AN INTERACTIVE IMAGE PROCESSING, DISPLAY AND PROGRAMMING SYSTEM

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ABSTRACT

We have been developing a minicomputer laboratory for performing research in computer graphics and image processing. This paper deals with those aspects related to the latter, where the primary emphasis has been on applications to the biomedical sciences and on a general scene analysis system for analyzing color pictures. A difficulty arises in the utilization of the laboratory because of the multiplicity of peripherals and computers, as well as prospective users of varying degrees of experience. To cope with this problem we have developed an interactive image processing, display and programming system. The objective is to facilitate the operation of the hardware, to allow for various programmers, and to make the system interactive. This has been achieved by developing independent modules for each function and linking them as overlays by means of system software. This local image acquisition and processing system is being linked to the university IBM computer so that it may play the dual roles of input and output for the FORTRAN based PAX II picture processing system.

UN SYSTÈME POUR LE TRAITEMENT DES IMAGES À ACTION RÉCIPROQUE, POUR VISUALISATION ET PROGRAMMATION

ABRÉGÉ

Nous avons mis au point un mini-ordinateur constituant en quelque sorte un laboratoire destiné à effectuer de la recherche en systèmes graphiques par odinateur et en traitement des images. Le présent mémoire traite des aspects liés au traitment des images où l'accent a été placé principalement sur les applications aux sciences biomédicales et sur un système d'analyse générale des images en couleur. L'utilisation du laboratoire pose des problèmes en raison de la multiplicité des périphériques et des ordinateurs, ainsi que de l'expérience inégale des usagers éventuels. Dans le but de résoudre ce problème, nous avons conçu un système pour le traitement des images à action réciproque, pour visualisation et programmation. L'objectif consiste à faciliter le fonctionnement du matériel et l'utilisation par divers programmeurs, de même qu'à faire du système un système à action réciproque. Nous avons atteint ce but en créant des modules indépendants pour chaque fonction et en assurant leur recouvrement au moyen d'un logiciel de système. Ce système local d'acquisition et de traitement d'images est relié à un ordinateur IBM de l'Université de façon à pouvoir servir à la fois d'entrée et de sortie pour le système PAX II de traitement des images à base FORTRAN.

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1. INTRODUCTION

For several years now we in the Department of Electrical Engineering have been concerned with research in computer graphics and image processing. To facilitate this work we have developed a laboratory for digitizing, processing and displaying pictures and this paper deals with the computer image processing aspects of this system. A variety of input and output devices are available to the user and these will be described. Our philosophy has been to allow each user complete access to the system, thereby forcing a maximum degree of man/machine interaction. This activity has been aided by MIIPPS (McGill Interactive Image Processing and Programming System), the software system to be described below [1].

Two major areas of picture processing research have been considered: (i) biomedical engineering applications and (ii) a scene analysis system. With respect to the first topic we have investigated several problems, both of a clinical and a research nature, each of which has involved the analysis of image information. This kind of data is of course very common throughout the biomedical field. Generally the analysis is done visually and manually and our goal has been to automate these processes. For example, one recent project dealt with the determination of the human lung volume by means of an analysis of the anterior and lateral radiographic projections of the chest [2]. Another project was concerned with an image processing technique for delineating the outline of the human spinal column as it appeared on a specially prepared radiograph [3]. Shape parameters may then be computed from a derived spinal centreline and related to the degree of scoliosis or kyphosis suffered by the patient. The second area concerns itself with the long term goal of designing a general purpose scene analysis system for three dimensional color images. Most of the emphasis to date has been on low level nonpurposive processing with some preliminary work on the knowledge base associated with the higher level cognitive processing.

In the next section we discuss the laboratory facilities followed by a description of the software system in section 3.

2. HARDWARE CONFIGURATION

In this section we shall briefly describe the physical resources available in the computer graphics and image processing laboratory. These consist of three classes of devices: (i) processors, (ii) picture inputs, and (iii) picture outputs, some of which have been developed in the laboratory.

The primary processing system is a DEC PDP-15 with 32K core, 1/2 million words of disc space, two Dectape drives, high speed reader/punch, and line printer. Communication with the system is via a Tektronix Graphics Computer Terminal model T4002. This computer is connected to two other processors. One of these is a 4K DEC PDP-8 with two Dectape drives which is interfaced to the PDP-15 via a direct memory access channel. It is to the PDP-8 that most input and output devices have been connected to date. The second processor is the IBM 370/158 system situated at the McGill Computing Centre which is connected to the PDP-15 via a 1200 baud communications link.

At the present time two kinds of picture inputs exist with a third nearing completion. The primary input is an ITT image dissector camera which together with an associated integrator is capable of scanning and digitizing an optical image. The latter may be a 35 mm. transparency illuminated by a light box or a histological slide viewed directly through a microscope. A second input is a standard ITC VF - 301 television camera which when used in conjunction with a Hughes Model 639 scan converter can provide a dynamic picture source. The system presently under development uses a Cohu model 4353-100 silicon diode camera as the electro-optical device and a sequential column digitizer for scanning and digitization. The camera is compatible with standard television monitors and requires about seventeen seconds to digitize a picture with a 525 x 525 resolution.

Hardcopy, black and white, and color displays are available as outputs from the system. The color graphics video system is described in detail in a companion paper [4]. The Tektronix terminal can be utilized to output vector and alphanumeric data and an x - y display can present gray-tone images refreshed from core or disc. In addition, the Hughes scan converter can accept data randomly under program control and output on a standard black and white Conrac 525 line television monitor. For hardcopy we have available a dedicated Tektronix Display Unit Type 602 with an attached Polaroid camera and a computer controlled electronic shutter. The resolution of the picture output is restricted to 256 x 256 points. A photographic camera attachment is also available for the Tektronix terminal on the PDP-15 and is used typically for recording graphs and histograms.

Because of the multitude of devices it was necessary to develop software systems for accommodating users interested in certain classes of tasks. The next section deals with such a system used by researchers in picture processing.

3. PROGRAMMING SYSTEM FOR IMAGES

The MIIPPS system can run in a reduced version on the PDP-8 alone, or with its complete power using both the PDP-8 and the PDP-15. The major aspects of the command repertoire of both versions are discussed briefly in this section. The reader is referred to the MIIPPS manual for further details [1]. In general the MIIPPS programs are structured in a comprehensive and tutorial form so that the user will have little difficulty using the system. Furthermore, these programs are modular and it is quite simple to modify the modules or add new modules.

Although the PDP-8 is used as a slave peripheral controller for the PDP-15, it may nevertheless be operated independently for the purpose of focussing, selection of the scan field, and digitization. Both a fast and slow scanning mode are available. In the fast mode the user can display on the Tektronix x-y display any 65 x 65 image sub-array of the full field of the picture or the central sub-field of the picture in either a square or hexagonal raster. The resolution can be altered easily and the display adjusted to fill the complete screen, providing an equivalent to electronic zooming. During this process the distance between the input image and the camera can be increased or decreased to achieve the desired focussing action. Once a proper focus has been obtained for the desired field, the slow scan mode can be used to digitize the image.

The PDP-15 program is composed of a number of FORTRAN IV and MACRO-15 routines, which are assembled and linked into a system of overlays. By using the CHAIN and EXECUTE system programs of the DOS-15 Operating System, the scan program can be run in the 24K of free memory space available. With the PDP-8 as a peripheral device, the program provides the user with options for fast scanning, automatic focussing, digitization, data compression, histogram plotting, hardcopy, and display. Interaction between the user and the system is provided mainly via the terminal keyboard and the PDP-15 data switch register. In most cases, messages and instructions are explicitly displayed on the screen of the Tektronix graphics computer terminal. An option is also provided to allow the user to run the PDP-15 without the PDP-8. Table 1 lists the available command repertoire.

Table 1

MCSCAN SYSTEM
DEC. 1973
S = FAST SCAN
F = AUTO FOCUS
D = DIGITIZATION
C = COMPRESSION
H = PLOT HISTOGRAM
P = PHOTOGRAPHING
O = LINE PRINTER OUTPUT OF SQUARE RASTER PICTURE
B = BINARY IMAGE CONVERSION
X = HEXAGONAL BINARY LINE PRINTER OUTPUT
G = OUTPUT ON PDP-8 GRAPHICS MONITOR
R = RESET

INPUT COMMAND: S, F, D, C, H, P, O, B, G, X or R?

Use of the D command results in the digitization of the image into arrays of size 128 x 128, 256 x 256, or 512 x 512. That is, the intensity at a particular point is transformed to an electrical signal which is subsequently digitized and converted to a 12 bit number. This number is read into the PDP-8, transmitted via the high-speed communication link to the PDP-15, and finally stored in one of fifteen data buffers in memory. When one buffer is filled, the next one is used to store the incoming data while the contents of the filled buffers are transferred to the disc under an asynchronous mode of operation on a FIFO basis. The compression command C then allows the user to compress the raw data file in 12 bit format to a more compact form. The following compression schemes are available: (i) logarithmic, (ii) linear, (iii) inverse logarithmic, (iv) equal quantization of the raw data histogram, (v) low pass filtering. In all of the above except the last the total number of gray levels for each pixel is reduced to 64 (6 bits). The resultant data are automatically packed so that three adjacent pixels occupy an 18 bit computer word. Typically a 256 x 256 array will require about 50 seconds for a compression stage.

Hardcopy may be obtained by means of photography or the line printer. The command P allows the user to use the Polaroid camera and Tektronix display to produce a photograph of resolution 256 x 256 for the three sizes of image array. This resolution gives the best picture based on the spatial resolution of the display screen. A typical example from reference [3] is shown in Figure 1. The command O allows the user to print a specified section of an image array on the line printer. A coded symbol is output to represent each gray level.

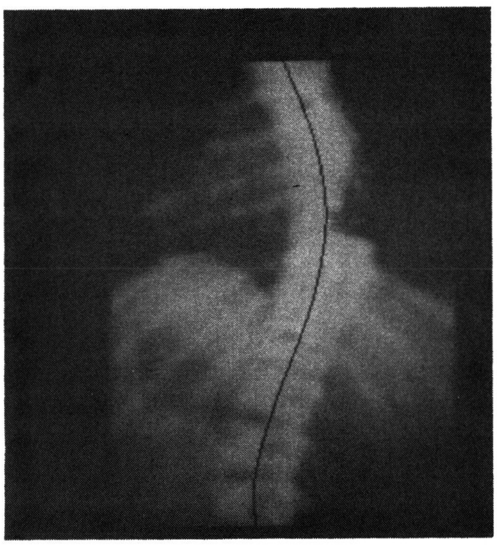

Figure 1. Computed centre-line of the diseased spinal column.

Storage on the disc of the image arrays is always done in the same format [1]. This allows the user to easily write programs to process his images as specific applications require. Six utility programs are available in MIIPPS to allow the user to access or manipulate a particular line or particular element of a picture file conveniently. They are compatible with the picture files generated under MIIPPS and can easily be incorporated into individual user programs. The latter are primarily written in FORTRAN although some subroutines have been coded in MACRO-15 to increase efficiency.

4. CONCLUSIONS

In general the system described above has been quite satisfactory from the point of view of man-machine communications. A detailed manual describing the step-by-step procedures for using the hardware and software has also proved valuable.

Future plans include the integration of the PAX II picture processing system [5] which runs on the university IBM 370/158 system with the MIIPPS system in our laboratory. PAX is a FORTRAN based system which contains a comprehensive set of subroutines for image processing. In this way all picture input and output and low level processing would be done on the minicomputer system while the applications program would be developed on the large IBM computer system.

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