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SOFTWARE DEVELOPMENT ACTIVITIES IN IMAGE PROCESSING

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14. Abstract/Notes

In this work, an overview of INPE's software development activities related to Image Processing is presented. These activities are grouped into five projects. The goals associated with each project are described. Emphasis was given on the SITIM project, which aims at the development of an image processing system based on a 16-bit machine produced in Brazil. A brief description of the hardware and software facilities available at INPE in the IMAGE-100 system is also given.

15. Remarks

1. INTRODUCTION

The purpose of this document is to provide an overview of the activities related to Image Processing, which have been developed at INPE for the past several years.

More specifically, the research and development activities in the area of Image Processing and Recognition started at INPE in 1975. At that time, an image processing system IMAGE-100 (I-100) produced by General Electric, was acquired. This system, of which a complete hardware and software description will be presented in section 2 of this document, still constitutes the main computacional facility, available at INPE, to support the development activitives related to Image Processing.

In Section 3 the software development projects which are presently being carried out at INPE will be briefly described.One of these projects refers to the development of an image processing system (SITIM) based on a 16-bit machine produced in Brazil. The main features of SITIM will be presented in Section 4.

2. THE IMAGE-100 SYSTEM

The IMAGE-100 is an user-oriented digital image data processing system,based on a minicomputer PDP 11/45 produced by DEC (Digital Equipment Corporation).

This system has been extensively used since 1975 in analysing LANDSAT images, with the purpose of fully explore their capabilities in the process of finding solutions for existing problems in several areas. Some of the areas in which INPE has found promissing applications of LANDSAT images are listed below.

a) Oceanography

- pollution detection and monitoring of coastal sea water
- sea surface temperature mapping
- subtropical convergence studies in the South Atlantic
- upwelling studies in the southeast coast of Brazil

b) Agronomy and Forestry

- soil identification and classification
- crop identification and acreage
- deforestation detection and monitoring
- forestry plantation identification and acreage

c) Geography

- Land Use:
  - urban and rural areas
- Applied Geomorphology:
  - soil erosion
  - watershed monitoring: studies of flooding processes and silting processes in man-made reservoirs.
  - environmental pollution: studies of areas affected by coal-mining activities.

d) Geology

- oil and mineral prospecting
  - digital filtering techniques in the enhancement of structural patterns of Landsat Data in oil exploration.
  - supervised classification with digital MSS Landsat Data in mineral exploration of titanium deposits in semi-arid regions.

- band-rationing and contrast stretching techniques of Landsat imagery in the evaluation of tin deposits associated to greisen zones of granitic provinces.
- definition of clay deposits in alkaline intrusive massif using supervised classification.
- evaluation of occurences of iron-deposits; tin-granitic bodies and bauxite in tropical jungle using thematic classification of Landsat Data.

• Geologic and structural mapping

- characterization of structural patterns of alkaline intrusions associated with uranium mineralizations by enhancement techniques of Landsat Data.
- evaluation of digital enhancement techniques in the definition of intrusive granitic bodies located in high metamorphic belts.
- discrimination of rocks and products of alterations based on enhancement techniques of digital MSS Data (principal components, band-ratio and canonical analysis) in tropical semi-arid regions.

2.1 - HARDWARE FACILITIES

EQUIPMENT	TYPE AND MODEL	PRODUCED BY
1 CPU (160 k bytes)	PDP 11/45	DEC
1 CPU (64 k bytes)	PDP 11/45	DEC
32 k bytes of additional memory	-	DEC
1 magnetic tape unit (800/1600 bpi)	TE-16	DEC
1 magnetic tape unit (800/1600 bpi)	TU-16	DEC
1 magnetic tape unit	BUCODE	MDSC
1 printer unit (300 lpm)	LP-11	DEC

EQUIPMENT	TYPE AND MODEL	PRODUCED BY
1 graphic terminal	4092	TEKTRONICS
2 printer terminais	LA-36	DEC
1 hardcopy unit	-	TEKTRONICS
1 paper tape reader	PC-11	DEC
1 magnetic disk unit (88 Mbytes)	RP-04	DEC
1 magnetic disk unit (2.4 Mbytes)	RK-05	DEC
1 digitizer tablet	TALOS-SBL660	TSI
1 fotographic film recorder	-	DC

2.2 - SOFTWARE FACILITIES

The existing software may be classified into three groups:

a) SYSTEMS, comprising sets of programs aiming at more general applications;

b) I/O PROGRAMS, corresponding to input/output procedures developed for communication between peripherals;

c) SPECIFIC PROGRAMS, developed for specialized applications. A more detailed description of each of these groups is given below.

- SYSTEMS

a) IMAGE - The IMAGE system consists of the original software developed by General Electric for the IMAGE-100, plus additions made by INPE's personnel. The original software includes parallelepiped classification and histogram

modification techniques. Among the additions, programs for area counting, scale modification and radiometric correction may be mentioned. Altogether, this system includes 35 programs.

b) MAXVER - The MAXVER system comprises 16 programs, including maximum-likelihood classification and clustering procedures (K-means algorithm). Existing programs consist in sample acquisition and classification routines, interchanges with peripherals and special applications (such as ellipse drawing). These are also programs for test area definition, enabling the user to compute the confusion matrix for the classification results.

c) SIS2CN - Used for faster computation, compresses an original LANDSAT four-channel image (with 256 levels) to a two-channel image (with 64 levels). Classification is achieved by means of a table look-up approach, and there are also clustering procedures. The system is composed of 11 programs.

d) REALCE - It is a group of programs developed for visual enhancement and linear transformations for MSS data, through the use of procedures such as principal components, canonical analysis and logarithmic enhancement. Presently it is composed of 6 programs.

e) FILTRO - The FILTRO system has the purpose of unifying developments in the area of two-dimensional digital filtering including convolution masks and methods for filter design starting with their frequency response. Altogether there are 6 programs.

f) SELAM - These programs for feature selection enable the user to select 4 out of 12 channels, generated from the original LANDSAT data through the use of 3 x 3 spatial

filters. There are two possible criteria for the selection process: J-M distance and entropy maximization, comprising a total of 7 programs.

- I/O PROGRAMS - Used for input/output procedures, such as:

  a) DICOMED - interface between the I-100 and DICOMED.

  b) TIROSN - loads tapes from TIROS/N into the system.

  c) SMSQQ - loads tapes from SMS into the system.

  d) EZDQJA - loads tapes from LANDSAT into the system.

- SPECIFIC PROGRAMS - This package includes 15 small and medium-size programs, developed for various applications, of which the most important are:

  a) atmosferic correction for LANDSAT data, using atmospheric modelling.

  b) false-color generation.

  c) post-processing of classification results.

  d) interpolation.

It should be also mentioned that the development of an integrated system for geometric correction and registration is under way, and it is expected that the first version of this system will be avaliable in the next few months.

3. SOFTWARE RESEARCH AND DEVELOPMENT ACTIVITIES

These activities are grouped into five projects. In what follows, a very brief description of the goals associated with each project is presented.

a) PREPRO

- Differential border and edge detection algorithms (Gradient and Laplacian), as well as statistical methods, taking into account the pixel's neighbours.

- Visual image enhancement algorithms, by principal components.

- Two-dimensional filter design, with application to visual enhancement.

- Image registration by sequential hypothesis testing, for Gaussian or binary images.

- Image registration by SSDA-style schemes ("Sequential Similarily Detection Algorithm").

- Image interpolation, with application to scale changes in geometric correction; study of resulting distortions.

b) SELEC

- Image compression methods, with acceptable visual distortion, using transform techniques (Cosine, Hadamard, Haar, etc.).

- Dimension reduction, from four dimensions to two, for LANDSAT images, in order to allow two-dimensional viewing of data clusters, both for visual data-interpretation and as additional features for image classification.

c) CLASS

- Multispectral image classification algorithm, under the Gaussian assumption and the maximum likelihood criterion ("MAXVER").

- Spatial hierarchical data clustering algorithm, using the minimum mean squared error criterion.

- Algorithm for class proportion estimation within a resolution element (pixel), using quadratic programming methods. Study of the influence in the proportion variance of the geometry of the class means.

d) CONTEX

- Classification algorithm using texture data, obtained by Haralick's co-occurrence matrices.

- Classification algorithms using spatial features, obtained by local filtering, in addition to satellite spectral features. A feature selection system, using the concept of distance between distributions, was developed as part of the project.

- Texture border detection algorithm, using a local border detection scheme followed by region expansions and contractions.

e) SITIM

- This project has as goal the design and implementation, for later production, of a general purpose image processing system, based on Brazilian produced hardware (computer, terminals, etc.). The corresponding software package is being designed in a flexible, modular manner, assuming that the end user will not be a computer expert. The modules are being structured to be very user-friendly, as viewed through a supervisor module. The operation will also be transparent to the user, controlled by a managing module. A more detailed description of this project appears in the next section.

4. SITIM - AN INTERACTIVE IMAGE PROCESSING SYSTEM

4.1 - INTRODUCTION

In response to the increasing number of applications of satellite imagery, due mainly to the launching of new satellites, INPE started developing a simple system for image processing, the hardware portion of which should be produced in Brazil.

The general specifications of the System were:

a) it should have a wide range of applications, from remote sensing to meteorology, as well as others;

b) it should be easy to use: not only it should be "friendly" to a new user, but it should also allow the concise expression of complex operations;

c) it should be expandable, both in hardware and software.

In order to attain the specifications listed above, the guidelines for the system design were:

1) the system should provide for a uniform vision of images: there should be an internal format for the images, upon which all the operations are defined. In this format, the number of bits/pixel is constant within an image but can differ for different images. This permits the creation of "logical" images, as well as "floating-point" images. All details related to image storage should be transparent to the user and the application programmer;

2) the communication with the system should be made in an interactive language, where the statements should be used in two different ways: one, in which the user supplies all the

necessary parameters and another, where the parameters are requested by the system. It should be also possible to combine several functions in one statement;

3) the software should be modular and the routines should communicate through minimum and standard interfaces, making the addition of new application and input/output routines easier. It should be also possible to subtract routines from the system in order to adapt the system to the actual hardware on being used;

4) the image display sub-system should have a limited but independent processing capability. This is important not only because it alleviates the system from part of the processing but also because it allows the tayloring of the system for, specific use.

4.2 - HARDWARE CONFIGURATION

The intended SITIM hardware configuration is shown in Figure 1.

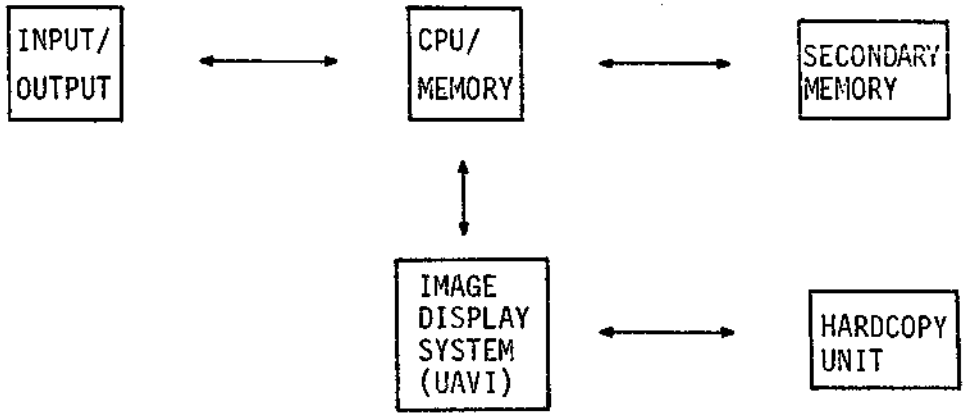

Fig. 1 - SITIM Hardware configuration.

The heart of the system is the CPU/MEMORY sub-system, composed of a DISCO MB-8000 CPU (compatible with Data General's NOVA 3) with 250 kB, 16-bit main memory (64 kB minimum, 256 kB maximum). The secondary memory is composed of a 300 MB magnetic disk, the minimum configuration being 80 MB. The input/output sub-system comprises 2 magnetic (1600 bpi) tape drives, line printer, plotter, digitizing tablet, alphanumeric and/or graphic CRT terminals (one of which will be used for communication with the SITIM software, others for support and/or software development). The Image Display sub-system is composed of an Image Memory with a maximum of 4096 x 4096 x 8 bits (reconfigurable), a color TV monitor (512 x 512), joystick and/or trackball, a microprocessor and a hardware unit for routing and processing of video data. The Image Display sub-system will be, in its first version, capable of roaming and zooming. In future versions it will able to do some additional processing, such as spatial convolution, look-up tables etc. - There will be also a hardcopy unit capable of making black and white permanent copies of the image memory content.

4.3 - SOFTWARE FUNCTION DESCRIPTION

SITIM's software will be designed to support interactive image processing, where the Image Display sub-system plays a central role. All the processing will be done in "working sessions", which consist, tipically, of:

1 - image input;

2 - image visual analysis;

3 - image processing;

4 - image output.

Steps 3 and 4 may be repeated as many times as wished, until the user is satisfied with the results. To express all these actions, the system will provide for a simple yet powerful

language. Besides several book-keeping and input/output commands, this language will have function commands, with syntax in the following form:

[<image list>$_1$: =] <function> (<image list>$_2$) [<parameter list>]
([....] denotes an optional item),

where <function> is an identifier-the name of the called function; <image list>$_1$ and <image list>$_2$ denote the lists of output and input images, respectively. The list of parameters is given in the <parameter list>, which can be omitted. In this case, the system asks for the necessary parameters.

Externally to the system, an image is defined by four attributes:

- number of channels (bands);
- number of lines;
- number of columns;
- number of bits/pixel.

The acess is made through routines that read/write a line at a time. The application programmer has no knowlegde of how the image is stored internally.

4.4 - SOFTWARE STRUCTURAL DESCRIPTION

SITIM's software will be organized in four modules:

- Supervisor
- Image Management
- Applications
- Library

The supervisor module will be responsible for the analysis of user commands and for calling routines (assynchronous tasks) that will perform the action described in the comand. The Image Management module will take care of the image input/output, storage (in disk) and access to the images. This module will provide for an interface to the images, being transparent to the programmer the internal details of how the images are actually stored. The routines of the Application module will do the actual image processing and some restriced image input/output. The Library module is a collection of sub-routines used by more than one module. The Image Management and Application modules are collections of independent assynchoronous tasks, which are, in the case of the Application module, called in an uniform way: In the case of the Management module they have common access to the Image Directory. Figure 2 shows the dynamic graph of the system.

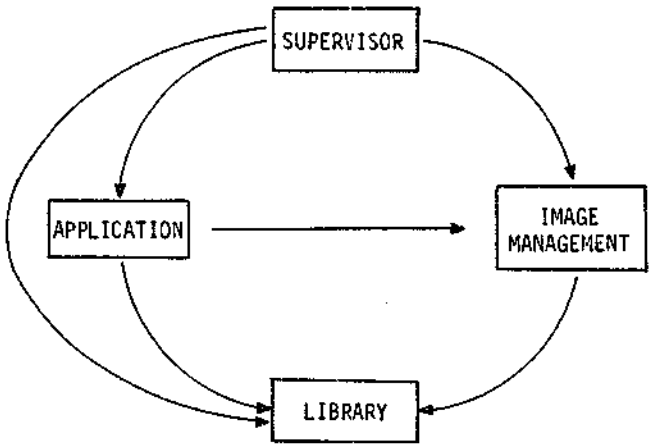

Fig. 2 - Calling graph of SITIM.

In order to perform analysis and execution of commands, the system will have two main tables:

- Image Directory

- Function Table

The Image Directory will contain information about the images and will be common to the Supervisor and Image Management modules. The Image Directory will include the following information: image name, attribute values, creation date, last access date, image files, annotation text and mode of storage.

The Function Table will contain information related to the application routines, as the function name, task name, input and output image information (number, semantic restrictions) and parameter information (number, type, text, etc.).

In the first version of the system, the Application module will be composed of a set of basic routines that will allow the preprocessing (radiometric and geometric corrections, filtering, histogram manipulation, image arithmetic, etc.), classification (supervised and unsupervised), transformation, statistics, etc. In future versions, the system will be augmented to suit specific needs of INPE, such as applications in meteorology (wind field computation, cloud classification, image animation etc.) and in agriculture (procedures for crop area determination).