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A Microcomputer Based Image Processing System for Remotely Sensed Data*

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ABSTRACT

A low cost image processing system based on a CROMEMCO microcomputer called KAIS-MIPS, is developed for processing remotely sensed Landsat data. Its hardware system can be easily interfaced with other peripheral devices. The sofware system provides flexibility, expansibility, portability, and maintainability as well as extensive processing capacity.

As an example, processing and land use classification of Landsat 2 data for the Inchun city and its vicinity in Korea are provided.

I. Introduction

There has been a rapid development in the processing and analysis technology for remotely sensed data during the last two decades. A number of image processing systems have been introduced for extracting the information about earth resources from data obtained by the Landsat series satellites [1]. Most of them contain a mainframe or minicomputer with large memory capacity from extensive computation and processing. However, with the rapid development of integrated circuit (IC) technology, 8 or 16 bit microcomputers can be used to process Landsat data. The Computer Science Research Center of Korea Advanced Institute of Science and Techno-

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logy (KAIST) has a large computer system for multi-user. Since it is not used for image processing exclusively, the processing time is longer and the input/output (I/O) function is not convenient. Therefore, we have developed a 16 bit microcomputer based image processing system for remote sensing called Korea Advanced Institute of Science and Technology - Microcomputer based image processing system (KAIS-MIPS). In spite of using microcomputer, KAIS-MIPS executes most procedures that image processing systems using large computer can execute.

The KAIS-MIPS includes a CROMEMCO microcomputer with a MC68000 CPU and 512 Kbytes of main memory. Its hardware possesses the following characteristics:

(1) low cost

(2) easy interfacing of I/O

The software of KAIS-MIPS is almost completely written in FORTRAN 77 language. The only part not written in FORTRAN 77 is a few 68000 assembly subroutines used for data input/output. And its other characteristics are as follows. First, the processing speed is relatively fast since the table look-up method for multiplication and assembly subroutines for I/O are used throughout all the programs. Second, since each processing function is performed by a few commands and the messages required to execute these commands appear on the screen, the system is user-friendly. Third, this system provides a flexibility to add new processing functions easily. Finally, this system provides portability and maintainability since the most source programs are written in FORTRAN 77 and use the structured programming technique.

The disadvantages of microcomputer are slower speed than large computer and insufficient memory capacity. Since the processing of remote sensing data, such as Landsat data, does not require real time execution and single user operates KAIS-MIPS in comparison with large computer for multi-user, the problem of speed is not serious. The problem of main memory insufficiency is solved with fast disk which is used as the main image storage medium.

II. System Configuration

Fig. 1 shows the configuration of KAIS-MIPS. It is composed of:

- o a microcomputer,
- o a magnetic tape drive,
- o two disk drives,
- o a color display system and
- o a color printer.

KAIS-MIPS uses a CROMEMCO microcomputer which includes 16 bit processor (MC68000), 512 Kbyte memory and interface boards. MC68000 takes charge of processing Landsat data and controlling peripheral devices such as color display system, magnetic tape drive, disk drive and color printer.

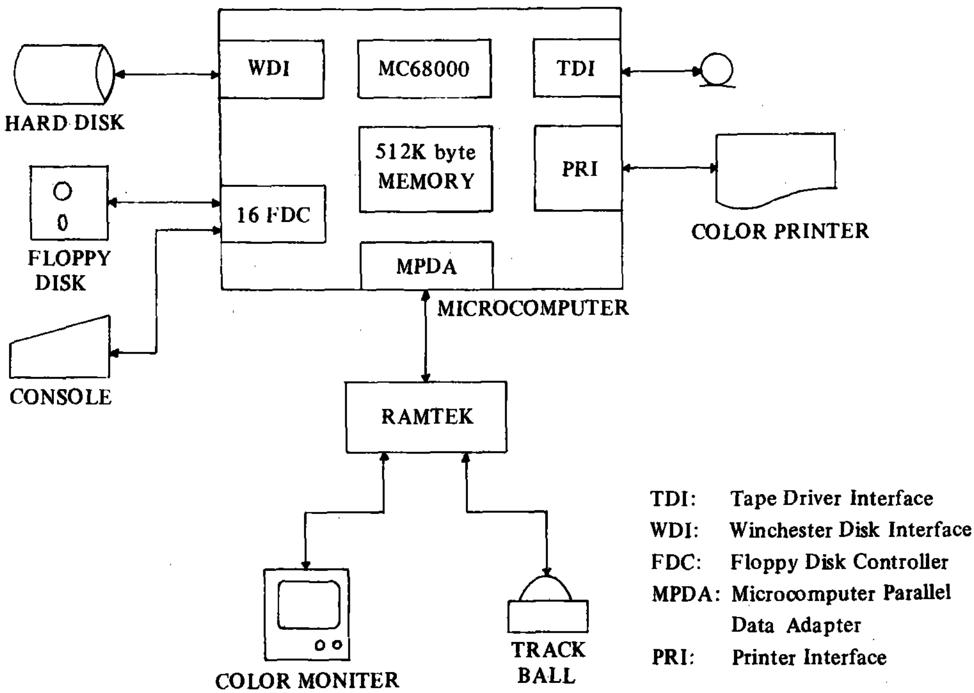

Fig. 1. KAIS-MIPS Configuration

The half inch magnetic tape with 9 track stores Landsat image data and the 10 Mbyte capacity hard disk is used for application programs and processing image data. The RAMTEK graphic display system is attached to the microcomputer via MPDA (Microcomputer Parallel Data Adapter) which was made to interface between microcomputer and color display system. The track ball of the RAMTEK is used for interactive processing, such as selecting a training field or setting a ground control point.

The dot matrix color printer is installed in KAIS-MIPS. It is able to print image data file in disk or display image on screen with 35 colors combined of red, yellow, and blue. The resolution of printing is 0.02 inch/pixel.

III. Processing Software

There are 21 commands available in KAIS-MIPS and they execute several processing functions to be mentioned below. All the currently available, processing functions, commands, and their processing times are listed in Table 1.

A. Preprocessing

The Landsat multispectral scanner has 24 solid-state detectors, six for each band. Both bias and gain distortions can appear at a six line interval in uncalibrated Landsat image data [2]. This six-line stripping effect can be reduced by simple operation, which is to multiply the pixel values in the distorted lines by normalized factors of the standard deviations and to shift the mean differences, so that the altered values may have a mean and standard deviation equal to those of the normal lines. The command SIXLINE executes the correction function for the six-line stripping.

B. Geometric Correction [2]

Four commands are used for alteration of the Landsat image geometry to correct geometric distortions introduced by Multispectral Scanner (MSS). The command CURSOR reads the coordinates of ground control points (GCP) of Landsat images displayed on the color monitor with cursor control. The command GCPTABL makes a GCP table which includes the coordinates (column, row) of GCP pairs in Landsat image and on a map. In order to determine the coefficients for two mapping polynomials, the command POLYNOM is issued. A least mean square error (LMSE) algorithm is applied in POLYNOM. The nearest neighbor resampling algorithm is implemented in the command RESAMPL. Since each term of mapping polynomial is used repeatedly for all pixels of a resampled image, much computation time can be saved by precomputing a table of values and using the table look-up method. This method is useful, especially when the mapping polynomial is higher and a large size image is processed.

C. Karhunen-Loeve Transformation[3] and Linear Contrast Stretch

The command KLBASIS computes a transformation matrix whose rows are eigenvectors of the covariance matrix of 4 band Landsat image data. Another command TRANS linearly transforms 4 band Landsat image data into 2 principal component image data using the transformation matrix.

Along with the transformation, linear contrast stretch is performed so that the maximum value of the transformed pixels does not exceed one byte decimal value, i.e. 255 and their mean value may be about 128. This minimizes errors introduced by rounding of the decimal values.

Table 1. The Processing Functions, Commands, and Processing Times

Processing function	Command name	Data format		Processing time *(minute)
		Input	Output	
Preprocessing	SIXLINE	16 and data (1 byte format)	1 band corrected (1 byte format)	3 : 20
Geometric Correction	CURSOR	no	no	**
	GCPTABL	no	GCP table	**
	POLYNOM	GCP table	mapping function	
	RESAMPL	mapping function image data	resampled image data	40 : 03
K-L Transformation and Linear Contrast Stretch	KLBASIS	4 band data	transformaticn matrix	14 : 49
	TRANSFM	4 band data trans-formation matrix	2 new band data	25 : 45
Clustering: Unsupervised Classification	HISTOG	4 band data	histogram data (1 word format)	3 : 42
	CLASS	histogram data	classified data	11 : 54
	CLADAT	classified data	H-file data	0 : 30
	MCLOR	H-file data	H-file data	0 : 20
Supervised Classification	FDTABL	no	field definition table	**
	STATIS	2 new band data field definition table	class statistics	11 : 10 ***
	SCLASS	class statistics histogram data	H-file data	10 : 35 ***
Operation Process	OPERATE	H-file data 2 new band data	color map-image	03 : 20
Image Display and Enhancement	DISPLAY	color map-image	no	1 : 10
	3D	histogram data	no	1 : 20
	SMOOTH	image data	smoothed image data	3 : 45
	EDGE	image data	edge-detected image data	4 : 05
Hardcopy Image Output	RAMCOPY	no	no	: 48
	HDCOPY	image data	no	: 22

* for Landsat MSS image with the size of 600 x 500 pixels.

** depending on the number of GCPs, the number of classes, or operator skill.

*** for 45 training areas.

D. Clustering: Unsupervised Classification

The command HISTOG generates a 2-D histogram whose X-and Y-axis are the digital values of two new bands created by the command TRANS.

There are a number of clustering schemes employed in the unsupervised classification of Landsat data[4,5]. Since the ISODATA algorithm is widely used, its variation, CLASS algorithm[6] is implemented in KAIS-MIPS. After the command CLASS groups clusters on the 2-D histogram, the command CLADAT assigns the specified color code, which coincides with the color code in the RAMTEK graphic system, to each cluster. This color-coded histogram is called H-FILE.

E. Supervised Classification

The conventional Bayes classifier[7] is designed with 3 commands: FDTABL, STATIS, and SCLASS. FOTAB produces the field definition table for training areas which consists of the field names, the class names, the coordinates of the training areas in new band image, color codes, and a-priori probabilities of the classes. From the field definition table and two new bands, the means and covariance matrices for classes can be computed by STATIS. SCLASS assigns the specified color code to the input patterns using Bayes decision rule, resulting in generation of the H-FILE.

F. Operation Process

The command OPERATE generates a final color map-image by combination of pixel values of the two new bands with a H-FILE.

G. Image Display and Enhancement

Through the command DISPLAY, a classified color map-image is displayed on the color monitor via the RAMTEK graphic system. The command 3D is used to display a 3-dimensional histogram on the color monitor. The command SMOOTH employs a $n \times n$ moving window to generate a smoothed image, where n is a selectable integer. The smoothed pixel value is the most frequent value or mean value in the window. The command EDGE detects the class boundaries in the color map-image.

H. Hardcopy Image Output

The command RAMCOPY prints out color map with the dot printer COLORPLOT.

IV. Example

The KAIS-MIPS operation procedure diagram is shown in Fig. 2. We have processed the Landsat MSS data of Inchun city and its vincinity in Korea in order to evaluate the performance of KAIS-MIPS, and obtained two kinds of (unsupervised and supervised) land use classification results as shown in Fig. 3.

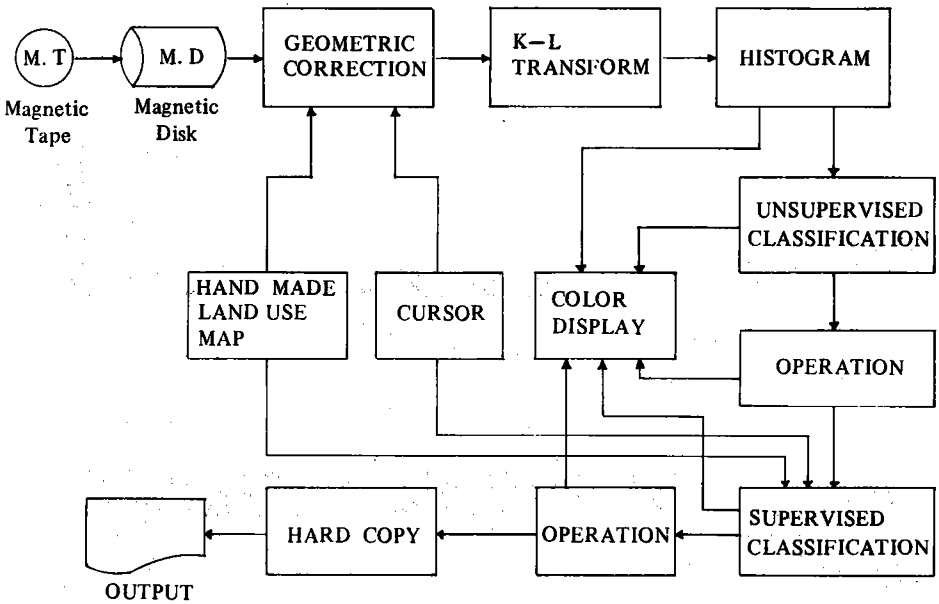

Fig. 2. KAIS-MIPS Operation Procedure

The Landsat image data used in the processing were acquired by Landsat 2 on September 4, 1981 and loaded into a computer compatible tape (CCT) at Tokyo Remote Sensing Center in Japan.

The 4 band data with the size of 600 pixels/line x 500 lines/scene are extracted from the original full scene data and then geometrically corrected in the reference of 1:50,000 map published by National Geologic Institute.

The number of classes resulted from the clustering is eighteen, but since five of them represent the sea area, they are merged into one color in Fig. 3(a) when displaying on color monitor screen. Forty-five training areas for nie ground cover types are used for designing the Bayes classifier and the same number of test areas for estimating the performance of the classifier. The training areas

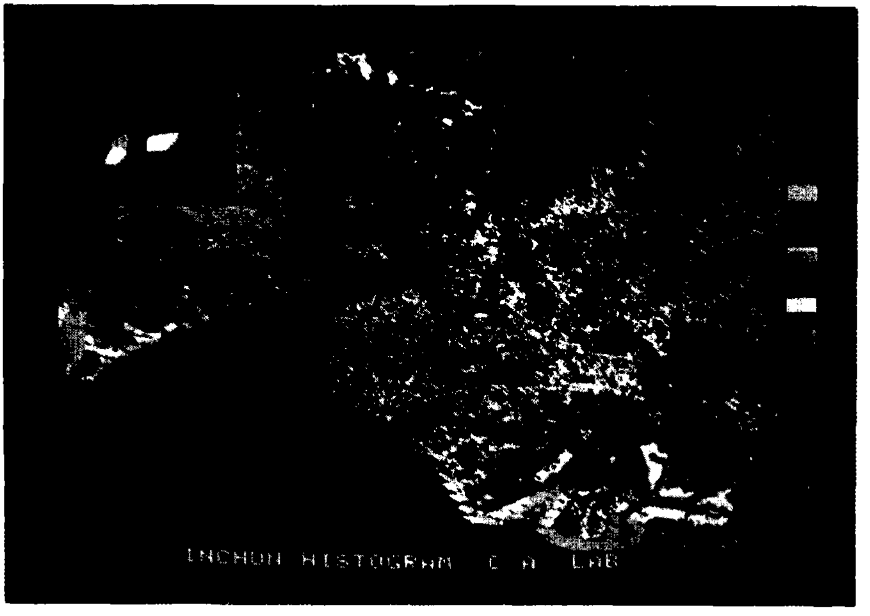

Fig. 3(a). UNSUPERVISED CLASSIFICATION RESULT OF INCHUN AREA

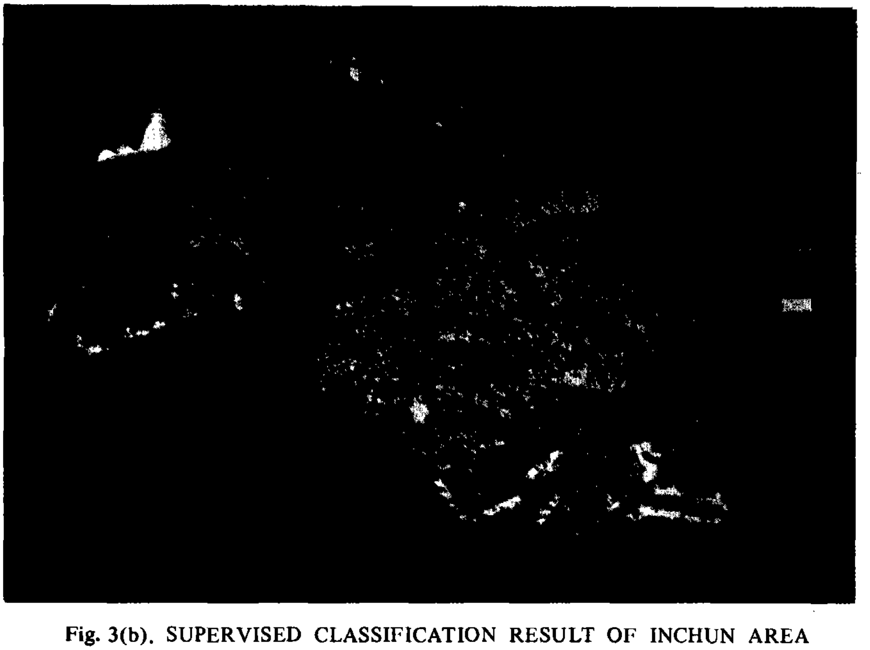

Fig. 3(b). SUPERVISED CLASSIFICATION RESULT OF INCHUN AREA and test areas are obtained from the existing land use map. The classification accuracy is found to be 85.5%.

V. Conclusion

The microprocessor based KAIA-MIPS, which is relatively inexpensive, is developed in order to process and analyze Landsat data. It will be useful for remote-sensing researchers in universities and laboratories who do not have access to a mainframe computer. Furthermore, it is easy to interface peripheral devices, such as digitizer and printer when we need to upgrade the system.

Its software is user-friendly. Also, program package is highly portable and is easy to maintain because of FORTRAN 77 programming and the structured programming technique used.

On the other hand, KAIS-MIPS can improve its classification performance by employing various sophisticated classification strategies, e.g., textural classifiers and contextual classifiers although it has basic classification algorithms in unsupervised and supervised analysis.

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