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# Digital Image Processing Using the Apple II Microcomputer

**The Apple II microcomputer provides an effective, yet inexpensive, means of demonstrating, teaching, and using digital image processing procedures.**

ABSTRACT: *The inexpensive Apple II microcomputer can be used for digital image processing in operational and educational environments. The Apple II is portable enough to be taken directly into the classroom for lecture demonstrations and laboratory exercises. It is easily taken into the field for on-site data analysis or local presentations. Processing results can be displayed on a color monitor/TV screen in either low-resolution or high-resolution graphics, or can be printed on a line printer. At least five digital image processing systems (software packages) are in use in the United States: Apple II Digital Image Processing System (A/DIPS), Apple Image Processing Educator (AIPE), Oklahoma Landsat Training Program System, Apple Personal Image Processing System (APPLEPIPS), and Mini-LARSYS.*

## INTRODUCTION

THE APPLE II provides an effective, yet inexpensive, means of performing digital image processing on a microcomputer. At least five different systems for interactive digital image processing on the Apple II are in use. Described in this paper are systems developed at the University of Wisconsin-Madison, NASA Goddard Space Flight Center, University of Oklahoma, Telesys Group (Maryland), and Purdue University.

## THE APPLE II MICROCOMPUTER

The Apple II is undoubtedly the most pervasive microcomputer at colleges and universities in the United States. It is very well suited to classroom demonstrations of digital image processing and also to use in introductory laboratory sessions because of its relatively low cost, its graphics capabilities, its versatility, and its portability. These same capabilities also make it very useful to scientists, to small businesses, and to regulatory agencies.

The Apple II microcomputer is based on the 6502 microprocessor. It is supplied with a Basic language in ROM(Read-Only Memory) and can also be programmed in machine language. With the addition of appropriate hardware and software, Pascal, and FORTRAN can also be utilized.

The Apple II typically has 48K bytes of RAM (Random-Access Memory). Since one "K" of memory is equal to 1024 bytes, the Apple II has 49,152 bytes of RAM. The disk operating system takes up 10.5K bytes and system software and keyboard buffers take up some RAM space. The user has 36.4K bytes of available random access memory for storing programs and data. Ancillary data storage of up to an additional 256K can be achieved through the use of peripheral cards and special software. Data and programs are normally stored on 5 1/4-inch floppy disks with up to 136K bytes capacity. However, the Apple II can be interfaced



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with 8-inch floppy disk drives with a storage capacity of 1.1 megabytes (1.1 million bytes) per disk using double-sided double-density disk storage or with hard disk drives with a storage capacity of 10 megabytes or more.

For the display of output, the Apple II can be connected to a black-and-white monitor, a color monitor, and/or a color TV set. The Apple II has internal circuits and software to generate text characters and display them as part of a video signal. It can also display both high-resolution and low-resolution graphics. In the low-resolution graphics mode, the Apple II can display 40 rows of 40 columns plus 4 rows of text, with each pixel displayed as one of 16 colors. Alternatively, it can display 48 rows of 40 columns with no text. In the high-resolution graphics mode, the Apple II can display 192 rows of 280 columns in six colors (or 160 by 280 plus 4 rows of text). However, not every color can be plotted at every point on the screen using the high-resolution graphics mode (Bishop, 1980; Williams, 1982).

The Apple II has eight expansion slots that can accommodate interface cards that control a wide variety of input/output devices, such as line-printers, digitizing tablets, and *x-y* plotters. In addition, the Apple II can serve as a remote terminal to another computer by means of a communications card and modem (or a direct-coupled "micromodem"). This allows, for example, the capture of Landsat data from a large mainframe computer.

## THE A/DIPS SYSTEM

The Apple II Digital Image Processing System (A/DIPS) was developed by Professor Ralph W. Kiefer at the University of Wisconsin-Madison. It provides an effective means of demonstrating digital image processing concepts to students in various remote sensing and image interpretation courses. Existing programs include density slice, training set extraction, histogram plotting, scatter diagram plotting, and parallelepiped classification programs. Programs under development include minimum distance to means classification, band ratio display, and smoothing (generalization) of classification data. These programs are in the public domain and available for distribution.

At the University of Wisconsin-Madison, a class handout that is used to explain many aspects of digital image processing is prepared using the Apple II. After the students have been exposed to this printed material, the Apple II is brought to the lecture room for a demonstration of interactive digital image processing. After the lecture demonstration, the Apple II is used in laboratory exercises by students working in groups of two.

The programs are written Applesoft Basic and then compiled into machine language for increased speed. The process of compiling speeds up the programs by a factor of four to six times.

The size of the data sets captured from a larger computer and stored on Apple disk files is 120 rows by 120 columns. Various size subsets can then be taken from these files. Data sets are available from a number of geographic areas and include both Landsat data and scanned photographic data.

The data set used for the class handout consists of a 50 row by 60 column subset of Band 5 and 7 Landsat data acquired 13 July 1974 over southern Wisconsin (Lillesand and Kiefer, 1979, pp. 546–547). The subset size was selected as 50 by 60 pixels in order to fit the printed output onto an 8-1/2 by 11 inch page.

Plate 1 shows the outline of this 50 by 60 matrix superimposed on a color-infrared photograph. Each rectangle on the overlay outlines the location of 10 Landsat rows by 10 Landsat columns. This data set is referred to on the printouts as the "MADISON" data set and contains a variety of land-cover types, including water, aquatic vegetation, trees and grass, and a variety of impervious surfaces (roofs and pavement).

The program HISTOGRAM was used to print the histogram of Landsat Bands 5 and 7 shown as Figure 1.

The program SLICE was used to produce the level slice of Landsat Band 7 shown as Figure 2.

HISTOGRAM FOR 'MADISON' DATA FILE (3000 PIXELS)

| | NUMBER OF PIXELS | | | NUMBER OF PIXELS | |
|---|---|---|---|---|---|
| LEVEL | BAND 5 | BAND 7 | LEVEL | BAND 5 | BAND 7 |
| 0 | 0 | 0 | 50 | 12 | 0 |
| 1 | 0 | 49 | 51 | 11 | 0 |
| 2 | 0 | 425 | 52 | 0 | 0 |
| 3 | 0 | 225 | 53 | 7 | 0 |
| 4 | 0 | 33 | 54 | 3 | 0 |
| 5 | 0 | 23 | 55 | 4 | 0 |
| 6 | 0 | 21 | 56 | 0 | 0 |
| 7 | 0 | 9 | 57 | 3 | 0 |
| 8 | 0 | 9 | 58 | 1 | 0 |
| 9 | 0 | 4 | 59 | 1 | 0 |
| 10 | 0 | 9 | 60 | 1 | 0 |
| 11 | 1 | 13 | 61 | 1 | 0 |
| 12 | 18 | 8 | 62 | 2 | 0 |
| 13 | 130 | 7 | 63 | 1 | 0 |
| 14 | 332 | 11 | 64 | 2 | 0 |
| 15 | 367 | 11 | 65 | 0 | 0 |
| 16 | 169 | 34 | 66 | 0 | 0 |
| 17 | 109 | 56 | 67 | 0 | 0 |
| 18 | 87 | 51 | 68 | 2 | 0 |
| 19 | 114 | 82 | 69 | 2 | 0 |
| 20 | 64 | 122 | 70 | 3 | 0 |
| 21 | 182 | 203 | 71 | 0 | 0 |
| 22 | 113 | 239 | 72 | 0 | 0 |
| 23 | 138 | 258 | 73 | 0 | 0 |
| 24 | 90 | 320 | 74 | 0 | 0 |
| 25 | 87 | 260 | 75 | 0 | 0 |
| 26 | 85 | 179 | 76 | 0 | 0 |
| 27 | 115 | 130 | 77 | 0 | 0 |
| 28 | 110 | 88 | 78 | 0 | 0 |
| 29 | 99 | 46 | 79 | 0 | 0 |
| 30 | 52 | 27 | 80 | 0 | 0 |
| 31 | 34 | 9 | 81 | 0 | 0 |
| 32 | 30 | 9 | 82 | 0 | 0 |
| 33 | 80 | 4 | 83 | 0 | 0 |
| 34 | 8 | 2 | 84 | 0 | 0 |
| 35 | 36 | 3 | 85 | 0 | 0 |
| 36 | 48 | 2 | 86 | 0 | 0 |
| 37 | 24 | 7 | 87 | 0 | 0 |
| 38 | 7 | 2 | 88 | 0 | 0 |
| 39 | 28 | 2 | 89 | 0 | 0 |
| 40 | 25 | 4 | 90 | 0 | 0 |
| 41 | 16 | 0 | 91 | 0 | 0 |
| 42 | 34 | 2 | 92 | 0 | 0 |
| 43 | 0 | 2 | 93 | 0 | 0 |
| 44 | 13 | 0 | 94 | 0 | 0 |
| 45 | 27 | 0 | 95 | 0 | 0 |
| 46 | 32 | 0 | 96 | 0 | 0 |
| 47 | 22 | 0 | 97 | 0 | 0 |
| 48 | 5 | 0 | 98 | 0 | 0 |
| 49 | 11 | 0 | 99+ | 2 | 0 |

FIG. 1. Histogram of Band 5 and Band 7 data for a 3000 pixel area.

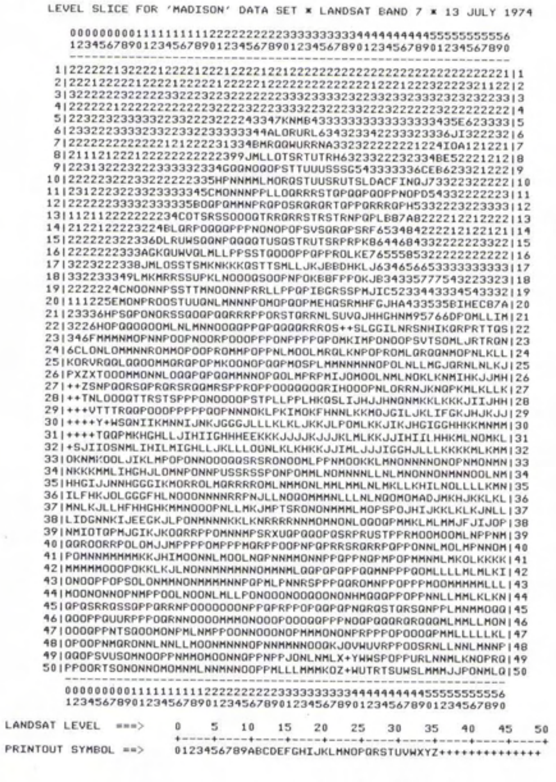



FIG. 2. Level slice showing 38 levels of Landsat Band 7 data.

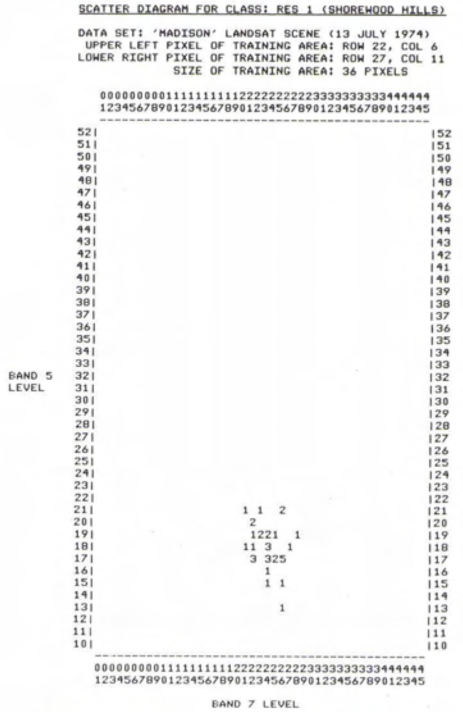



FIG. 3. Scatter diagram of Landsat Bands 5 and 7 for a 36 pixel training set in a wooded residential area.

The program TRAIN/STATS was used to extract training set data and the program SCATTER was used to print the scatter diagram shown as Figure 3. This scatter diagram shows the number of occurrences of each combination of Band 5 and Band 7 values in the training set.

The program BOXCLASS was used to compute and print a two-band, six-class, parallelepiped classification (Figure 4) based on data presented in a number of scatter diagrams.

Figure 5 and Plates 2 through 5 were photographed from the Apple II display screens (black-and-white monitor and Sony TV). The data set used is a 40 by 40 pixel area in the upper right of Plate 1 and Figures 2 and 4 and is referred to as the "PICNIC" data set in Plates 2, 3, and 4. The 40 by 40 pixel size is set by the size of the Apple II display in the low-resolution graphics mode. More pixels can be shown in the high-resolution graphics mode, but the number of colors is limited to six.

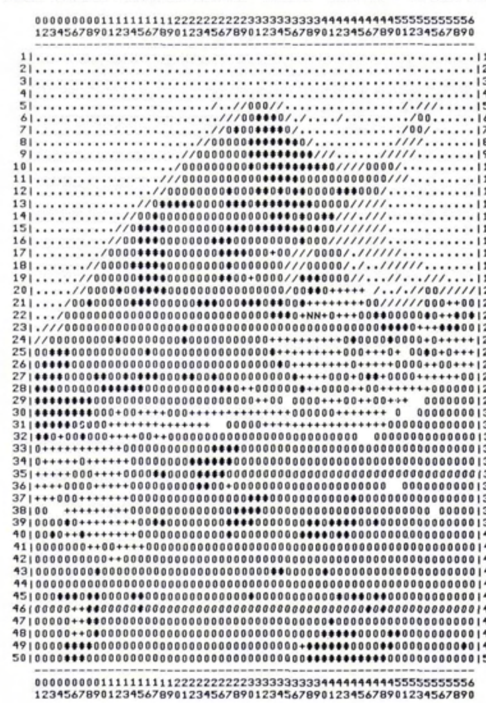
The program HISTOGRAM/SLICE was used to display the histogram shown as Figure 5. To examine the Landsat data level number for each of 1600 pixels, compute the histogram, and plot the results on the screen takes 7 seconds on the Apple II.

The program HISTOGRAM/SLICE was also used to display the level slices shown as Plates 2 and 3. Each pixel is displayed as its color is computed, and the full 1600 pixel display is completed in 24 seconds. The four lines of text below the low-resolution display are used for labelling the display.

The program BOXCLASS, a parallelepiped classifier, uses data from two or more Landsat bands. The training set data (principally represented as scatter plots) from the printed output described above are used to select the bounds for each class. A two-band, six-class, parallelepiped classification using the program BOXCLASS is shown as Plate 4. For purposes of illustration, the same bounds and classes used for Figure 4 are used here. To determine the class for each of the 1600 pixels, select the appropriate color for plotting, and plot the results on the color TV screen requires 40 seconds. Each pixel is desplayed as it is computed, with the results being displayed at a rate of about one row (40 pixels) per second.

Student reaction to seeing these programs run in "real-time" on the Apple II computer has been very positive. The 40 by 40 data set displayed in the low-resolution graphics mode is large enough to show recognizable features and yet small enough to allow for reasonably rapid computation/display times.

PARALLELEPIPED CLASSIFICATION FOR 'MADISON' DATA SET * 13 JULY 1974



| CLASS NAME | SYMBOL | BAND 5 LB | BAND 5 UB | BAND 7 LB | BAND 7 UB | NUMBER OF PIXELS |
|---|---|---|---|---|---|---|
| LAKE MENDOTA | . | 0 | 20 | 0 | 3 | 699 |
| AQUATIC VEG/SHORELINE | / | 0 | 25 | 4 | 16 | 147 |
| VEGETATION | ♦ | 10 | 38 | 27 | 63 | 328 |
| MIXED VEGETATION/IMPERVIOUS | 0 | 10 | 38 | 17 | 26 | 1538 |
| IMPERVIOUS SURFACES | + | 39 | 99 | 0 | 63 | 269 |
| NIELSEN STADIUM | N | 100 | 127 | 0 | 63 | 2 |
| UNCLASSIFIED | | | | | | 17 |
| | | | | | | 3000 |

FIG. 4. Parallelepiped classification for a 3000 pixel area. Classes and bounds are shown on the printout.

Long-term plans for the A/DIPS system include the provision for including environmental data (e.g., elevation, slope, slope-aspect) and ecological data (e.g., probability of vegetation species occurrence on various elevation and slope-aspect combinations) in the classification process, and (2) the development of a geoinformation system for the purpose of land use suitability evaluation.

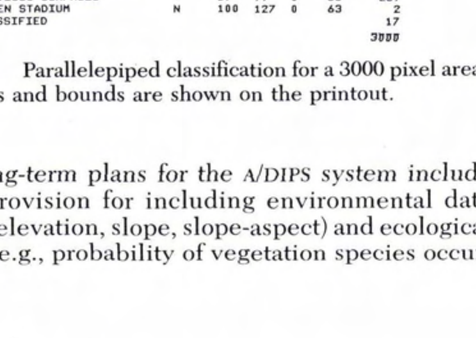



FIG. 5. Histogram of Band 7 data for a 1600 pixel area (photographed from black-and-white monitor screen).

## THE AIPE SYSTEM

The Apple Image Processing Educator (AIPE) system was developed by Dr. Fred Gunther of the Computer Sciences Corporation working at the Eastern Regional Remote Sensing Applications Center of NASA. The AIPE system uses the Apple II for personalized computer-assisted instruction (CAI) in the digital image processing of Landsat images. It was designed to be a "user friendly" system that would ease the introduction of the new user to the technical aspects of digital image processing. Programs were written in both Integer Basic and Applesoft (floating-point) Basic to provide "proof-of-concept" demonstrations and to explore system capabilities. The AIPE programs are in the public domain and available for distribution.

The AIPE system disk includes the following programs and data:

- A menu program that welcomes the user to the system, provides general system information, and gives a "menu" of image processing programs. It provides optional short explanations for each program, an optional step-by-step demonstration of each image processing procedure, and the automatic loading of a selected instructional or image processing program from disk.
- A set of image processing programs that perform various image processing functions. They provide for automatic disk storage of user image and statistical files, under user-selected names.
- Image data files for analysis.

The programs described below are presently operational on the AIPE system. On-screen displays are in the low-resolution graphics mode (40 by 40 pixels).

- ORSER INPUT takes Landsat data previously extracted and downloaded from a data file on the ORSER (Pennsylvania State University, Office of Remote Sensing of Earth Resources) system, captures the data as Applesoft Basic "DATA" statements, and writes the data onto a disk as an Apple "text file."
- REFORMAT converts the Landsat data from "text file" to "binary file" format. The binary format permits faster data loading and the binary data occupy less RAM space in the Apple than data arrays.
- DENSITY-SLICE, QUICKDS, and TRAVERSE display a low-resolution color level slice of Landsat data. In addition, TRAVERSE provides a one-row or one-column display of pixel brightness values for a user-selected traverse across the image. DENSITY-SLICE is an Applesoft Basic program that operates slowly, but will provide a level slice of the "norm" of all four data channels in addition to a level slice of each individual channel. QUICKDS and TRAVERSE

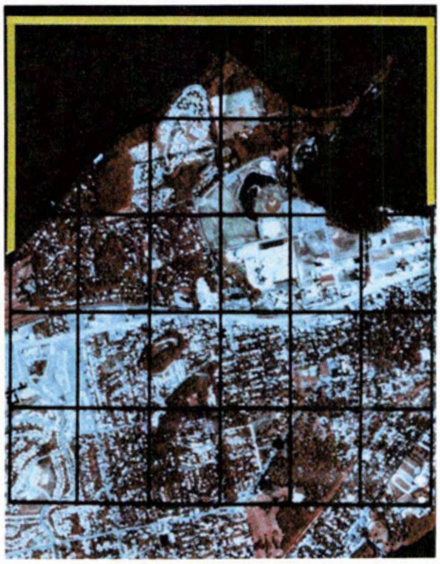


PLATE 1. Color infrared aerial photograph with superimposed grid showing the location of a 50 row by 60 column Landsat data set. Madison, Wisconsin, 31 July 1974 (NASA photograph).


PLATE 2. Four-level slice of Band 5 Landsat data. Colors and levels are as follows: Blue—0–15; green—16–38; red—39–99; white—100–127 (photographed from color-TV screen).

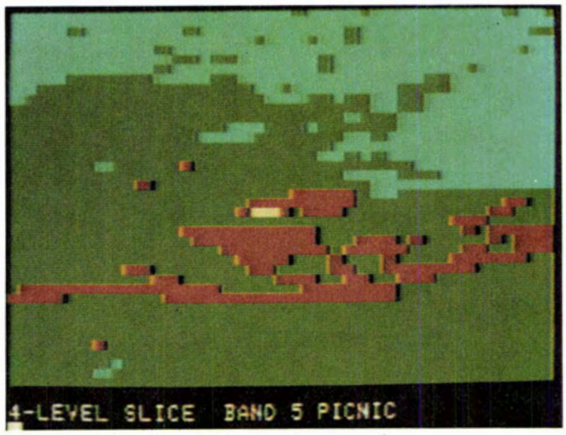



PLATE 3. Five-level slice of Band 7 Landsat data. Colors and levels are as follows: blue—0–3; green—4–11; orange—12–21; yellow—22–26; white—27–63 (photographed from color-TV screen).

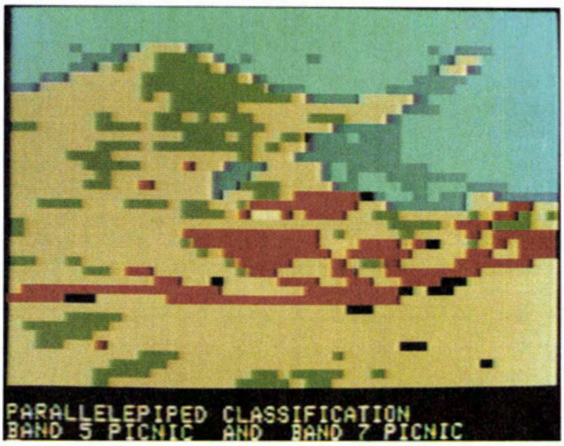



PLATE 4. Parallelepiped classification for a 1600 pixel area, using the same bounds as tabulated in Figure 4. Colors and classes are as follows: medium blue—open water; dark blue—aquatic vegetation/shoreline; green—vegetation; yellow—mixed vegetation and impervious surfaces; red—impervious surfaces; white—roof of tennis stadium (photographed from color-TV screen).

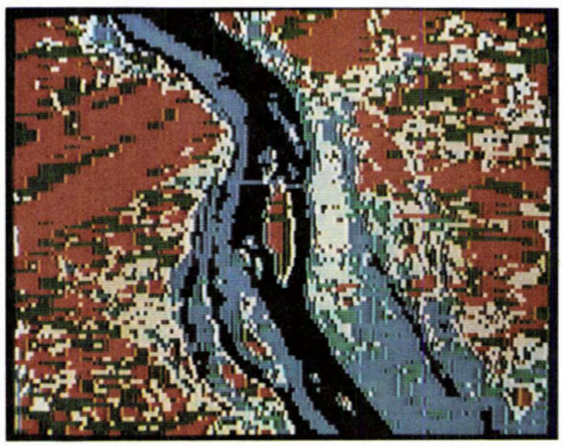


PLATE 5. Level slice of 140 by 96 pixel Landsat Band 7 data (using Apple II high-resolution graphics), April 1978, Harrisburg, Pennsylvania (photographed from color monitor screen) [courtesy of the Telesys Group].

use Integer Basic to operate faster, but will level slice only one channel at a time. All programs have the ability to let the user make printed copies and disk copies of level-slice color codes in image format.

- STATS and QUICKSTATS compute whole-image or training set statistics, including mean, variance, skewness, and kurtosis. Training sets can be selected from an on-screen display by using an Apple II joystick or game paddles to control the position of the on-screen cursor. The image with the training area marked can be saved as a disk file or printed in image format. The training set statistics are printed and can be saved in a disk file with a user-selected name.
- FILTER applies a 3 by 3 box filter (choice of smoothing or contrast filter) to image data. Each channel is filtered separately. After filtering, interactive color level slices may be applied to the data by the user. Both the multichannel filtered data and the display image can be saved as disk files for subsequent analysis.
- CONTINGENCY is a bivariate tally program that assists in comparisons of color-coded images saved as disk files.

The presently-supplied data set is a four-channel Landsat subscene of Harrisburg, Pennsylvania, acquired during July 1973. The image covers part of the Susquehanna River at the I-81 bridge. The subscene includes several land-use/land-cover classes, including urban, suburban, forest, lake water, and river water.

From its first unofficial demonstrations in 1979, the AIPE system has attracted the attention of both professional scientists and educators interested in computer-assisted image processing. It has seen successful use in demonstrations at various conferences on the applications of remote sensing technology and in technology-transfer short courses. AIPE demonstrations have stimulated the use of digital image processing by several university professors.

The AIPE system is being prepared for distribution through COSMIC (a national governmental clearinghouse for the distribution of computer software located at the University of Georgia). A spectral-signature classification program is being written. The capability for the user to select individual threshold levels and colors is being added, and documentation is being prepared.

## The Oklahoma Landsat Training Program System

The Oklahoma Landsat Training Program System was developed by Professors Charles E. Barb, Jr. (School of Civil Engineering), and John A. Harrington, Jr. (Department of Geography), of the University of Oklahoma. This system is used principally for demonstrations and laboratory sessions in a basic remote sensing course. The programs are in the public domain and available for distribution.

Existing programs use 40 by 40 pixel data sets and include (1) a program to move selected Landsat data sets from an IBM 3081 computer to an Apple II computer, (2) programs to display histograms and density slices, and (3) an unsupervised classification program that can generate up to 15 classes that are displayed using the low-resolution graphics display.

Under development are (1) a supervised classification program (a parallelepiped classification that uses minimum statistical distance to resolve the classification of pixels that fall within more than one parallelepiped), (2) a training set extraction program, and (3) an Apple-based geoinformation system that will include such items as slope and soil data as well as spectral reflectance data.

The use of the Apple II in remote sensing classes at the University of Oklahoma has greatly facilitated the learning process. Students indicate that the "hands-on" experience associated with computer-assisted instruction helps clarify many misconceptions that can be generated in the usual slide-lecture learning environment. Individuals using the Apple II system asked substantially more questions and several were stimulated to improve existing programs and experiment with writing their own software routines.

## The APPLEPIPS System

The Apple Personal Image Processing System (APPLEPIPS) was developed by James F. Rose, and others, of the Telesys Group (5455 Wingborne Court, Columbia, MD 21045). The APPLEPIPS system was designed as a modular and expandable software package. It was developed to be suitable for both educational classroom/laboratory instruction and to serve as an inexpensive and expandable research tool to analyze digital image data quickly and efficiently in a dedicated user-controlled environment. The APPLEPIPS system is a commercial system. APPLEPIPS Version 1.0 is available for $495.00. APPLEPIPS Version 2.0 is scheduled for release in Summer 1983 at a price to be announced. Several multispectral data sets are available, including Annapolis (Maryland), Baltimore (Maryland), Harrisburg (Pennsylvania), Providence (Rhode Island), the San Raphael Swell area of Utah, and Mt. St. Helens.

Both an interpreted Basic language for interactive communication with the user and Assembly language for image processing speed have been used. This combination has resulted in an efficient, yet maintainable, package of routines.

The APPLEPIPS system uses a larger data set than the other systems described here. It operates with a full data set of 280 by 192 pixels and can display a subset of 140 by 96 pixels using high-resolution graphics. This subset is the working image for most of the image processing programs. Training sample selections are taken from a 40 by 40 "subset of a subset."

The following programs are available in APPLEPIPS Version 1.0.

- SUBSET A SCENE allows a user to select a subimage from the standard 280 by 192 pixel full scene. This is typically a 140 by 96 pixel subimage such as shown in Plate 5.
- DISPLAY A BAND produces a color image from one band of digital image data by density-slicing (Plate 5). The display is limited to the six colors provided by the Apple II high-resolution graphics mode. To aid in the selection of boundary values for slicing, this program includes a histogram display of the band. APPLEPIPS can calculate and display a histogram in 2 seconds and display a high-resolution image in 6 seconds.
- IMAGE ALGEBRA is a package of algorithms that allow the user to average images, compute the difference between two bands, compute the ratio of two bands, and perform other mathematical or logical operations on the images.
- NORMALIZATION computes the "norm" for each pixel over all selected bands. This function reduces the variations in the overall image and has been found useful in detecting urban or water boundaries.
- SUBSET A SUBSET allows the user to focus on a 40 by 40 subset of the image. Using this program, the user scans (or "flies") over the 140 by 96 pixel subset viewing a 40 by 40 pixel "window" in up to 16 colors.
- SIGNATURE TRAINING enables the user to select individual pixels to form a training set. As the user moves a cursor over a 40 by 40 pixel scene, the individual spectral values for all bands are displayed. When the user adds or deletes pixels from the training set, revised statistics are displayed. Statistics may be gathered from several 40 by 40 pixel subsets and training set statistics may be saved on a working disk.
- SIGNATURE EDITING retrieves training statistics from disk storage and allows the user to modify the statistics, compare spectral signatures, combine signatures, or even enter a hypothetical set. Graphic displays of signatures in spectral space are available to assist in the analysis
- CLASSIFICATION (PPD) is a parallelepiped classification program that can have up to 8 bands of input data and can output results with up to 64 classes. The iterative algorithm used produces both a classification and threshold image of the 140 by 96 subset.

The following additional programs will be available in APPLEPIPS Version 2.0:

- UNIFORMITY PATTERNS is a textural analysis program that identifies regions within the scene that have relatively uniform spectral values.
- CONVOLUTION is a texture analysis program that will use a 3 by 3 pixel filter to smooth data, enhance edges, or isolate local spatial features.
- TEXTURE ANALYSIS is a collection of texture analysis algorithms designed to perform specialized analysis of the local 3 by 3 pixel neighborhood of each pixel. Unlike CONVOLUTION, these algorithms employ non-linear approaches including absolute difference, minimum and maximum searches, and a number of conditional (logical) operators.
- SPECTRAL TRANSFORMATION of the original bands is facilitated with this package of routines. Linear combinations of each channel of reflectance data are calculated for each pixel in the image.
- HADAMARD TRANSFORMATIONS provides a set of routines that provide for images to be filtered or convolved with any filter reducing low or high frequency noise.
- CLASSIFICATION (MINDIS) is a minimum distance to means classification program.
- UNSUPERVISED CLUSTERING allows the analyst to perform a classification and collect spectral signatures at the same time, without requiring prior sinature training.
- COMMUNICATION UTILITIES transfers digital image data from another computer to the Apple II (presently available to Version 1.0 owners).
- HARDCOPY UTILITIES generates gray-level maps on dot-matrix printers.

The APPLEPIPS system also provides for computer-based user training. Each option within the system has its own internal menu to assist the user with data analysis. In addition, a TRAINING menu lists a variety of topics that can be explained on the Apple II screen.

## The Mini-LARSYS System

The mini-LARSYS system is under development by Terry L. Phillips at the Purdue University Laboratory for Applications of Remote Sensing (LARS). LARSYS is a comprehensive data analysis system for remote sensing research developed at LARS. Mini-LARSYS is an Apple II adaptation of LARSYS that was designed for research and teaching purposes. Mini-LARSYS programs are not currently available for public distribution. When available, they will be sold through the Purdue University Department of Continuing Education.

Mini-LARSYS programs use a 40 by 40 pixel low-resolution graphics format. Existing programs include (1) a data extraction program (from the LARS mainframe computer), (2) a histogram plotting program, (3) a level slice calculation and display program, and (4) a training set extraction program. A minimum distance to means classification program is under development.

The mini-LARSYS developer, Terry Phillips, points out that, in addition to the use of the Apple II for the kind digital image processing programs illustrated here, the Apple II is extremely well suited to "idea development." A variety of geoinformation and remote sensing problems can be initially addressed and tested using a "personal" computer (the Apple II) as the research/development "tool." If greater computer power is eventually required, the methodologies developed on the Apple II can be transferred to a larger computer system.

### Summary

Several systems that use the Apple II microcomputer for digital image processing have been described. The examples here have dealt with the use of the Apple II for the processing of digital Landsat data. Other digital data can also be processed on the Apple II. Scanned (digitized) aerial photographs can be analyzed, as well as many image types from such diverse fields as cartography and medicine. APPLEPIPS, for example, is currently being used to analyze spiral galaxies. In addition, small geoinformation systems, blending spectral reflectance data with environmental data, can utilize the Apple II.

The Apple II can also play an important role as a "personal" computer for developing basic concepts and algorithms that can later be employed on larger computer systems.

Although the Apple II does not have the computing power of large mainframe computers or minicomputers, it does have the great advantage of being inexpensive and portable. In an instructional setting, the same basic operations that are employed on much larger computers can be explained and demonstrated on the Apple II in lecture and used by students in laboratory sessions. In addition, the Apple II can be utilized for digital image processing in research and consulting environments.

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## Forthcoming Articles

*G. E. Borman* and *E. Vozikis*, Map Projection Transformation with Digitally Controlled Differential Rectifiers.

*Dino A. Brugioni*, The Census: It Can Be Done more Accurately with Space-Age Technology.

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