THE STI IMAGE PROCESSING SYSTEM

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ABSTRACT

This paper describes the STI image processing system developed at the Laboratoire d'Informatique Appliquée of the Université de Montréal. This system is capable of handling multi-spectral images of varying origins, sizes, numbers of bands, etc. Its effectiveness for processing LANDSAT images has been demonstrated.

STI was conceived to be useful in educational, research and production environments. The main design objectives were thus a highly flexible user interface (interactive) and efficiency in handling large volumes of data.

STI uses two computers: a CYBER-173 (time-shared) and an INTERDATA-4 (dedicated), communicating over a 9600 baud asynchronous line. Each computer has a copy of the images to be processed. The INTERDATA is augmented by a specialized, high-speed processor (built in-house) called UPT. UPT has a cycle time of 100 ns. and can compute a complex classification of a full-screen image (240 x 320 pixels) in less than 3 seconds. The combination of the CYBER-173 (containing most of the software) and UPT makes STI a very powerful system which has been realized at a very low cost.

STI: UN SYSTÈME POUR LE TRAITEMENT D'IMAGES

RÉSUMÉ

Ce document décrit le système de traitement d'images (STI) développé au Laboratoire d'Informatique Appliquée de l'Université de Montréal. Ce système peut manipuler des images multi-spectrales de différentes origines, grosseurs, nombres de bandes, etc. Son efficacité pour le traitement d'images LANDSAT a été démontrée.

STI a été conçu pour servir dans plusieurs contextes: pédagogie, recherche, production. Nos principaux objectifs furent donc une interface usager (interactive) très flexible et un traitement efficace d'une grande quantité de données.

STI utilise deux ordinateurs: un CYBER-173 (en temps partagé) et un INTERDATA-4 (dédié), communiquant sur une ligne asynchrone à 9600 baud. Chaque ordinateur a une copie des images à traiter. L'INTERDATA est augmenté d'un processeur spécialisé, à haute vitesse (construit ici) appelé UPT. UPT a un cycle de base de 100 ns. et peut calculer une classification complexe d'une image 240 x 320 en moins de 3 secondes. L'utilisation du CYBER-173 (contenant la plupart du logiciel) et de UPT fait de STI un système très puissant développé à un coût très peu élevé.

THE STI IMAGE PROCESSING SYSTEM

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1. Introduction

STI is an interactive image processing system capable of handling multi-spectral, digital images of varying origins and characteristics (size, resolution, number of bands, etc.). STI includes a specialized image processor. The software is flexible and easily extensible by the user. Both the processor and the software were developed in the Laboratoire d'Informatique Appliquée of the Université de Montréal.

The reasons for developing this system were:

* to provide an adequate tool for research in image processing,
* to support graduate courses in image processing and pattern recognition,
* to establish a facility for processing LANDSAT (and other) imagery of interest to external users (geographers, for example), and
* to demonstrate the applicability and effectiveness of an inexpensive high-speed processor (called UPT) in image classification and analysis.

Although LANDSAT image analysis was a specific requirement, STI was intended for a much wider range of applications. This desired generality and the limited funding available gave rise to the following design objectives:

* flexibility of the basic operations, vis-à-vis unknown future requirements,
* extensibility by user-programmers(students, researchers) with ease and without mutual interference,
* simplicity of access for computer-naive users,
* efficiency in handling large volumes of data (using UPT), and
* economy through use of available resources.

STI differs from other image processing systems [1],[2], [3],[4] in the following respects:

* Use of a special processor: most systems either do not have special hardware, or have expensive, arithmetically-oriented hardware. UPT, however, is an inexpensive ($5 K) processor oriented towards logical operations.

* flexibility and extensibility: there is a strong tendency for most image systems to fall under the influence of one specific application. STI, on the other hand, was explicitly designed to foster easy and natural development of new applications by offering a large set of powerful primitives to user-programmers.

2. Hardware

Figure 1 shows the hardware configuration of STI. The main components are: the computing centre facilities, the INTERDATA, UPT, the control console and the color display unit.

Computing centre facilities

The computing centre possesses two CYBER-173 mainframes with a PDP 11/45 front-end. These facilities serve the entire campus and are used on a time-shared basis; they offer speed, large disk space, and a wide range of software and peripherals. One CYBER is used mainly for interactive processing and contains most of the STI software. The other CYBER is used principally for batch processing and STI will occasionally route jobs to its input queue.

INTERDATA minicomputer

The INTERDATA-4 is a small dedicated minicomputer whose function is essentially to control peripherals (particularly UPT and the color display unit).

The INTERDATA is entirely command-driven by the CYBER. Its role has been intentionally kept minimal so that a microcomputer could eventually replace it.

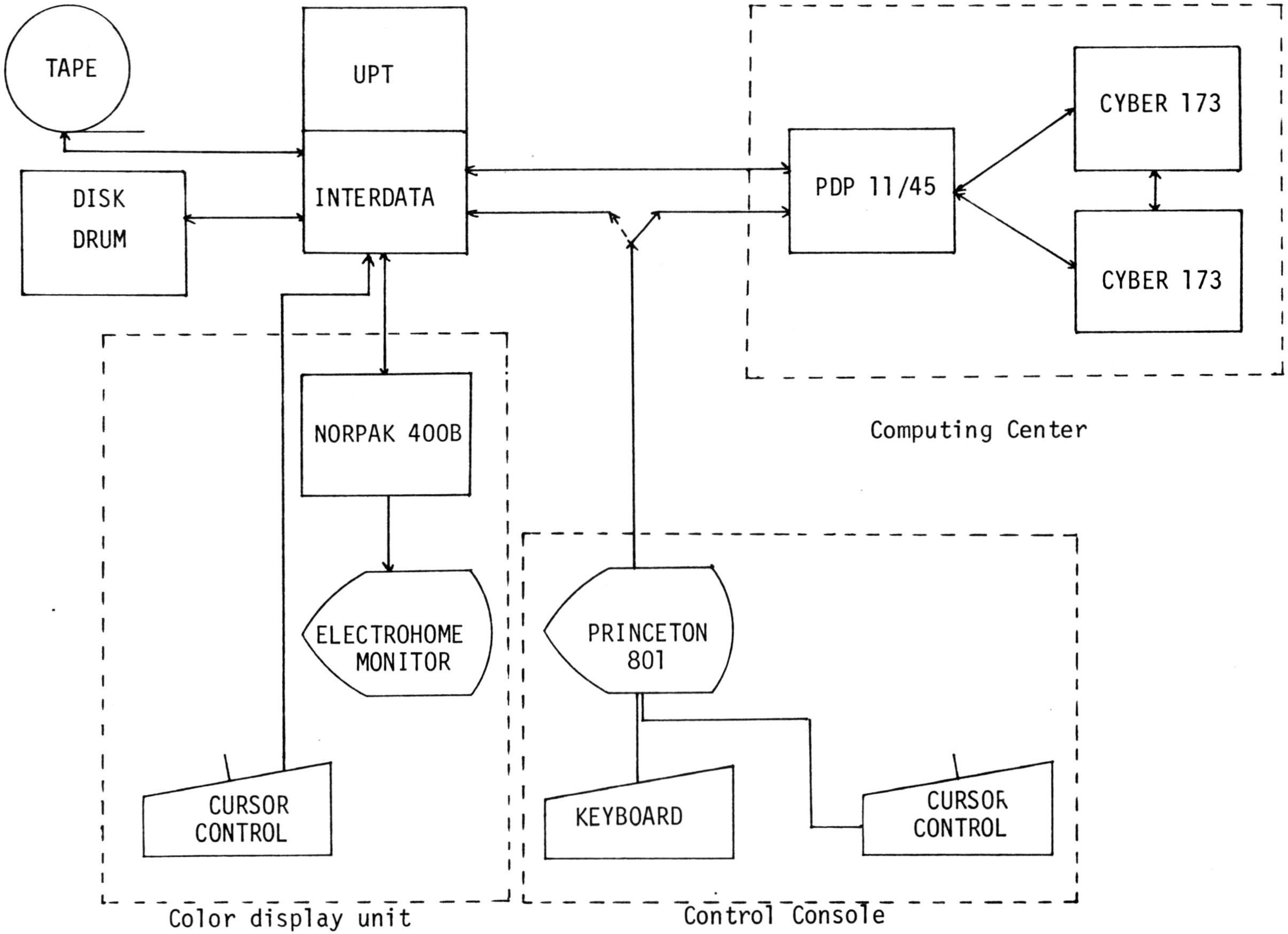
UPT processor

UPT is a specialized, programmable logic processor [5]. Its central component is a balanced binary tree of 31 elements (nodes). This tree is a programmed combinatonal logic circuit which calculates boolean functions of 32 variables formed by inserting AND, OR, LEFT and RIGHT functions into the elements. The assignment of functions to nodes is done by software analysis of image data. Hardware has also been designed to produce tree functions adaptively [6]. Such tree function have desirable properties for pattern recognition in general [7]. In particular it is useful for determining if an 8-bit measurement in a given spectral band exceeds a fixed threshold, and for combining such threshold values logically to form multidimensional boxes. The tree is surrounded by a number of fast-working registers and by three 45 ns. RAM memories for functions, input data, and sequencing instructions. UPT is pipelined and has a cycle time of 100 ns. UPT communicates with the INTERDATA through shared memory, avoiding input and output bottlenecks.

Control console

The control console is a Princeton 801 graphics terminal with keyboard and cursor control unit. The Princeton can display alphanumeric information (full ASCII, 3 sizes), vectors (1024 x 1024 visible screen), and gray-scale images (32 levels). It is used to display commands, histograms, scattergrams, etc.. STI can be used in a mode involving only the Princeton and the CYBER.

Figure 1


TAPE
UPT
INTERDATA
DISK
DRUM
PDP 11/45
CYBER 173
CYBER 173
Computing Center
NORPAK 400B
ELECTROHOME
MONITOR
CURSOR
CONTROL
Color display unit
PRINCETON
801
KEYBOARD
CURSOR
CONTROL
Control Console

Color display unit

The Electrohome color monitor is driven by a Norpak 400B raster graphics unit with eight memory planes (240 x 320 bits each). Of these, six are used to display images with 64 colors, while the remaining two are overlay (priority) planes: one overlay is bright green, used to show "alarmed" areas when performing classification; and the other is bright white, used to display a software-controlled cursor.

3. Software

The major part of STI software runs on a time-shared CYBER 173. In such a context, an efficient, interactive system must have a low memory occupancy (using overlays) and must minimize terminal I/O (because of swap-in/swap-out costs). A menu-oriented system would not satisfy these requirements. STI, then, is command-oriented: to realize a given operation, the user enters the command name followed by a list of parameter values. To make use of STI simple, all input is free-format and all parameters have default values. Complete error detection and reporting is, of course, provided.

The STI software is composed of a resident monitor, a utility library and an open-ended set of subsystems (see Fig. 2). The monitor and the library form the nucleus of STI; together they facilitate development of new subsystems. It is principally through this mechanism that STI is extensible.

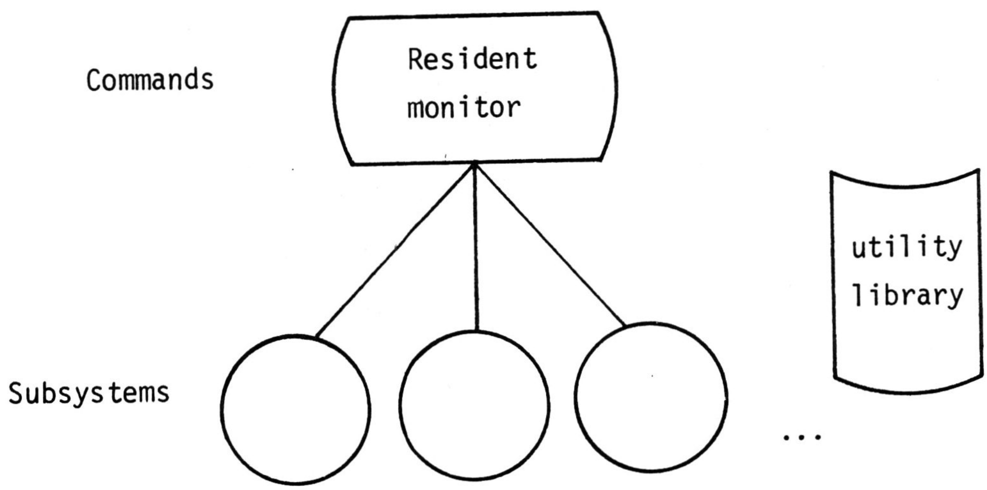


Figure 2

Resident monitor

The resident monitor acts as a command dispatcher: it receives user commands, decodes parameters and activates the proper subsystem. It also handles requests emanating from subsystems. The monitor contains the primitives that define the organization of subsystems and the extensibility mechanism; we shall discuss both of these topics below.

Subsystem organization. Every subsystem has a name, a prompt character and a set of commands. These are stored in tables within the monitor. A subsystem may be activated by entering its name. The monitor will then transmit the subsystem's prompt to the control console and recognize the subsystem's commands. This organization is useful because of its modularity and because it prevents interference i.e. when a new subsystem is added, it does not affect previous applications.

In contrast to other systems, the subsystems of STI are not mutually exclusive: it is possible to activate a subsystem within another currently active one. In general, any number of subsystems may be active at any time. The sequence of prompts emitted will always reflect the current hierarchy of activated subsystems. Command names will be searched for in those of the most recently activated subsystem, and so on. This is similar to name references in a block structured language.

This organization is very flexible: any command (of any active subsystem) may be used at any time. The user never has to terminate one subsystem in order to execute a command in another; he may thus quite naturally determine his own optimal path through image operations.

Interactive extensibility. The entire development cycle of a new subsystem can be handled within STI. Indeed, it is possible to enter the CYBER interactive editing system from within STI, perform source modifications, and recreate the subsystem overlay. Terminating the editor gives control back to the STI monitor. If a new subsystem or command is created during such editing, it can be declared by use of monitor commands DEFSYS or DEFCOM.

Furthermore, even if testing produces execution time errors, the resident monitor will always regain control (upon any abnormal termination), and produce diagnostics. The user may employ available interactive debugging tools or he may simply reset the subsystem; he may also reenter the editing system. During this testing cycle, other subsystems may be active and their status will not be affected in any way.

Utility library

The utility subroutine library defines a set of powerful primitives useful to the subsystem designer. The functional capabilities of these primitives include:

* command decoding
* error handling
* debugging
* file handling functions (attach, create, catalog, purge)
* file and image access (sequential or random)
* a graphics package for the Princeton 801
* communication with the INTERDATA and the other CYBER
* screen space allocation.

This last function illustrates well the flexibility of STI. Both the Norpak and Princeton screens can contain any number of rectangular "graphical objects" (images,histograms, etc.). This enables the user to simultaneously view images in different bands, enlargements, results of different classifiers, etc.. Routines maintain, for each screen, a table of objects containing object position, type, and other parameters. Routines will also automatically find free space of specified size when an object is to be displayed. Finally, it is possible to override this automatic allocation and specify directly the desired position and size using the cursor.

Existing subsystems

The following subsystems are currently available (prompt character in parentheses):

CONTROL(*) : image display, histogram generation, file handling, etc.

SHOW (>) : multi-spectral classification using UPT

CHECK (?) : interactive debugging

MULTERM(=) : INTERDATA control

These systems and their commands are defined by DEFSYS and DEFCOM monitor commands stored on the user's initialization file executed at the beginning of an STI session. A user may thus change command names at his discretion.

4. Scenario: multi-spectral classification

Let us now consider multi-spectral classification of water, say, in part of a LANDSAT scene showing the island of Montreal and vicinity. We assume that subsystem CONTROL is currently active. The following is a typical sequence of commands (prompts are underlined):

*DISPLAY MONTREAL B=4

This displays band 4 of the disk-resident image called MONTREAL on the color display unit. Note that bands are numbered from 1. This command thus displays MSS band 7, useful for detecting water. The user now enters the SHOW subsystem (within CONTROL) and declares the class identifier:

*SHOW

*>CLASS WATER

The user, by means of the PLUS command, may now identify regions of water on the image with the rectangular cursor (indicated by a □ below). The regions indicated are histogrammed in all four (or more) bands. A user-adjustable percentage of pixel measurement vectors is removed from each histogram to obtain minimum and maximum threshold values in all bands. These values define a box in spectral 4-space which, by means of the BOX command, can then be used to classify the entire image using UPT.

*>PLUS □

*>BOX

The classification appears as a bright green overlay on the image. At this point the user may notice a small river has not been included in his class. Since it is unfortunately too small to be accurately indicated with the cursor, the user requests an enlargement of a small region (specified by the cursor) containing the river:

*>DISPLAY □ SCALE = 3

This displays the indicated region, enlarged 3 times, somewhere on the color monitor where it will not overlap the previous image. The river may now be easily specified:

*>PLUS □

*>BOX

The BOX commands produces a new classification corresponding to the union of the two boxes now specified. We suppose that the session is terminated at this point:

*>STOP

The WATER class (boxes) is automatically saved. During a subsequent session, the user may recall it and refine his specification. Besides PLUS, the MINUS command is available to subtract parts from the current set of boxes. In general, a hierarchy of up to 32 boxes can be defined: UPT will perform such a classification on a full screen image in about 3 seconds.

5. Conclusion

The hardware and software of the STI system have been outlined. A scenario has illustrated the ease with which the system can be used. Our design goals of flexibility, extensibility, simplicity, efficiency, and economy have been attained.

Acknowledgements

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