T. H. Lee Williams
Christopher Gunn
Jeffrey Siebert
*Department of Geography-Meteorology
and Kansas Applied Remote Sensing (KARS) Program
The University of Kansas
Lawrence, KS 66045*

Instructional Use of a Mainframe Interactive Image Analysis System

While at first sight the mainframe environment may appear to offer virtually unlimited storage and processing capabilities, the realities of time-sharing systems do place limits on these.

Introduction

The value of remote sensing techniques in applied resource analysis is being increasingly recognized in the academic, public, and private sectors. There is, therefore, a substantial and growing demand for discipline specialists trained in remote sensing. The more traditional skills of visual aerial photointerpretation will remain at the foundation of this training, and will be extended to visual analysis of less conventional material such as space photography and imagery, and thermal and microwave data. However, the large volumes of data produced by a system such as Landsat, and the more complex spectral, spatial, and temporal analyses being performed on these data, require the use of digital image analysis techniques. Thus, training in remote sensing must include at least the elements of digital image processing. Furthermore, this training should be widely available, and some mechanism is required whereby training programs may be established in many more centers around the country. One approach that can facilitate this expansion is the implementation of instructional image analysis packages on university and college mainframe computers, to be accessed on-campus or from remote sites. Because of their availability and accessibility, academic computer systems are generally well suited to this diversified training function.

Abstract: *The increasing demand for training in digital image analysis techniques calls for the widespread development of suitable training courses in academic institutions. Implementation of image analysis program packages on college and university mainframe computers can aid this development in a cost-effective manner. The Department of Geography-Meterology and the Kansas Applied Remote Sensing (KARS) Program have developed an instructional interactive image analysis program package that runs on the University of Kansas central computer. A brief description of the program package is given, followed by a discussion of the advantages and limitations of image analysis instruction in a time-sharing mainframe environment.*

This paper focuses on the use of academic mainframe computers in a time-sharing environment for instruction in digital image analysis. Other papers in this edition of *Photogrammetric Engineering and Remote Sensing* address the use of mainframe computers (operating in a batch environment), minicomputers, and microcomputers.

There are several factors to be considered when evaluating the use of a mainframe computer, among them being memory, mass data storage, central processor unit (CPU) speed, input/output (I/O) devices and data transmission rates, acquisition and operating costs, and user access to the computer. While specific systems will present

Photogrammetric Engineering and Remote Sensing,
Vol. 49, No. 8, August 1983, pp. 1159-1165.
0099-1112/4908/-1159$02.25/0

unique situations and problems, there are many factors common to all such image analysis systems. This paper draws primarily upon experiences at the University of Kansas, but the discussion will be applicable to many mainframe time-sharing environments.

The following section outlines the characteristics of the instructional system developed at the University of Kansas. Later sections will introduce and discuss the considerations, advantages, and disadvantages of instructional image processing in a time-sharing mainframe environment, illustrated by reference to the Kansas system.

The University of Kansas System

The Department of Geography-Meteorology and the Kansas Applied Remote Sensing (KARS) Program have developed an interactive digital image analysis program package that runs on the University of Kansas (KU) central computers. The University operates a Honeywell Information Systems Level 66 DPS-3E dual-processor computer under the GCOS operating system. The package was designed specifically for instruction and has been used in semester-long courses and in five-day off-semester short courses. The modular, subroutine-oriented structure, simple FORTRAN programming, and interactive time-sharing mode of operation have also made it a useful vehicle for image processing research.

A successful instructional system should illustrate the underlying concepts of image processing and pattern recognition and, at the same time, also expose the trainee to operational procedures. The operational emphasis should not be on the hardware aspects of a particular system, but should address the algorithms and general data analysis strategies common to most systems. The approach taken in Kansas was to develop a software package that employs processing algorithms and data analysis sequences in common use and to structure the trainee work along the lines of a realistic resource analysis project. Emphasis is placed on basic concepts rather than processing efficiency. The students in the course at KU, working in groups of two or three, adopt roles (e.g., urban planner) and projects (e.g., evaluating urban expansion). They then progress through the various stages of a digital classification of Landsat multispectral scanner (MSS) data with the objective of producing a land-cover map that provides information relevant to their stated role and project. In this way the exercise is as realistic as possible and the students are motivated by working on a specific project of their choosing.

Each group selects a study area from within one of a set of Landsat images provided. A batch program (SUBIMAGE) then takes the user-specified start line and column coordinates and from a Landsat tape extracts, unpacks, and deskews a 120 by 120 pixel image segment. Four single-band images are written to online disk storage as random-access files. SUBIMAGE is the only batch program in the package. Further geometric correction beyond deskewing is not normally applied to the image segments. A display program, (HISTO) is used to print the images on a hard-copy terminal, using different characters and overprinting to produce grey-shade images. The program also allows a number of radiometric enhancement options prior to display—contrast stretching, histogram equalization, and direct histogram specification (density slicing). Other image enhancement procedures are available through programs RATIO, TVI (a modified version of the Transformed Vegetation Index (Rouse *et al.*, 1973)), EDGE, SMOOTH, TEXTURE, and CHROM (chromaticity values). The modified images can be saved and used later in the classification routines, if desired. Each student group uses the display and enhancement programs to produce a usable hard-copy image for locating and identifying training sites.

Two programs allow for supervised (SCLAS) and unsupervised (UCLAS) classifications. The students normally perform a supervised classification of their study area, followed by an unsupervised classification. By running the supervised classification first, the students discover the limitations of this approach and are more ready to accept the unsupervised classification approach. They determine accuracy figures for both classifications and compare the two approaches. A summary of the classification procedure the students follow is given in the following paragraphs.

Based on their role and project, the students define the land-cover/land-use categories they wish to map. Using the output images from HISTO and aerial photographs, they select training sites for each category and refine their training samples using programs which print out the digital number values (PIXVAL) and generate scatter plots (SCATPLOT) for the training samples. The students are then prepared to run the supervised program (SCLAS), shown in schematic form in Figure 1. They input their training site data (STRSAM) and determine the statistical separability of their categories (SEPRA) using a modified version of the transformed divergence statistic (Swain, 1978) (a constant in the algorithm was changed to prevent early saturation of the computed value). Training sample data can be displayed (SCATPLOT) and categories then combined or deleted (SCONDENS) if desired. The image is then classified using a minimum distance (MINDIST), parallelepiped (PARALLEL), or maximum likelihood (MAXLIKE) algorithm, and a classified map is produced. The training sample data are used to assess the accuracy of the classifier (ACUCHECK), producing a classification accuracy contingency table. Separate test samples

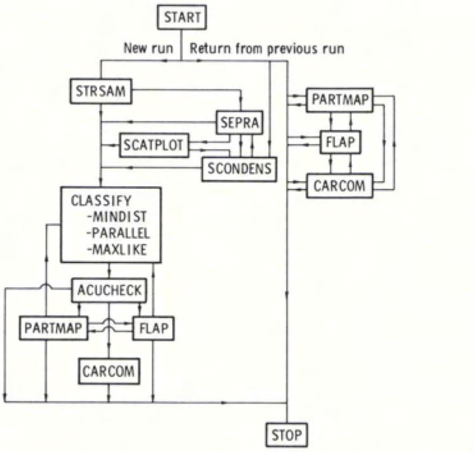


FIG. 1. General schematic diagram of the supervised classifier SCLAS.

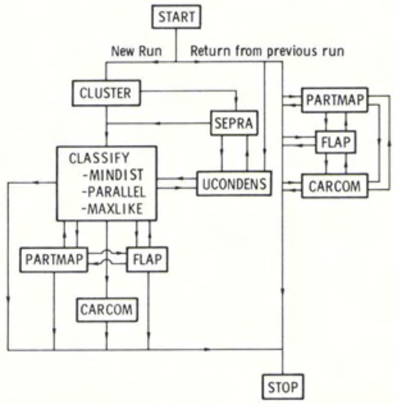


FIG. 2. General schematic diagram of the unsupervised classifier UCLAS.

would provide a more rigorous accuracy assessment but would require too much additional work. The students then have the option of producing partial maps of selected categories (PARTMAP) or binary maps of individual or groups of categories (FLAP). The binary maps are used to generate a final color map using diazo transparencies. When a student terminates the program run, the classified image and category training data are written to a disk file. On subsequent runs, the image and training data are read from this file and the analysis session can be continued from where it was interrupted. The final option available in producing classified maps is individual selection of category symbols. This is used to cartographically combine (CARCOM) categories that are spectrally distinct but may be informationally similar with regard to a specific application (e.g., bare soils having different moisture levels).

After the students have completed the supervised classification, they are introduced to unsupervised cluster analysis and classification and subsequently run the unsupervised classification program (UCLAS). A schematic diagram is given in Figure 2. A sample of pixels is taken from the image and a sum-of-squared-errors clustering routine is used to generate up to 20 clusters (CLUSTER). The cluster convergence level is defined by a maximum single cluster location error and is generally set at a distance of 1.0 for a four-band classification. The student specifies the number of clusters and has the option to seed cluster center point values into the program. Cluster category statistics and a scatter plot of cluster means are produced. A statistical category separability analysis is obtained (SEPRA). The image is then classified using a minimum distance (MINDIST), parallelepiped (PARALLEL), or maximum likelihood (MAXLIKE) algorithm. Partial maps or flaps of categories can be produced. The classified map is then compared with ground data (aerial photographs and/or field data) to identify the cover type of each category. Category combinations are planned using the ground data, separability analysis, and project information needs. Categories can be statistically combined (the categories are merged and a new cluster analysis (UCONDENS) and classifier run) or cartographically combined (the categories are classified separately and combined in the output by using the same map symbol (CARCOM)).

Both the supervised and unsupervised routines, SCLAS and UCLAS, are interactive and allow great flexibility and choice by the student in the sequence of operations and parameters set. Within the limitations imposed by the instructional function of the programs, they expose the student to contemporary basic image analysis algorithms and techniques, and develop in the student both a sound conceptual grasp of the techniques and a practical understanding and experience of their application. Near the end of the course, the students are introduced to the operational image analysis systems at the University of Kansas and the EROS Data Center, and have the opportunity of working with these briefly, to familiarize themselves with some of the hardware aspects of image analysis not covered previously.

EVALUATING THE MAINFRAME TIME-SHARING APPROACH

Comparisons between mainframe computers and other computer systems are generally made in a number of areas—main memory, mass data storage, central processor unit (CPU) speed, I/O devices and data transmission rates, overall system throughput, acquisition and operating costs, and system availability to users. Comparisons between batch and time-sharing modes center on cost, overall turn-around time, and the level of programmer-user interaction. These considerations are addressed below.

DATA STORAGE

While mass storage of Landsat or other image data can be a serious problem to users of micro- or minicomputers limited to floppy disks or other small devices, storage limitations can also have a major impact for users of large time-sharing mainframe systems. Programs that run in a batch environment normally have easy access to high-volume storage media such as magnetic tapes or dedicated, removable disk packs. Programs running under a time-sharing executive, however, may be limited to data that is part of the system's permanent, on-line file system. At KU, for example, magnetic tapes may be read only by batch programs, and dedicated disk packs can be accessed in time-sharing only through techniques that verge on subterfuge.

This restricts users of time-sharing image analysis programs, in general, to the system's permanent file structure. Although this structure may be very large, users are forced to compete with each other for resources. The KU system has 2G bytes of file space on ten drives, but this serves more than 2,000 active project accounts representing many more thousands of individual users. As a result, the default permanent disk allocation for a project is less than 200K bytes. Arrangements have been made for the KU remote sensing classes to have access to 5M bytes during the semester. At KU, there are usually ten groups of two or three students, each group requiring a separate file catalog containing four single-band 120 by 120 pixel image files (58K bytes per image), one temporary file for enhanced images, two files for classified images, and two files for classification statistics (30K bytes), totally 440K bytes per group. This figure represents the minimum practical file space requirements per group.

CPU AND TIME-SHARING

Mainframe computers generally possess large enough main memories that their size is not a limiting factor, and they are fast enough (typically one or two orders of magnitude faster than a micro) that raw CPU processing time is not a problem when running complex analyses (e.g., statistical classification routines). However, as they are multi-user systems supporting as many as one hundred or more simultaneous time-sharing sessions, competing demands for their time can so reduce the proportion of time the CPU is allocated to an individual job that the overall elapsed time to run a program can be significant. The simplest solution to such a problem is to use the computer during slack times. However, during a very busy period, e.g., at the end of semester, the system may be busy at all times except in the early morning. The priority assigned to a job in time-sharing will determine how fast the job will run and is based on some combination of CPU requirements, project priority, number of I/O operations, and elapsed time in the job scheduling queue. The KU system is similar to most systems configured for instructional purposes in that it bases job priorities on memory needs and favors the smaller programs. Computer systems oriented more towards research applications will tend to favor the larger programs and data analysis needs of research computing. Most of our image analysis instructional programs are small and therefore run quickly. Problems are encountered when running the classification programs SCLAS and UCLAS, however, as they are both 1500 lines of code in length and require 300K bytes each. Although each uses less than three minutes raw CPU time, during busy periods it is not unusual for these programs to take over three hours to run. The programs are configured as a driver module directing data flow in and out of a set of subroutines which perform the various analysis steps (Figures 1 and 2). Thus, during any given phase of a program run a large proportion of the program code is not used and the run time is unnecessarily slow because of the overall large program size. To overcome this problem, the classification routines are being rewritten as a set of individual programs, which will be run sequentially.

The choice of classification algorithm to be used is often assumed to be a major factor in determining program run time. The parallelepiped and Euclidean distance algorithms are simpler and require less complex computations than the statistical classifiers, and are therefore favored in microcomputer systems. However, in the mainframe time-sharing environment CPU time is generally a small fraction of the total run time, and the difference in run time between the simple and complex algorithms is often not significant. Note, however, that the CPU costs will be higher for the complex algorithms.

INPUT/OUTPUT DEVICES AND DATA RATES

Data input and output and display of images and maps can be achieved on a variety of devices, ranging from conventional hard-copy terminals to continuous-tone CRT devices with track-balls, cursors, etc. While the use of sophisticated and expensive devices will speed up the analysis process and allow more flexible image enhancement, the concepts and procedures of digital image analysis can be conveyed effectively using hard-copy terminals for input and output. The Kansas system uses Decwriter LA34 terminals which have vari-

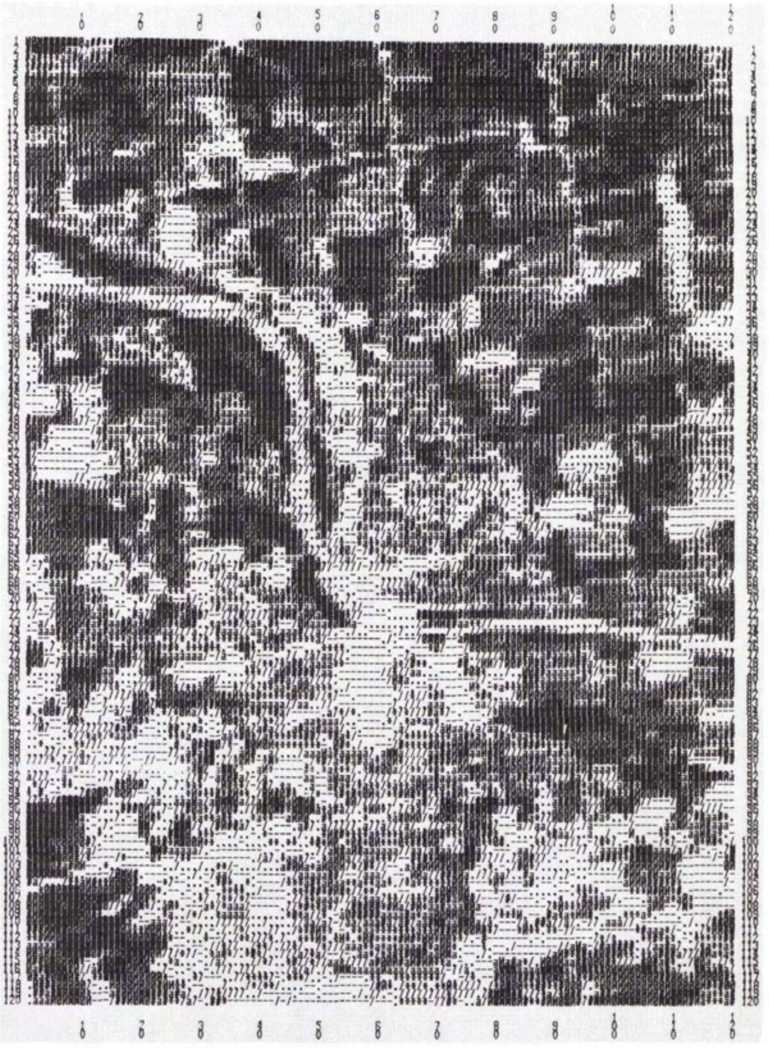
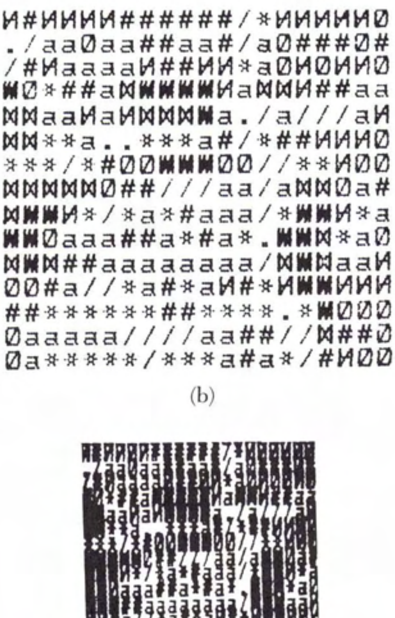


FIG. 3. 120 by 120 pixel histogram-equalized ten-level Band 5 Landsat hard-copy printer image, produced at settings of 16.5 characters per inch (cpi) and 12 lines per inch (lpi). 50 percent reduction.

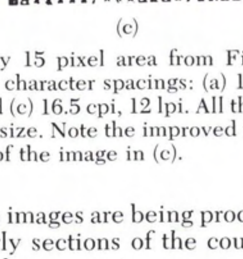
able character and line spacing, allowing Landsat images to be displayed with little or no distortion: X-format images are printed at 16.5 characters per inch (cpi) and 12 lines per inch (lpi), giving a linear distortion less than 1½ percent (Figure 3); EDIPS-format images are displayed at 12 cpi and 12 lpi. A further advantage is that the closer spacing produces a darker black tone than is possible on conventional terminals (10 cpi and 6 or 8 lpi) and hence gives a wider tonal range and superior image (Figure 4). Hard-copy terminals can also be used as conventional remote terminals, thus making it easier to justify their purchase.

A particular concern in time-sharing is the data transmission rate between computer and terminal. The LA34 terminals operate at 300 baud, which is adequate for transmission of program prompts, user commands, and tabular and graphic data listings. It is, however, problematic in the transmission of image data for display. Typically, a 120 by 120 pixel image will take 20 minutes to print. Using a 1200 baud terminal would reduce this time to five minutes. However, 1200 baud terminals cost approximately double the 300 baud versions. As funds to purchase terminals are likely to be limited in most institutions, the extra cost may not be worth the savings in display time. Our experience in Kansas has been that, although the students complain about the slow rate of printing images, it is only a significant inconvenience

(a)



(b)



(c)

FIG. 4. A 20 by 15 pixel area from Figure 3 is here printed at three character spacings: (a) 10 cpi, 6 lpi; (b) 10 cpi, 8 lpi; and (c) 16.5 cpi, 12 lpi. All three are printed at their original size. Note the improved tonal range and overall quality of the image in (c).

when multiple images are being produced, mainly during the early sections of the course on image display and enhancement.

OVERALL SYSTEM SPEED

Overall turn-around time is the total elapsed time between initiating a program and terminating that program run and is a function of the various factors discussed above. The most significant limiting factors will be the priority assigned to the program by the time-sharing system and the time required to transmit and print an image at the remote terminal. The former will depend on the prioritizing scheme on a particular system but, in general, segmenting a complex program into a sequence of separate smaller programs and minimizing the number of I/O operations will produce the best results. The latter factor is a function of the data transmission rate. This is usually less of a problem than the job priority as in practice the students are less irritated by the time spent waiting for an image to print out (when something is happening) than they are by waiting for the terminal to respond to a prompt (when nothing appears to be happening). Thus, the way to ensure an optimal turn-around time is to structure the programs according to the time-sharing scheduling scheme on a particular system.

COSTS

Costs can be divided into those associated with acquisition and implementation and those associated with operation of the system. In a mainframe environment, the costs of acquiring and maintaining the central computer system will be borne by the institution. The costs incurred in developing an image analysis system will therefore occur in the area of peripherals, software, and usage fees.

Acquisition costs can be divided into hardware I/O devices) and software costs. When operating in batch mode, only one output device is required, whereas when operating in time-sharing a number of terminals is needed to provide multiple-student access to the system. The exact number needed will of course depend on the size of the class and the number of hours the terminals are available for use. We use conventional hard-copy terminals, which were acquired through normal departmental acquisitions. A minimum of one terminal per five student groups is recommended.

Software costs involve either purchasing existing software or the programmer and computer costs of developing a new system, which requires a minimum of four months work. Our system was initially developed in two graduate seminars in the Department of Geography-Meteorology. A graduate student then spent one summer programming the classifiers, and subsequent seminars and course preparation work have served to refine the system. Between one-half and one year's work in total was involved. A potentially cheaper approach would be to acquire existing software. However, there are very few instructional systems available that are designed to operate in time-sharing on a mainframe computer. Most software is also configured for a particular system and may not be transportable.

The Kansas system is written in an extended ANSI-1966 FORTRAN, similar to WATFOR and other common extensions. The program code differs from ANSI-1966 FORTRAN in its use of free-form statement positioning, upper and lower case, variable names of up to eight characters, and character data strings delimited by " or " . The programs use both sequential and random-access disk input and output. Random I/O supports user-specified record lengths. Terminal I/O requires 132-column lines. The non-standard aspects of the program code conform to most extended FORTRAN codes and the program package is therefore transportable, with possible minor modifications required in the I/O statements. The program package is available at a nominal charge from the senior author. Jensen (1981) has developed an instructional program package in BASIC that has been successfully implemented on a number of systems. There are undoubtedly more instructional program packages in existence, but they are not as well publicized as their larger operational counterparts.

Operation costs can be subdivided into computer resources and hard resources. In student coursework, computer resource costs normally involve 'soft' allocations and usage costs are not a concern. However, some university mainframe systems charge 'real' money for usage, in which case costs are a major concern. To reduce costs the number of study areas may be reduced, the exercises may be more limited, and the simpler classification algorithms may be used. There will often be no significant difference between the costs of batch versus time-sharing system operation. Hard resource costs involve such items as telephone line rentals and usage charges and incidentals such as paper, ribbons, etc. Telephone line charges are minimal for on-campus courses but for off-campus courses they can be considerable, particularly on time-sharing systems with their long connect times. In this case a combination of time-sharing and batch mode is more economical.

SYSTEM AVAILABILITY

A disadvantage of using university mainframe computers is that the user has little or no control over computer operations and scheduling, primarily with regard to down times due to system failure or periodic maintenance. The latter is often scheduled in advance and can therefore be planned for, but the former can cause problems if the system fails during a long time-sharing analysis session. Serious problems can be averted by structuring the programs to save relevant data in permanent files frequently during a session, thus avoiding loss of results. Considerable flexibility must also be incorporated in course schedules to allow for delays in completeing assignments.

Conclusions

University mainframe computers can provide an economical and practical means of providing instruction in digital image analysis techniques. Time-sharing systems allow a high level of interaction between the student and the analysis routines, thus improving the educational value of the exercises. While at first sight the mainframe environment may appear to offer virtually unlimited storage and processing capabilities, the realities of time-sharing systems do place limits on these. However, if the system is designed with these limitations in mind, much-needed hands-on instruction in digital image analysis can be made available in many colleges and universities without large capital investments in equipment.

References

Jensen, J. R., 1981. IMAGES—An Interactive Image Processing System. *CORSE-81, Proceedings of the 1981 Conference on Remote Sensing Education*, Purdue University: 254–258.

Rouse, J. W., Jr., R. H. Haas, J. A. Schell, and D. W. Deering, 1973. Monitoring Vegetation Systems in the Great Plains with ERTS. *Proc. Third ERTS-1 Symposium*, Vol. 1: 309–317.

Swain, P. H., 1978. Fundamentals of Pattern Recognition in Remote Sensing. Chapter 3 in *Remote Sensing: The Quantitative Approach*, Eds. P. Swain and S. Davis, McGraw-Hill Advanced Book Program, 396 p.

(Received 30 April 1982; accepted 1 January 1983; revised 4 March 1983)