The Digital Image Analysis System (DIAS): Microcomputer Software for Remote Sensing Education

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ABSTRACT: The Digital Image Analysis System (DIAS) is a microcomputer-based software package for training in computer processing of remotely sensed data that emulates some of the techniques and procedures used on larger, more powerful mainframe and minicomputer systems. Major capabilities of the software include (1) data entry, (2) image restoration, (3) image enhancement, (4) information extraction (classification), (5) data display, and (6) utilities. A justification for software development, educational aspects of the software, and instructional implementation in remote sensing courses at the University of Oklahoma and at The State University of New York College at Geneseo are discussed. We conclude that the use of DIAS improves student understanding of digital image processing of remotely sensed data.

INTRODUCTION

TECHNOLOGICAL DEVELOPMENTS in remote sensing during the last decade have centered on the increased use of computers to analyze and interpret the digital data gathered from satellite remote sensor systems. These advances have necessitated a change in remote sensing educational objectives. Remote sensing educators are now addressing the ramifications and implications of teaching machine processing of remotely sensed data and including hands-on experiences (Jensen, 1983). Dobson (1983) identified the need for "a substantial developmental program to create new materials for automated instruction" in remote sensing, computer cartography, and geographic information systems. In this regard, "the personal computer offers new opportunities for the application of technology to instruction" (Arons, 1984). This paper describes the Digital Image Analysis System (DIAS), a microcomputer-based software package that can assist remote sensing educational efforts dealing with digital image processing of Landsat or other satellite data. The following sections discuss (1) the rationale behind DIAS software development, (2) educational aspects of the options available within the package, and (3) examples of the use of DIAS in instructional situations.

JUSTIFICATION AND PACKAGE DESIGN

Concurrent with rapid expansion in satellite remote sensing technology has been a growth in both the types of computer systems and the techniques used in processing remote sensor digital data. Initially, mainframe or dedicated minicomputers and associated software packages were used for the majority of image processing. These systems have two major limitations for educational purposes:

- They are usually found in research laboratories, which are few in number. Also, computer processing time for instruction of college or university students generally receives a low priority. Costs of the necessary computer equipment and associated software are generally at least an order of magnitude above the purchasing capabilities of most colleges and universities (Whitley, 1976; Barb and Harrington, 1980). Hence, a lack of available mainframe and dedicated minicomputer-based systems limits their effectiveness for remote sensing educational efforts.
- From a teaching perspective, another limitation is the philosophy that accompanied software development: these mainframe and minicomputer-based packages were designed to permit state-of-the-art research in remote sensing. Programming designed for remote sensing research has a different orientation from software developed for teaching the principles of digital image processing.

Popularity and availability of inexpensive microcomputers has resulted in the development of several remote sensing software packages (Kiefer and Gunther, 1983; Welch *et al.*, 1983; Jensen, 1984), and microcomputer-based systems now provide a major source for hands-on education in digital remote sensing (Jensen, 1983). DIAS was developed on an

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Apple II Plus microcomputer (48K RAM) equipped with one disk drive (DOS 3.3) and a color monitor (Harrington, 1981). A modem and communication interface are used for initial data input. Once data are available on diskette, the modem and interface are no longer necessary. The hardware was selected based on a philosophy of minimizing costs while maintaining color graphic display capabilities. Apple II microcomputers have been cited as "the most pervasive" in United States colleges and universities (Kiefer and Gunther, 1983).

DIAS was written to be "user-friendly" and "menu-driven" in order to limit the amount of computer expertise required of the student. Memory, CPU speed, and processing capabilities limit the scope of many of the tasks that can be performed on a microcomputer. Procedures accomplished in one step on mainframe or dedicated minicomputer-based systems were broken down into component steps for the DIAS package; this facilitates increased student knowledge of the workings of each analysis technique (Eyton, 1983). Knowledge of the Earth Resource Laboratory Applications Software (Junkin *et al.*, 1980) and several summaries of digital image processing techniques (Moik, 1980; Lillesand and Kiefer, 1979) provided background information for the overall design of DIAS.

Programs were written in Applesoft Basic, an interpretative floating point language, because use of a widely known language allows others to add or update programs. Several programs were compiled due to the length of machine processing time associated with interpreting Applesoft Basic, allowing some routines to execute much more rapidly (Taylor and Taylor, 1982). The major objective in software programming was the development of a series of related processing steps that paralleled the procedures used on mainframe and minicomputer-based systems.

Landsat Multispectral Scanner (MSS) measurements of surface brightness were chosen as the primary data for development of the DIAS package. A major stumbling block for microcomputer-based image processing systems is the development of an ability to transfer Landsat MSS data from a Computer Compatible Tape (CCT) to a 5 1/4 inch diskette (Jensen, 1983). Data from other satellite-based sensing systems such as Seasat, GOES, the NIMBUS series, or the Landsat Thematic Mapper can also be processed using the system. Obtaining data on 5 1/4 inch floppy diskette in a format that can be read by an Apple microcomputer is the only limitation. A scene size of 40 pixels by 40 pixels was chosen for data manipulation and display. This relatively small size is based on the low resolution color display capabilities of Apple II microcomputers. If a site is carefully selected, these data can contain information about several land-cover types or interesting geologic structures.

In summary, four factors, (1) the high cost of either mainframe or minicomputer systems for remote

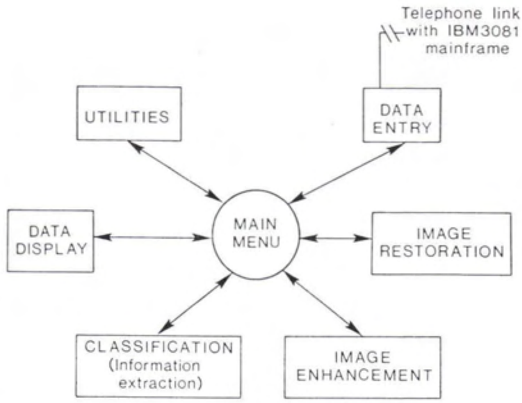

FIG. 1. Organizational flowchart for the Digital Image Analysis System (DIAS) software package.

sensing data processing, (2) the limited availability of these systems in educational environments, (3) the research philosophy underlying software development, and (4) the establishment in many colleges and universities of labs equipped with microcomputers, led to the development of DIAS. Our major goal in linking together microcomputers, remote sensing software, and Landsat MSS data was to emulate, for teaching purposes, the techniques and procedures used on more powerful computer systems.

EDUCATION ASPECTS OF THE DIGITAL IMAGE ANALYSIS SYSTEM

DIAS includes several of the most important image processing techniques. Major capabilities include (1) data entry, (2) image restoration, (3) image enhancement, (4) information extraction (classification), (5) data display, and (6) utilities. All software is accessed from the main control program menu, and additional menus allow students to select individual analysis programs (Figure 1). Some of the pedagogical advantages of the software will now be reviewed.

DATA ENTRY

Three algorithms are available within the Data Entry section: (1) File Transfer, (2) Text-To-Binary-Packing, and (3) Geocoding. The File Transfer program is based on the specific characteristics of the IBM 3081 mainframe computer at the University of Oklahoma. It allows transmission of data from the IBM 3081 to the DIAS package operating on an Apple microcomputer. The File Transfer program provides the data on a 5 1/4 inch diskette that the image processing software and associated computer system can access.

Text-To-Binary-Packing is the second step in data entry. Even though the data are now on a diskette and in a format (a text file) that may be read by the microcomputer, execution speed is greatly increased if the data are stored as 8-bit integers in specific memory locations. Data in binary format can be readily transferred between machine memory and disk storage, whereas text files require longer analysis time due to the large amount of disk I/O required. Another advantage of packing the data in binary form is a saving of disk storage space. This program improves the speed of image processing while helping students realize (1) that there are several ways computers can read and store the same data, and (2) that some means are more efficient in both processing time and data storage.

Geocoding allows keyboard entry of ancillary data (i.e., soil type, slope, aspect, etc.) that may be combined with the remote sensing data in subsequent analysis steps. Users must geographically register the ancillary data with the Landsat pixel grid. Students working with this routine gain an appreciation for some of the problems associated with geographic registration.

Image Restoration

Programs designed to test for and correct any degradation that may have occurred during data collection comprise this section. An additional routine transforms the raw Landsat data into radiance and reflectance. Examples of these procedures include (1) Scanner Correction, (2) Atmospheric Correction, and (3) Physical Values Conversion.

The Scanner Correction program permits the student to examine the data to search for detector miscalibration. If an inconsistency is found, the routine allows the user to input a correction factor, modify the data, and then save the transformed data set on diskette.

The Atmospheric Correction program allows the student to examine the data for effects of Rayleigh scattering. Two common techniques are available within this routine: (1) using the *y*-intercept from regression analysis with the Band 7 data, and (2) using the minimum value of the band of data under scrutiny (Switzer *et al.*, 1981). This routine shows students the need to examine data for possible effects produced by atmospheric interaction with radiation transfer from the reflecting or emitting surface to the sensor location.

A Physical Values Conversion routine changes the original Landsat data into actual measurements of radiance and reflectance (Robinove, 1982). This procedure allows students to compare data sets from different dates because the transformation equations standardize the data collected from differing satellites and/or sun angles.

Image Enhancement

Algebraic transformation of the data can be performed to highlight specific features not readily displayed in the raw data (Gillespie, 1980; Short, 1982). Of the myriad of possible manipulations, DIAS includes six functions: (1) Ratio, (2) Smooth, (3) Enhance, (4) Shift, (5) Stretch, and (6) Combine. In addition, students can use several of these routines on the same data set to create some of the more complex linear combination transformations, such as the vegetation indices (Lulla, 1983).

While each of the programs performs a specific data manipulation, the overall effects are similar because each creates a new data set which highlights certain features from one or more original data sets (Harrington and Cartin, 1984a). Students quickly learn that the spatial patterns change with each transformation. Instructional objectives can focus on the types of changes produced and on understanding the mathematics involved. For example, this section of the DIAS package is useful for teaching the difference between high-pass (edge enhancement) and low-pass (smoothing) filtering.

Information Extraction or Classification

The DIAS package allows students to use supervised or unsupervised classification techniques. Little human interaction is involved in the unsupervised approach. The algorithms search the 40 by 40 matrix of data for areas that have relatively homogeneous statistical properties and identify the different spectral signatures found. Supervised classification relies on analyst selection of spectral signatures. Areas of known cover types are identified by the analyst, and statistical data for these areas are used to define a spectral signature for each land cover.

Differences between these two procedures become obvious when the student attempts to interpret the classification results. Using a supervised approach, the final result is a classification with known cover types because they were defined *a priori*. In the unsupervised approach, the student must determine *a posteriori* the cover type associated with each spectral signature identified through the analysis. Spatial associations become a primary decision making tool in this procedure; additionally, knowledge of how individual surfaces reflect solar radiation aids in interpretation of the corresponding spectral signatures. The routines contained within the DIAS package allow students to observe the major differences between these two methods.

Both the minimum distance to means and the parallelepiped classification strategies are available. These two strategies demonstrate that there are several different ways of statistically evaluating and then classifying individual pixels. Because both classification strategies can be used in either the supervised or unsupervised approaches, an instructional objective is an understanding of the differences between classification methods and the statistical strategies employed in class assignment.

Data Display

Computer graphic display of spatial patterns is of prime importance in digital image processing because computers are unable to make the complex human decisions required in the interpretation process (Moik, 1980). Display on a CRT permits the student to observe both the geographic and radiometric characteristics of the data. Six different visual products can be produced using routines within the DIAS package: (1) Single Band Histogram, (2) Low Resolution Density Slice, (3) High Resolution Density Slice, (4) Two-Space Scatter Plot, (5) Profile, and (6) Signature (Figure 2). Both high- and low-resolution graphics are used. Low Resolution Density Slice is the primary display for spatial patterns whereas graphs are presented using the high resolution capabilities.

The data display capabilities included in DIAS greatly enhance its potential as a remote sensing educational tool. Development of a remote sensing tutorial package for exploration geologists (Harrington and Cartin, 1984b) revolved around the use of Apple microcomputer graphic displays for demonstration of important concepts.

UTILITIES

Data management and graphic display refinement are the primary functions of the Utility section of the DIAS package. Programs available are (1) Text File Reader, (2) Binary File Reader, (3) TED, (4) Printer Dump, (5) Color Check, and (6) Titler. These algorithms improve the capabilities of DIAS as a remote sensing tutorial package because they allow students greater flexibility in data handling.

INSTRUCTIONAL IMPLEMENTATION

The DIAS package, which provides a collection of intra-connected algorithms for digital image processing of remote sensor data, has been used to provide "hands-on" training in remote sensing courses at several colleges and universities. This section reports on the instructional objectives and experiences in remote sensing courses at two sites, the University of Oklahoma and the State University of New York College at Geneseo.

THE UNIVERSITY OF OKLAHOMA

A precursor to DIAS was first introduced in the classroom in 1982. Emphasis at that time centered on demonstration of an ongoing software development project. Students were shown the capabilities of microcomputers for data display and analysis. Discussion focused on spatial and radiometric aspects of the data as shown in the graphic displays (i.e., pixel size, spectral signatures, data variability and redundancy, and classification of spatial patterns).

By 1983, the software had been improved and expanded. Three class sessions were devoted to student use of DIAS. Instructional objectives included (1) expanding student knowledge of how a computer works, (2) increasing awareness of the nature of the data, (3) demonstrating the importance of color graphic display, (4) improving cognition of the effects of data transformations, and (5) showing students the differences in method and results associated with supervised versus unsupervised classification.

In 1984, the package was incorporated into a formal series of laboratory exercises designed to provide further insight into the material presented in the classroom. Four exercises were developed: data entry, data familiarization, image enhancement, and classification. Students were required to select an area of interest and extract the corresponding data from available Landsat CCT's. Subsequently, these data were transferred to diskette for analysis. The major assignment for students was to interpret and then classify the land-cover types for their individually selected data set plus one area (with bare soil, vegetation, and open water) which was assigned to everyone.

Following a brief introduction to the use (and misuse) of the microcomputer and the DIAS software, the formal laboratory exercises allowed students to work at their own pace and without immediate faculty supervision. In comparison with previous classes, student responses in answering the laboratory exercises and examination questions demonstrated an improved understanding of the capabilities and limitations of digital image processing. In addition, awareness of the components and workings of a computer system increased.

THE STATE UNIVERSITY OF NEW YORK COLLEGE AT GENESEO

The DIAS package has been used in undergraduate remote sensing courses at the State University of New York College at Geneseo since 1983. In addition to using DIAS, students perform digital image analysis using software available on the mainframe computer. The user-friendly nature of DIAS, combined with the students' preference for using the Apple microcomputers, has greatly increased the scope of digital image analysis currently offered in these courses.

Students were given specific weekly "homework" assignments which, when all were completed, comprised an introduction to digital analysis of remotely sensed data. These assignments began with the preparation of histograms (Figure 2a) and density slices (Figures 2b and 2c) for the four spectral bands of one study area. In some cases these raw data sets were linear contrast stretched, illustrating the utility of data enhancement routines. Students then performed both an unsupervised and a supervised classification of the study area and were asked to report the results of the classifications, including the number of pixels, and the area and location(s) of each class. In many cases, spectral characteristics of specific features such as highways, ponds, or subdivisions were identified and mapped employing DIAS programs such as Profile (Figure 2e), Binary File Reader, and Signature (Figure 2f).

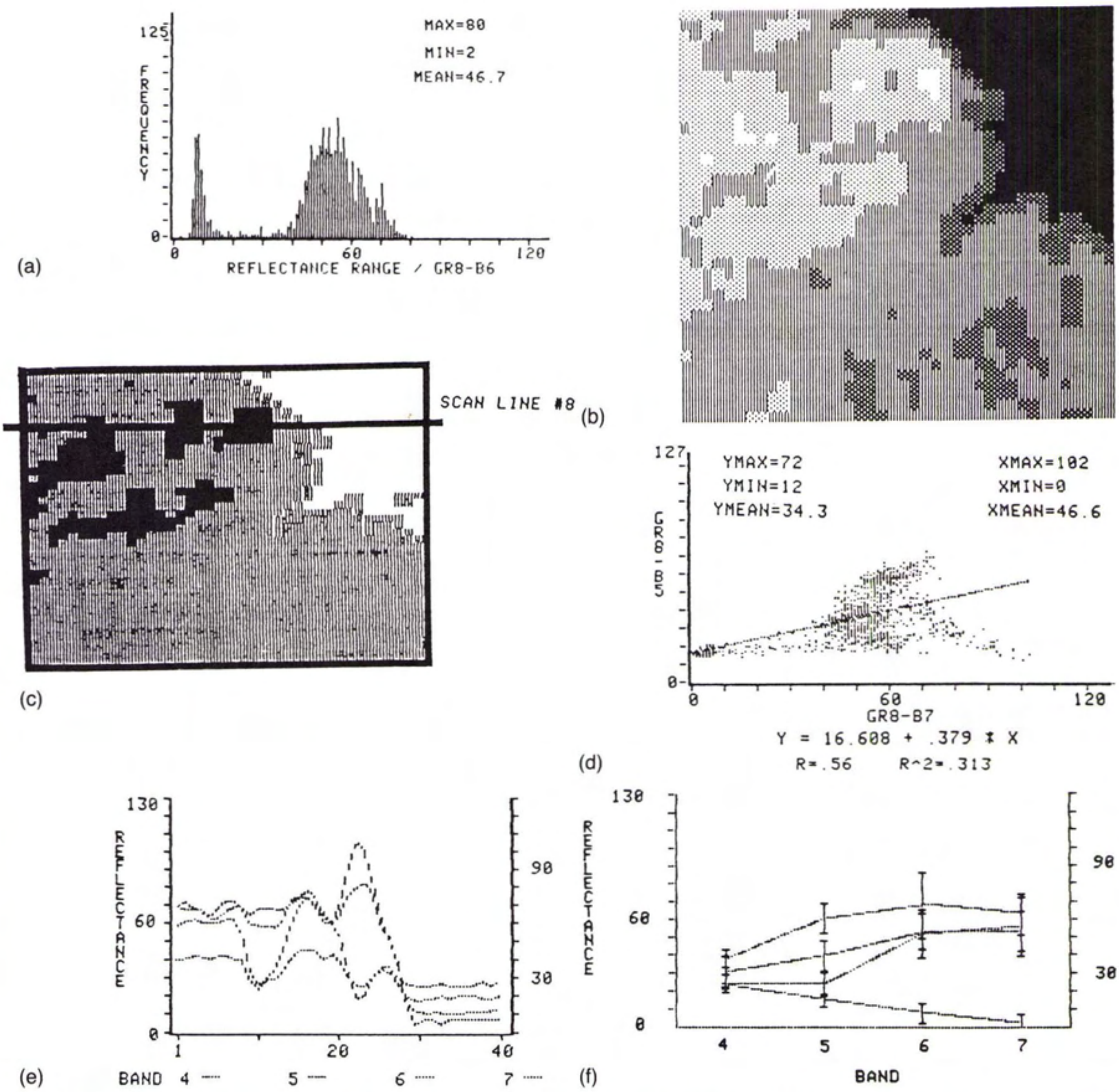

FIG. 2. Screen displays generated by the Digital Image Analysis System software package using Landsat MSS data from the west side of Lake Altus in southwestern Oklahoma (Scend ID: 20492-16344, 10 July 1979). (a) Single Band Histogram of band 6. (b) High Resolution Density Slice of band 6. Black = 0–14, crosshatching = 15–44, lines = 45–59, dots = 60–74, white = 75–80. (c) Low Resolution Density Slice of band 6. Water areas are shown in white and highly reflective areas (primarily bare soil) are in black. (d) Two-Space Scatter Plot, including best-fit regression line, of band 5 (vertical axis) and band 7 (horizontal axis). (e) Profile of the four bands of data along scan line eight. (f) Signature plots of four spectral classes determined through use of the Statistics, Homogeneity Table, and Lookup Table routines within the Unsupervised Classification programs.

At first, the relatively small size, a 40 by 40 pixel matrix of Landsat MSS data, seemed to be a serious limitation. However, experience has shown that, with careful selection of the study area, a 1600 pixel area (approximately 5 sq km) is quite adequate for classroom demonstration. The relatively small study area is an advantage when combining the use of DIAS with field work to identify and field check environmental conditions present in the data set area.

DIAS has greatly enhanced remote sensing instruction at The State University of New York College at Geneseo. Basic concepts of digital image analysis are presented to the students, and their subsequent understanding and application of these concepts is improved. Perhaps most significant is the fact that while using this microcomputer-based software package students performed several multispectral image analyses, and worked with the application of these image interpretations to real world problems of land-use monitoring, land-cover classification, and geographic mapping. It was not possible to accomplish all of these tasks and generate universal student acceptance and understanding of digital image analysis in a mainframe computer environment. It is hypothesized that the rapidly generated color graphic output and the user-oriented software are important factors in aiding student understanding of the similarities and differences between computer-based digital image analysis and human interpretation of photographic image products.

CONCLUSIONS

In summary, a need existed for an education-oriented image processing software package that emulated the capabilities of larger mainframe and minicomputer-based systems. Costs associated with these state-of-the-art systems were a primary factor. DIAS, the Digital Image Analysis System, was developed in response to this need using a low-cost Apple microcomputer. Package design was directed towards development of a series of task-specific processing steps that demonstrate the capabilities of mainframe and minicomputer-based image processing software packages. A menu-driven and user-friendly format limits the computer expertise required of students. It has been found that the routines successfully emulate software designed for more powerful computer systems and improve student cognition of digital image processing. Thus, DIAS is useful for interactive training in remote sensing in college and university classrooms. Educational software of this type should become of increasing importance in the information age of the 1980's.

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