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First Interim Report for IBM Houston Scientific Center/LARS Joint Study

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First Interim Progress Report for IBM Houston Scientific Center/LARS Purdue Joint Study Program

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Summary

Progress in the joint study effort between IBM-HSC and LARS* Purdue is reported on in this first report. Activities during the first phase of the study concentrated on analysis of the HSC vidicon film scanning system and comparison of data derived from this system with similar data from the LARS Purdue/University of Michigan multispectral airborne scanner system and data from a rotating drum film scanner. Also work by HSC on a closed boundary finding algorithm for image data is described.

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Introduction

A variety of techniques currently exist for the acquisition, digital processing and display of remotely sensed earth resource data. This report first briefly summarizes the major categories of techniques and then discusses the evaluation of acquisition, processing, and display methods under joint study in the Houston Scientific Center, LARS Purdue study.

We are entering an era of increased interest in the analysis of image data as it relates to a view of the land around us, its resources and variables of environment. This has classically been an area of visual study, whether from mapping surveys, photointerpretation of aerial photography, or general visual acquisition and interpretation of environmental data. With the growing ability of digital computers to process large volumes of information rapidly, more interest is being given to the role of automatic acquisition and processing of synoptic data as it relates to a study and understanding of the pattern and components of picture data.

The new field of remote sensing has arisen to acquire this data from a distance. That distance may be a few feet to a hundred miles. Remote sensing has been used for a number of years in aerial exploration and interpretation. The major changes have been in the increasing amounts of such data and the growing potential of automatic processing.

This report discusses those aspects of remote sensing which acquire data in image form. This data is acquired on a point by point basis using scanning sensors in several regions of the electromagnetic spectrum, or photographically as an image representing selected portions of that spectrum. The promise is that the utilization of spatial, spectral and temporal information in synoptic analysis greatly increases the efficiency for the extraction of certain types of earth resources information through remote sensing.

Different system requirements exist for different applications in the analysis of remotely sensed data. On the one hand, sophisticated techniques at the forefront of the state of the art are needed to acquire and study as much information as possible in a research mode to meet the needs of the investigator. On the other hand, practical application spin offs of reduced complexity are becoming increasingly common for special circumstances using readily available technology. It was for this reason that it was decided to evaluate the capabilities of a conventional vidicon image scanner, small processor and television display for analysis of photography. This approach was compared with high resolution densitomater photographic scanning and multispectral airborne scanner techniques. The vidicon system is described in Houston Scientific Center reports (see references 1 and 2). The LARS multispectral scanner and analysis system is described in reference 3 and the densitometer film scanning and analysis system is described in reference 4.

The vidicon system will be evaluated as to its capacity as a film data conversion device and the impact of its deficiencies on the automatic processing and classification of ground cover. Finally, conclusions will be drawn as to modifications of the vidicon technique and processing methods which might optimize the use of this approach.

It is not suggested in this evaluation that any approach is preferable to any other. However, a clear analysis of the tradeoffs of time and accuracy may assist in the selection of future methods within the appropriate range of techniques to optimize for certain operational requirements.

Vidicon System Analysis

In these studies one of the techniques has been to use a standard TV camera for extraction of data from color IR ektachrome transparencies using color separation filters. Using the scan converter digitizing system described in reference 1, photography of several segments of agricultural land in southern Indiana obtained as part of a LARS research program in 1970 was digitized by the IBM 1800 computer. This data was written on tape using an 1800 to system 360 channel adapter and 360 tape programs. The data was subsequently analyzed and classified using the Purdue LARSYS system (see reference 3).

The vidicon acquisition system was observed to have advantages and disadvantages which will be summarized. Some of the disadvantages noted in this series can be minimized if certain standardization and calibration procedures are carried out. In general it was noted that the expected disadvantages of noise and resolution were not as serious as anticipated.

Advantages

The state of the art in the video technology area makes the use of conventional video I/O for picture scanning a low cost, flexible, easy-to-use method compared to other higher precision alternatives. The ability for rapid feedback of scanned and scanprocessed pictures to black and white or color TV monitors enhances editing tasks. The use of pseudocolor presentations on the color display can further assist the recognition of marginally differentiated areas because of the possibility of using additional contextual information in this manner. Once digitized, a variety of small computer programs may be used to further enhance the data for visual display such as subtraction, edge enhancement, etc. This selection may be helpful before sending the data to a large processor for classification. No preprocessing enhancement was carried out on the classification reported here.

Intensity level slicing and histogram preparation of selected data areas was carried out with fair ease and rapidity using the 1800 system in order to get a general feeling for the capabilities of the system. Gross changes in field spectral characteristics were easily recognized in such studies, e.g., corn vs. soybeans at this stage of the growing cycle (August - September). Also, one of the advantages of the vidicon system is the ease in using material of differing formats. Both transparencies and opaque prints and different sizes have been used.

The need for registration of color separations is obviated as a result of needing only to change the filter in front of the camera. A variety of filters can be used although those maximally separating the emulsions were the most logical choice. However, the vidicon in this context could be used on the original scene itself where specific filters could have marked advantages. This is the approach in a much more refined sense for the ERTS satellite. Sequential manual registration of the same scene was found to be fairly easily achieved within several pixel (resolution) elements on the 256 by 350 arrays studied. Besides x,y translational registration, magnification and spatial distortion can also be compensated for by positioning the TV camera on the scene at the required angle and distance.

Disadvantages

A series of studies were carried out to more clearly define the disadvantages of the vidicon scanning technique as related to the sources of errors involved. These will be listed in order of importance with comments on methods to minimize their effects.

1. No Relative or Absolute Calibration

In conventional TV usage, and here as well, this characteristic may be considered an advantage. It is characterized by automatic gain and bias control which compensates for changes in picture characteristics to allow each picture to use the maximum dynamic range. The result for quantitative work, however, is that the bias and gain, as well as the non-linear gamma regions will vary from scene to scene depending on luminous content. A method for calibrating this which has not been completely evaluated is to use a calibrated two level wedge in conjunction with each

each picture to determine the relative correction necessary. This might entail using both transmitted and reflected light when the scene does not allow an adjacent calibration transparency.

2. Non-Uniformity of Scanning Area

Considerable non-uniformity exists in the field of view with the edges, particularly the right hand edge of the frame, appearing less bright. This is similar to the vignetting problem in photography. It is affected by both the gain and bias of the system but can be partially corrected for by subtracting a background level of frame non-uniformity when no picture is being viewed. This correction was not made for the scenes classified in this study.

3. Dynamic Random Noise

This is caused by system electronics and may cause signal degradation of more than 5%. System non-linearities e.g., response time at edges of dark or light areas, may create systematic errors at field edges. The use of an AC light source has the potential of creating spurious patterns on the scene although the buffer capability of the vidicon surface appears to compensate for this. No attempt was made in this study to minimize these errors. Random noise has been studied in other reports (reference 2) and can be removed by averaging. Likewise noise of particular frequency characteristics which is not important in the field classification can be removed by Laplician filter approaches (reference 2).

Comparison of Film Data Conversion Methods

The contribution of the various errors to the performance of the vidicon scanner in the detection of certain agricultural crop types is given in Table 1. This table compares the values and variances of spectral responses for 2 channels for each of three sensor systems. The values and standard deviations have been multiplied by the constants shown in Table 2 in order to approximate comparable values. The changes for video data are probably scene related as discussed in Item 1 above. The agreement between methods is not expected to be close since a variety of factors effect the relative scaling and linearity of the techniques used. However, the trend appears similar and the relationship between the variability and differences between field classes is clarified. The multispectral scanner data variabilities are shown in a per channel basis even though here several channels were averaged together to approximate the single photographic channels. If the variability between multispectral channels is taken into account, the total amount of field variability is similar in all three methods indicating a major source of variation is the point to point variability within a field. Certain field types, for example, mature corn (subclass, B, C) are visually quite heterogeneous. The vidicon scan for B and C showed bivariate distributions and consequently the low and high IR peaks were separated and placed in the B and C categories. The higher std. deviation, however, still refers to the double peak. This arrangement conforms closer for comparison purposes to the other methods. Some variation on the actual part of the fields classified by each technique may have led to the variability in results.

Comparison of Computer Classifications

The LARS/Purdue multispectral pattern classification system (LARSYSAA) was employed to classify a set of fields in a test site in sourthern Indiana. The color infrared photography and multispectral scanner data were gathered in late August 1970 near Worthington, Indiana by the NASA RB57F aircraft and by the University of Michigan IST DC-3 aircraft (see reference 5). The film scanned by the HSC vidicon system was reformatted to the standard LARS format for analysis by LARSYSAA. The same CIR film was separated by a standard commercial process and scanned and digitized on an Optronics P-1000 rotating drum microdensitometer. This data was reformatted and placed in the LARS format. The three color scans from the IBM scanner were digitally registered using the LARS image registration system (see reference 6), and a 3 channel (green, red, reflective infrared) data tape was produced. The same process was carried out for the microdensitometer scans. The third data form was multispectral scanner data. Three of the available 13 channels of this data were used to approximate the green, red, and IR bands from the photography.

The automatic classification of this data is summarized in Table 3 which includes a comparison with visual photointerpretation results. The results are what would be expected from the data of Table 1 with a decrease in recognition accuracy from that for the multispectral scanner through that for the photoseparation scans to the higher noise characteristic vidicon. Also, omly two channels were available from the vidicon system due to loss of the blue filter scan which resulted from low transmission in the blue and inadequate illumination. However, the accuracies are not as method-dependent as might be expected with this particular class of identifications because of the intrafield variability described earlier. Classification errors on the corn classes as would be expected are primarily between adjacent classes.

An important factor in this classification method is the point to point classification made in which each element of a field is classified independently of its neighbors. If the per field classification approach (see reference 7) were to be used increased field detection accuracy related to ground truth would result. It should be recognized, however, that in these studies fields are used as their own training sets and primarily show the recognizable variability in the total distribution of training set fields used.

Proposed Closed Boundary Field Detection Algorithms

Becuase many of the deficiencies of the per point classification technique can be minimized by using a per field rather than a per point classification approach, a field detection algorithm was developed and tested on the vidicon data studied. The per field classification approach is totally different from the per point approach. In the per field approach a sample is classified rather than a point (vector).
In the case studied here the sample is all vectors from an agircultural field. In per field classification statistics (either

parametric or non-parametric) is made as to which class the sample falls into. This method is discussed by Huang in reference 7 and by Wacker in great detail in reference 8. The field detection algorithm is required as part of the per field approach to define the sample (i.e., field) which is to be classified. A reliable field boundary finding capability is tantamount to implementation of an automatic per field classification system.

The closed boundary field detection algorithm (CBF) was implemented remotely using the IBM Cambridge, Mass. facility CP-67/CMS) from the Houston Scientific Center using a 2741 terminal. The original data tapes were sent by mail. Selective statistical and editing criteria as well as printouts via 2780 are done remotely. A detailed report on the CBF algirithm will be prepared following its extension to incorporate multiple channel data and training sets. Both single and cumulative techniques have been used to scan a picture as a group of subcells containing various numbers of pixels. On the single comparison technique each subcell is compared with each adjacent subcell and if the same it is so grouped. If different, a new group classification is tarted. In the cumulative technique, each new subcell is compared to all of the subcells previously forming an adjacent group. As a final step all groups whether adjacent or not are compared for similarity. A standard Student 't' test is used with the level of signifiaance of the test being one of the input parameters. The general technique with exception of the 't' test is similar to the method reported by Muerle (9) and may be contrasted with the clustering approaches used by Wacker (10) at LARS.

The boundary finding algorithm was applied to data from the vidicon scanner obtained from the photography of the agricultural test site. Figure 1 is a photograph of the area obtained from the color IR tranparency. The statistics generated by t e CBF lagorithm are listed in Table 4. A computer printout of the results of the CBF algorithm operating on this data is presented in Figure 2. The major fields found by the algorithm are labeled in Figure 2. Work is continuing on this algorithm to add multi-channel analysis capability and to improve the reliability of the results.

Closure

In summary, a video digitizing and display system can be sued for scanning and displaying remotely sensed data stored on color IR film. When classified by existing techniques, the results obtained were compared to methods using photometric scanning of photographically separated color IR film and high resolution multispectral airborne scanner approaches. A closed boundary field detection algorithm is presented which enables total field classification as opposed to point classification. It appears that the video scanner approach may have a place in the spectrum of approaches to remote sensing data handling particularly if it can be used in a direct sensing mode either on line or by video tape. The closed boundary algorithm shows promise as a means for automating the field classification method and continues to be researched under the joint study program.

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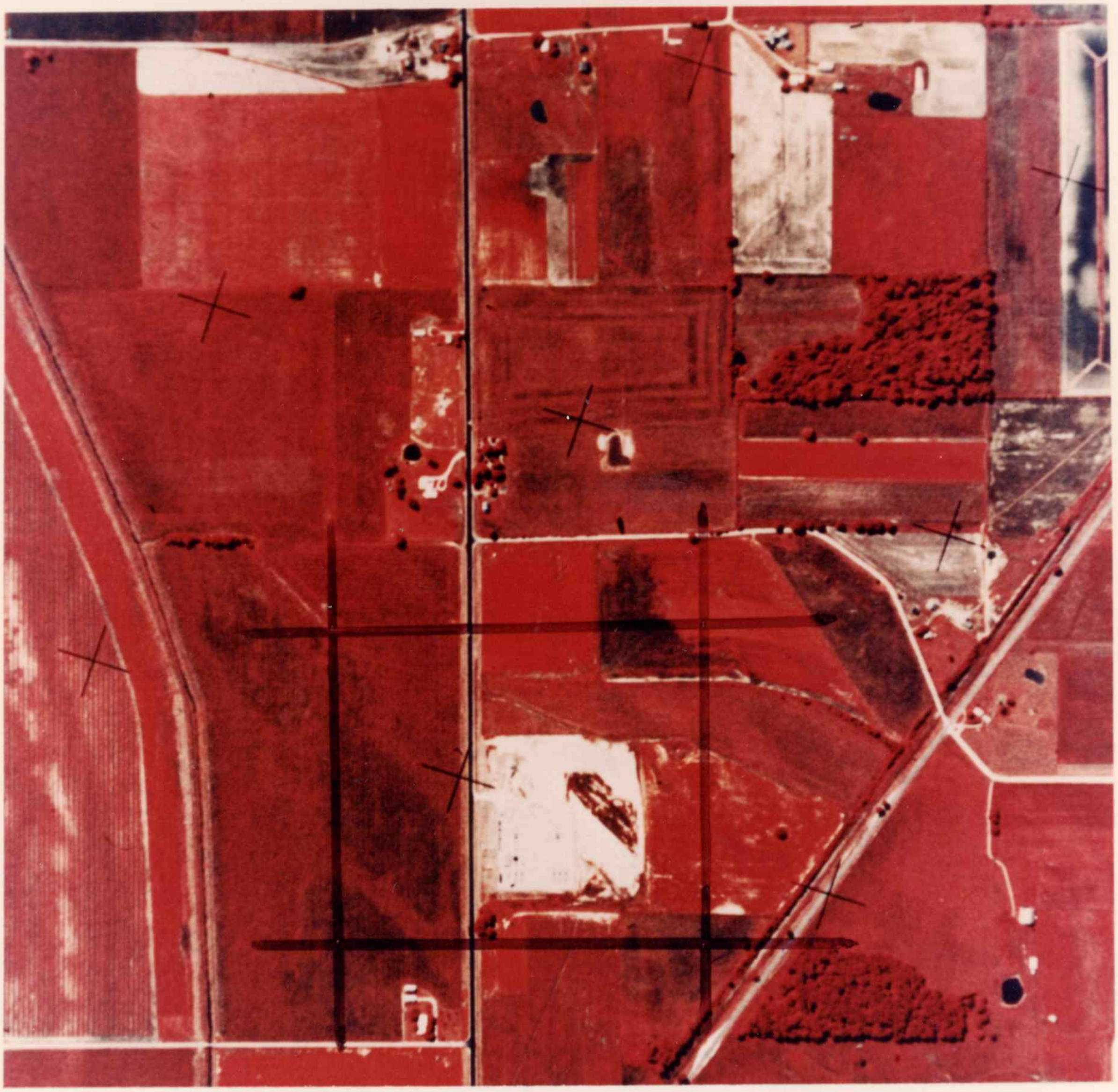

Figure 1. Digital Display Photograph of the .59-.71 micron (Red) spectral channel of the agricultural test site used in the study.

Table 1. Comparison of Vidicon Film Scan Data, Microdensitometer Film Scanned Data, and Multispectral Airborne Scanner Data for Agricultural Fields in August 1970.

Scan Method:	Vidicon Scan of CIR		Microdensitometer Scan of CIR Photoseparation		Multispectral Airborne Scanner	
Channel(s): Field	Red	IR	Red	IR	Red	IR
Corn A	9.5±1	14.5±2	11±1	13.5±1	10.5±0.5	13.5±1
Corn B	13±4	11±3*	13.5±2	7.5±2	10.5±1	9.0±1
Corn C	13±4	16±4*	14.0±2	7.5±2	13±0.5	15±0.5
Soybeans	7±2	19.5±3	8±2	18±1	8±1.5	11±2.5
Pasture	30±5	36±3	26±5	20±7	22±3	18.5±5
Mean	±26	±30	±20	±25	±12	±17

* Comparable bimodal distributions

TABLE 2

SCALE FACTORS USED FOR TABLE 1

Scan Method	Vidicon		Color IR Ektachrome Photoseparation		Multispectral	
Channel	Red	IR	Red	IR	Red	IR
Corn A	x0.8	x0.8	x0.2	x0.15	x0.1	x0.1
All Others	x0.6	x0.6	x0.2	x0.15	x0.1	x0.1

TABLE 3

CLASSIFICATION ACCURACY COMPARISONS

Method	Visual	Vidicon	Photoseparation		Multispectral
No. of Channels Used for Classif.	1	2	2	3	4
Class	(Panchromatic)	(Red,IR)	(Red,IR)	(Green,Red,IR)	(Best 4 of 13)
Corn Total	91%	88%	93%	95%	95%
Corn Subclass A	76	61	31	45	67
Corn Subclass B	73	37	52	58	76
Corn Subclass C	75	50	75	78	99
Soybean	--	80	74	92	79
Trees	--	32	79	91	92
Pasture	--	97	99	100	97
Mean	80	67	73	80	86

FIGURE 2 COMPUTER PRINTOUT OF BOUNDARY FINDING ALGORITHM RESULTS FOR AREA SHOWN IN RECTANGLE IN FIGURE 1

PIXEL GROUP SIZE IS 2 X 2

TABLE 4. STATISTICS OF FIELDS DEFINED IN FIGURE 2

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FIELD A    HAS  105 PIXEL GROUPS. MEAN =  1.0169E 01  SD =  1.0431E 00
FIELD B    HAS  610 PIXEL GROUPS. MEAN =  1.5660E 01  SD =  4.8377E 00
FIELD C    HAS   56 PIXEL GROUPS. MEAN =  2.3071E 01  SD =  6.4104E 00
FIELD K    HAS   78 PIXEL GROUPS. MEAN =  1.0526E 01  SD =  1.2060E 00
FIELD L    HAS   47 PIXEL GROUPS. MEAN =  2.4777E 01  SD =  3.8954E 00
FIELD [illegible] HAS  623 PIXEL GROUPS. MEAN =  9.1376E 00  SD =  1.2845E 00
FIELD P    HAS   87 PIXEL GROUPS. MEAN =  9.4224E 00  SD =  1.0866E 00
FIELD R    HAS   84 PIXEL GROUPS. MEAN =  1.1723E 01  SD =  2.3485E 00
FIELD 3    HAS  144 PIXEL GROUPS. MEAN =  6.2863E 01  SD =  1.3901E 00
FIELD 6    HAS   59 PIXEL GROUPS. MEAN =  5.8314E 01  SD =  7.4119E 00
FIELD <    HAS   57 PIXEL GROUPS. MEAN =  1.8487E 01  SD =  3.2492E 00
FIELD :    HAS   31 PIXEL GROUPS. MEAN =  3.9073E 01  SD =  9.4862E 00
FIELD '    HAS   62 PIXEL GROUPS. MEAN =  6.2343E 01  SD =  2.8792E 00
FIELD ?    HAS  111 PIXEL GROUPS. MEAN =  1.3234E 01  SD =  3.0894E 00
FIELD |    HAS   25 PIXEL GROUPS. MEAN =  2.9400E 01  SD =  4.5211E 00
FIELD 10   HAS   10 PIXEL GROUPS. MEAN =  4.4425E 01  SD =  9.8207E 00
FIELD 13   HAS   18 PIXEL GROUPS. MEAN =  2.0250E 01  SD =  4.7806E 00
FIELD 18   HAS   25 PIXEL GROUPS. MEAN =  1.2380E 01  SD =  1.5478E 00
TIME USED     9.84 SECONDS
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