Developing an Image Processing Workstation for Teaching Digital Remote Sensing

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Abstract

This paper examines how one undergraduate geography program designed and developed inexpensive image processing workstations and prepared related software for the purpose of teaching digital remote sensing at the undergraduate level. The workstations are built around IBM PC-XT microcomputers interfaced to high resolution (670 elements by 480 lines) monitor capable of displaying 512 colors simultaneously from a palette of 16.8 million and a host mainframe to perform large CPU functions and to transfer and store files. Software techniques for accomplishing high level graphics and linking existing software packages together into one sophisticated package are discussed. Software is written in Basic Computer Language. Methods discussed can be employed also in establishing workstations for automated cartography and geographic information systems.

Introduction

An image processing workstation can be a very beneficial tool for teaching digital remote sensing at the undergraduate level. In comparison to the conventional line printer approach for displaying and analyzing digital images, a workstation provides students the opportunity to test quickly and effectively concepts and ideas introduced in class, detect and identify readily the various spatial patterns associated with an image, and explore and analyze thoroughly different research avenues related to their particular environmental interest. In general, a workstation allows an instructor to cover more topics in the normal time allotted for a one semester course and students to create more rewarding and fascinating results than with a line printer. However, with beginning prices of image processing workstations ranging anywhere from $15,000 to $50,000 and some sophisticated stations exceeding $100,000 many small undergraduate geography programs do not have the financial resources needed to acquire and maintain such workstations, and thus, find themselves compelled either not to offer a digital remote sensing course or use less desirable tools. This paper examines how one undergraduate geography program (namely the program at the State University of New York (SUNY) at Oneonta) designed and developed its own workstations for less than $5500 each (an amount which might relate more favorably to a small department's budget) and prepared the related software.

SUNY-Oneonta Program

SUNY-Oneonta is one of the twelve four-year colleges within the State University of New York's 64 campus system. The college's student population of approximately 5500 is split rather evenly between two academic divisions, liberal arts and professional studies. The Geography Department, located within the liberal arts division, must compete with eighteen, mostly larger, departments for very limited equipment dollars, not a conducive environment for obtaining funds for an image processing workstation. The Department has a staff of five full-time faculty members and offers a solid undergraduate geography major with a special track in cartography and remote sensing. Four remote sensing courses are taught on a regular basis, one of which is entitled "Remote Sensing: Digital Image Processing." Also, three cartography courses, one of which is on automated cartography, are provided plus a computer-based geographic information systems course. The digital remote sensing, automated cartography, and GIS courses are taught once every two years, never at the same time. The digital remote sensing course generally has between 15 and 25 undergraduate students and is designed to have students work in teams of three people each. Each team initially works with a Landsat MSS data set based on a selected environment in New York State. Later the teams are moved up to either Landsat TM or SPOT HRV data sets. Using these data sets students are introduced to density slicing, supervised and unsupervised and various classification techniques. A large portion of the course centers on students having considerable hands on experience in order to receive a good understanding of how these techniques work and the problems associated with them. This course covers a large amount of material dealing with topics which are quite new to most students. To facilitate the learning of these materials image processing workstations were needed.

Instructional and Administrative Considerations

Before designing and building a workstation certain instructional and administrative considerations needed to be weighed. These considerations are common to most academic environments and play a key role in shaping decisions pertaining to equipment acquisitions and software developments. First, due to class size and maintenance problems more than one workstation had to be developed. The class was too large for one workstation, particularly with the numerous schedule conflicts each team faced while competing for the single station. Also, the amount of instructional material to be covered dictated the need for more than one station. Reducing the class size would only provoke administrative questions about offering a course with 10 or less students, especially a social science course with high equipment costs. Thus, the enrollment level had to remain basically at 24 students, the number established by New York State's Division of Budget for science laboratories.

Getting malfunctioning equipment repaired quickly and inexpensively was a major concern particularly with respect to those times when the course was to be taught. Most vendors would not provide on-site repair and if they would, the cost would sink the Department's budget. To ship specialized equipment back to a manufacturer for repair can normally take anywhere from three to six weeks, approximately twenty to forty percent of a semester. In addition, if little money was available to purchase equipment, even less was generally available to cover maintenance. Thus, to meet enrollment requirements and handle maintenance problems more than one workstation was needed.

Second, the workstations had to relate to other campus hardware and software especially college established standards. To have access to a large central processing unit's (CPU) number handling capability and the tape and/or disk devices required to load and store the large data files generally associated with image processing, the workstation had to be linked to the college network. The mainframe, the principal CPU on campus, and its related network determined certain standards which needed to be followed in order to accomplish the previously mentioned tasks. The network issue could have been overcome by purchasing a large, dedicated CPU with the needed I/O devices for the workstations, a path too expensive to pursue. By relating to college standards, maintenance and assistance services could be more readily available. The college generally had a comprehensive service contract for repairing standard computer equipment which could be extended to cover portions of the workstations. In addition, the college computer staff would be able to assist more when dealing with familiar equipment and software.

By relating to the college's computer standards, determined by a committee of faculty members and administrators, the number of operating systems, software packages, and hardware devices which students would have to learn in order to use the workstation would be reduced. By using the established standards introduced through beginning level computer courses students could develop a knowledge base on which to build when learning how to operate the workstations. They would not be faced with learning a completely new set of procedures. Too frequently computer-based courses are designed to teach students how to run particular pieces of software and/or hardware and not orientated toward introducing, with the aid of the computer, the basic concepts of the subject being taught.

Third, the use of the workstations could not be limited only to teaching digital remote sensing. With the course being offered once every two years, the equipment could not sit idle during the intervening period of time. The obvious solution to this problem was to use the stations in the automated cartography and GIS courses, a solution which greatly enhanced administrative and departmental support for the workstations. However this move meant designing a system directed toward both raster technology, appropriate for digital remote sensing work, and vector technology, more applicable to computer cartography. To maintain a balance between these two technologies certain design decisions had to be addressed. The basic consideration was one of determining how to obtain the greatest diversity of utilization for a piece of equipment when at the same time trying to design it for a specific application. As a partial solution to this problem, if more than one workstation was needed, each station could be designed slightly differently to meet the various applications. Due to the class size and maintenance considerations mentioned before, design flexibility was needed in order to change a station quickly from one application to another.

Hardware Configuration

SUNY-Oneonta has a single large mainframe, a Unisys A10, with a network of terminals scattered throughout the campus. A variety of microcomputers also exists on campus with the college standards being Apple IIs, IBM-PCs and XTs, and Zeniths. In general, microcomputers do not have the number handling ability required to process a reasonable size image based on remotely sensed data. Thus, the tasks of statistically analyzing images and handling large files stored either on tape or disk could be accomplished only on the mainframe. The mainframe terminals did not have the needed color graphics ability to display and analyze images. Thus, based on available facilities the best design was to have microcomputer workstations linked to the mainframe, a design not unique to the industry. The one major difference is that the stations would have to share the large CPU with a great many other campus users and a wide variety of computer uses.

After determining a station's basic design a microcomputer had to be selected. The microcomputer had to be able to handle high resolution graphics and be one of the college standards. Certain departments and administrative offices had acquired non-standard microcomputers, and in the process, many problems. Although initially recognized for its graphics capability, the Apple II machine did not provide the desired level of graphics and failed to interface well with the mainframe. Through their bus architecture the IBM and Zenith machines opened the door to many third party vendors, a number of which produced special graphics cards. Also, both machines interfaced with the mainframe. The Zenith, an IBM compatible, cost considerably less than the IBM. However, even though third party vendors generally advertised that their cards worked in all IBM compatibles, experience had shown that problems could occur with compatibles. Since a special card was going to be needed for the workstation, the IBM was selected as the preferred machine. The IBM cost more initially but most likely eliminated a number of problems later.

The final required components for putting together the workstation were a graphics card and high resolution monitor. A number of low priced, popular graphics cards were available but these cards failed to meet the

Figure 1. Basic Image Processing Workstation, IBM XT with a 670 × 480 Resolution, 9 Bits (512 Colors) Monitor.

desired requirements for the workstation. By searching various computer trade journals and newspapers, especially looking at the numerous advertisements, several less known but higher priced boards meeting the specifications were discovered. Three of these cards were reviewed, namely the Image Manager by Vermont Microsystems, the VXPC by Vectrix, and the Matrox PG-640A by Matrox Electronic Systems. Although each card met the minimum requirements the VXPC card set was selected because it permitted 512 colors to be displayed simultaneously from a palette of 16.8 million colors, provided a 670 x 480 pixel resolution, zoomed an image instantaneously up from between 2 to 16 times its original size, and allowed bit plane manipulation of its nine level memory plane. In addition, the card set provided a large firmware library of function commands which could be incorporated easily into any high level computer language and programmed with little difficulty to produce the needed workstation software. The card set consisted of two full length boards designed to occupy adjacent bus slots in an IBM-PC or XT and certain compatibles. The set does not work and can be damaged if another color board exists in the machine. The recommended high resolution monitor by Vectrix was also purchased. Thus, the basic hardware package consisted of an IBM PC-XT with 640K of memory, 20M bytes of hard disk storage, the VXPC card set, a monochrome monitor, and a high resolution color graphics monitor.

Table 1 provides the prices for a workstation's three major components. The IBM PC-XT price was determined by state contract but was comparable to what was being offered by many discount dealers. Even though IBM no longer manufactures PCs or XTs, a great many of the machines already exist on college campuses. Also, although the author elected not to use compatibles, these machines are available. The major problem with compatibles and some older IBM PCs and XTs when inserting large card sets is the low power supply which can be easily upgraded and replaced at minimum cost. The VXPC-16.8 card set listed in the table provides 16.8 million colors but for approximately $200 less one can get the VXPC-4096 set which provides all the same functions but has a palette of 4096 colors.

Table 1: Hardware Prices

IBM PC-XT	$2,072
VXPC-16.8*	1,950
High Resolution Color Monitor	1,295
Total	$5,317

*Includes Monitor Cable

Software Development

After determining the workstation's hardware configuration the next step was to select a programming language for preparing the necessary software. Four possible languages were available, specifically Basic, Fortran, Pascal, and C. The author is quite proficient with the first two and has some understanding of the latter two languages. The data handling and quantitative software for processing image files on the mainframe was written in Fortran. C was not available on the mainframe and Basic lacked a fast enough compiler and did not provide the file structure capability required. Pascal could have been used but a huge library of efficiently written Fortran routines already existed which could be easily incorporated into the image processing programs.

Even though Fortran was employed on the mainframe, Basic was a better language for developing software for the microcomputer-based workstation. Fortran was not well suited for designing software for an interactive computer environment. Also, the language lacked a good microcomputer compiler. Pascal and C were also good microcomputer languages but the author was less proficient in these languages and little assistance could be expected from the college's computer service staff with these languages since they were not extensively used on campus outside of a few advanced computer science courses. Basic was selected because of its suitability in preparing user-friendly, interactive software, the availability of good compilers, and the numerous Basic examples used by Vectrix in its VXPC's users manual. The selection of Basic did create one problem with respect to file transfer between the mainframe and the microcomputer. The large mainframe files were packed in order to save disk space. Fortran software had to be prepared to unpack the data files and repack them in a form easily handled by Basic.

Using Basic a professional appearing software package called Image was prepared which utilizes the monochrome monitor as the command screen and the high resolution monitor for all color graphics work. The program is a powerful piece of software which links together the various hardware components previously discussed to form a viable workstation and provides a wide variety of graphics capability. The program's power rests in the various VXPC function commands and certain special capabilities discussed below. Although portions of Image are designed to take advantage of certain features unique to the Oneonta computer environment, with some effort, most individuals familiar with Basic can develop a program similar to Image for their own workstation environment.

SHELL Command and. BAT Files

An important feature which greatly enhances Image's capability is its interrelationship with other software. Without exiting Image students can access any DOS command, WordPerfect (the college's standard word processing package), and Handshake (a terminal emulator). In other words students can perform directory checks, file copies, and other DOS operations without disrupting their work using Image. Also, through WordPerfect students can write their course papers and reports while viewing their displayed work on the high resolution monitor or maintain progress notes about their work, again without leaving Image. Students doing advanced work are expected to submit their papers on floppy disks as word processing files and the instructor can review their papers and retrieve their images by using Image. Finally, through Handshake students can convert the workstation into a terminal linked to the mainframe and run programs and other operations on the mainframe. The mainframe programs prepared for the course are designed to start initially in interactive mode to permit parameter input and then they switch to batch mode to handle the bulk of the processing. When running in batch mode, a student can leave Handshake, automatically returning to Image to continue his/her other work. Handshake is also the software used to transfer files between the mainframe and the workstation. All of the above mentioned operations are nested within Image and students only need to turn on the microcomputer and start Image in order to have a powerful workstation available to them.

To accomplish these tasks within Image one needs to utilize the Basic SHELL command and create DOS's .BAT files. Image is organized as a series of separate functional modules with each module being accessed through a key command. One of these modules deals with shelling which is the loading and executing of another program file while running another program. Below is an abbreviated version of the code used in this module.

```
PRINT "Enter SHELL Command"
INPUT"", SHEL$
CLS: SHELL SHEL$
PRINT "Press 'ENTER KEY' To Continue"
INPUT"", A$
GOTO (Return To Key Module)
```

The desired operation to be shelled is entered through a string variable. Next, the control monitor screen is cleared and the shell command performs the desired operation. For example, if the DOS operation, DIR A:, was entered, the files associated with disk drive A: would be listed. The purpose of the second print and input command is to maintain the screen information for viewing before the shell returns Image to its key module to enter the next function.

The procedures above work well with DOS commands but to run another program requires having adequate memory to hold both Image and the other program simultaneously, compiling the program into executable form, and creating a .BAT (batch) file for the program. Batch files are discussed in the DOS operational manual and developed through the Line Editor (EDLIN) program. For Image a batch file called IMAGE.BAT exists at the root directory level. This file is listed below.

```
ECHO OFF
CLS
CD\RSIMAGE
IMAGE
CD\
```

To initialize this file one only needs to type IMAGE without any extension at the root level. The ECHO OFF command inhibits the screen display of the DOS commands executed from the batch file. Next, the screen is cleared, followed by a change to the subdirectory called RSIMAGE where IMAGE.EXE exists. IMAGE.EXE is started and when the program is terminated by the user, the batch file returned the system to the root directory level.

Basically these same procedures are used when running programs such as WordPerfect or Handshake through the Image shell command. The WordPerfect batch file is shown below.

```
ECHO OFF
CLS
CD\WPERFECT
WP
CD\RSIMAGE
```

This batch file is located at the RSIMAGE subdirectory level and not at the root level. The other major difference between this file and the Image batch file is the subdirectories. The WordPerfect software is maintained in a parallel subdirectory called WPERFECT and not under the RSIMAGE subdirectory. Also, the batch file returns to the RSIMAGE subdirectory which allows the IMAGE batch file to terminate in a normal manner. The use of the shell command and the batch files can result in developing some sophisticated workstation software. Both WordPerfect and Handshake have built in shell commands and one can move, for example, between the two programs without returning each time through the Image program.

Final Remarks

This paper was written to show how one geography program proceeded in designing an inexpensive image processing workstation, particularly with respect to selecting hardware components and preparing software. As initially stated the purchase price of an established station was prohibitive and more than one station was needed. Approximately two years of work was required in order to acquire the various hardware components for different college budgets and to develop the program Image. Today, the department has four workstations being used in several courses. Figure 1 shows the basic workstation. An enhanced version of the workstation has been developed with a B&W graphics terminal. It is used to display graphically spectral signatures associated with the spectral classes illustrated on the high resolution color monitor. Putting together these workstations has taken considerable effort but it is very rewarding to see how the students become totally engrossed with their work while using the stations, so much so that they occasionally forget to attend their other courses. The workstations have greatly enhanced the learning process in the remote sensing-image processing course.