of zero-mean, band-limited white Gaussian noise to the data will be simulated by degrading, in a methematically proper fashion, the statistics of each information class. Using the USAP computer programs, the classification accuracy will be calculated for each degradation of the information class statistics, simulating the addition of increasing amounts of noise to the data. This approach avoids having to actually classify the data. Programs in USAP integrate error functions computed from the statistics of the training fields, a less costly and less time-consuming approach to obtaining the classification accuracy than actually classifying the data.

The results, to be presented in both graphical and tabular form, will document the effect on classification accuracy of noise added vs. information class and date during the growing season.

During the period January 1, 1980 - March 31, 1980, the first portion of this study, determining the effects of system noise on classification accuracy, will be completed. Work on the second portion of the study will begin. Also during this period, we will forward our comments concerning both the "Thematic Mapper User Sensitivity Analysis -- First Interim Report," Hughes Aircraft Company, December 1979, and "Thematic Mapper Performance Parameters as Related to User Considerations -- Final Report," General Electric Company, July 1, 1979.

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