A low-cost, general purpose image processing system is described, which is designed to handle a great variety of image processing applications. The system incorporates current trends in both software and hardware development. The hardware consists of a Brazilian-built 16-bit microcomputer, a display unit (developed at INPE), and interfaces to various input/output devices. The software will contain application programs for a great variety of users, including: remote sensing, meteorology, microscope and biomedical images, as the building of a geographic information system. Future developments are also pointed out.

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A LOW-COST, GENERAL PURPOSE IMAGE PROCESSING SYSTEM

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ABSTRACT

A low-cost image processing system is described, which is designed to handle a great variety of image processing applications. The system incorporates current trends in both software and hardware development. The hardware consists of a Brazilian-built 16-bit microcomputer, a display unit (developed at INPE), and interfaces to various input/output devices. The software will contain application programs for a great variety of users, including: remote sensing, meteorology, microscope and biomedical images, as the building of a geographic information system. Future developments are also pointed out.
1. INTRODUCTION

The area of digital image processing had its beginnings in the mid-sixties, motivated by NASA's space programs in USA. This new technology was originally applied to process satellite-obtained imagery, such as LANDSAT images (remote sensing of the earth resources) and SMS/GOES satellite images (meteorology). Furthermore, image processing soon found its way to new fields such as medicine, microscopy, optics, facsimile, and recently industrial machine vision. (Rosenfeld and Kak, 1982; Mascarenhas and Velasco, 1984; Ballard and Brown, 1982; Fu and Paulidis, 1979). In 1973, the invention of computerized tomography opened up a large number of applications in the medical area. (Herman, 1980).

The technological changes in computer hardware design in the last 20 years have also made it possible that image processing systems could decrease significantly in cost. Therefore, the new generation of 16-bit and 32-bit microprocessors enables the design of flexible and low-cost systems for image processing.

At INPE (Brazil's Institute for Space Research), the activities in image processing began in 1975, and in 1984 a project is under way to integrate a general purpose image-processing system. The guidelines for the system design are the following:

a) HARDWARE: The system should be based, as far as possible, in Brazilian-built hardware, and in its first version it is constructed around a 16-bit microcomputer.

b) SOFTWARE: The system shall have applications to enable its use in various fields, such as remote sensing, meteorology,
and microscopic imagery, as well as the building of geographical information system.

In the next sections, a general of the system is given, including both hardware and software.

2. ARCHITECTURE

The guidelines for the system's hardware design were that it should have a broad variety of input and output devices, and a capacity of connection to other computers. The operating system should enable facilities to ease up software development. The architecture of the first version includes a Brazilian-built microcomputer, its peripherals, and an image display unit.

The microcomputer is based on a 16-bit CPU, a floating point coprocessor, 256 K bytes of main memory, drivers for 5 1/4", 8" and Winchester disks, a printer and terminals. The maximum storage capacity of the Winchester disks is 20 M bytes. It is supported by a multiuser, multitasking operating system which has Fortran and C compilers.

The image display unit was developed at INPE and enables the display of image and graphical operations performed by the system. It consists of an expandable random access image memory; a typical configuration of that memory is 1 M byte, divided into 4 quadrants of 512 x 512 pixels (picture elements) of 8 bits each. Color composites are shown in the TV monitor when each quadrant contains the same picture acquired in different spectral bands. A variable-length cursor enables the selection of areas by the user.
A variety of input and output devices permits the system to be tailored to specific user needs, by a choice of the adequate options. Interfaces are available to digitizers, plotters, serial communication to computers, and to an image display unit. For microscopic image analysis, the microscopic is connected to a TV camera, and the TV signal is digitized and shown in the display unit.

3. APPLICATION SOFTWARE

The software specifications include general-purpose procedures for the various fields of image processing, as well as facilities to both the programmer and the user. These facilities include:

- a flexible user-system interface which incorporates default parameters for all processing options;
- use of processing session history records to document processing operations;
- use of well-defined program interfaces and procedures calls, to enable the user to easily program new applications and add them to the system;
- use of standard data formats and file structures for acquiring and storing data files within the system.

The application procedures designed in a modular fashion and comprise, in the first version, three subsystems: a) remote sensing and meteorology; b) geographic information systems; c) analysis of microscopic imagery.
3.1 - REMOTE SENSING AND METEOROLOGY SUBSYSTEM

This subsystem deals with the analysis and storage of satellite imagery, such as LANDSAT and SMS/GOES. The procedures in this subsystem will obtain information directly from the images. For remote sensing imagery, applications include crop classification, pollution analysis, forestry monitoring, geological mapping and urban expansion studies. The meteorological procedures will be responsible for cloud dynamics studies, frost and weather monitoring (Bracker, 1983).

In order to perform such analysis, the software comprises specific procedures for:

a) Image displaying on the TV monitor. Some preprocessing may be needed, as for example:
   - temporal registration;
   - sensor equalization;
   - geometric correction.

b) Enhancement, obtain better quality images and to emphasize desired regions. Software for enhancing features includes:
   - spatial high-pass and low-pass spatial filtering;
   - principal components analysis;
   - histogram modification;
   - false-color mapping;
   - ratio calculation.
Classification, whose output are thematic images where the various classes are separated, and includes:
- paralelepiped classification;
- maximum-likelihood classifier;
- clustering analysis;
- theme uniformization.

3.2 - GEOGRAPHIC INFORMATION SUBSYSTEM

This subsystem permits the integration of geocoded data from various sources, such as thematic and topographic maps, census data and classified satellite imagery. Information extraction procedures will enable combinations among existing data, as well as the use of mathematical and statistical methods in the analysis of georeferenced data.

Geographic information systems have proven to be very useful in urban and regional planning, and in natural resources analysis (Plagy and Waple, 1979). With this subsystem, the user will be capable to build his own geographical data base and to obtain combined information to support decision-making for specific tasks. Its modules are:

a) Entry:
- thematic and topographic maps digitization;
- tabular data entry by terminal of digital magnetic tape;
- thematic digital imagery integration.

All these different kinds of data are stored together in a geographic data base, in a uniquely referenced way, permitting easy retrieval and analysis.
b) Analysis module, which are the information-extraction routines, featuring:

- Search facilities, so as to find desired elements ("Which sites with ecological potential are near a gas pipeline").
- Area and statistical measurements: "How many acres of rice are grown in the Paraíba Valley?"
- Composite mapping: ability to combine data from two or more maps and to generate a composite one. ("What are the areas having high iron ore concentration, few agricultural units and have adequate river flows?").

c) Output module, by means either of color maps in the display unit, drawing of maps on a plotter or printed reports.

3.3 - MICROSCOPIC ANALYSIS SUBSYSTEM

The number of applications for microscopic imagery is growing steadily and presently includes such diverse applications as chromosome classification and karyotyping, grain sizing in steel and celulosis fibre analysis. (Cambridge, 1983; Gregory, 1983). The analysis performed will substitute work now done on a tiresome, manual basis by automatic procedures; the ultimate goal of such analysis is to perform specific measurements providing the user suitable interpretations. Usually, the automatic analysis gives more accurate results, saves measurement time and decreases the need for repetition. To accomplish this goal, this subsystem is divided into four modules:
a) **Entry and Calibration:** images are obtained by the microscope/camera combination, digitized and shown in the display unit. Through interactive manipulation, the operator may define microscope and sample parameters. Additional facilities include:

- shading effect correction;
- area definition by cursor;
- identification of the sample under study.

b) **Editing and Classification:** These procedures perform the segmentation of the image into various classes and the editing of desired features. Therefore, regions may be interactively eliminated, united or created, according to the user's concerns. The editing may be done manually (by means of a cursor) or automatically. In the latter case, available algorithms include:

- segmentation by thresholding;
- filtering: Laplacian, high-pass and low-pass;
- skeletonization;
- erosion/dilation;
- shape detection and manipulation.

The result of this module is an image ready to be measured.

c) **Measurement:** Depending on the application, the user may request a subset of the available measures, which include most common stereological calculations. Examples are:

- area and perimeter;
- Peret diameters;
- inertia moments;
- mass center.
The measurements are performed interactively, and at any time the objects whose features are within designated values may be shown in the display.

d) Result presentation and storage: The results may be presented by histograms or tabulations. The histogram will contain object counts for each measure performed, as well as the mean and the standard deviation. A printout of the image is also possible, as well as a storage in disk for subsequent processing.

4. FUTURE DEVELOPMENTS AND PLANS

The first version of the system is expected to be ready by the end of 1984, and a team of 30 hardware and software specialists is responsible for the development. Future developments will include both hardware and software upgrades.

In the architecture, the next version will be based on an improved 16-bit microcomputer or a new-generation 32-bit microcomputer. The display unit will have some specialized hardware functions, such as look-up tables and convolutions filters. A hardware processor for high-cost functions such as geometric warping is expected to be integrated to the system in a medium term basis.

As for the software, the next version will also contain application programs for medical analysis of X-ray and nuclear medicine imagery. New complex functions for remote sensing and meteorology, such as multipixel classification and wind field detection, are also in view. The geographic information system
package is expected to perform high-level interpretation functions, modelling those available in modern Data Base Management Systems. The microscope analysis subsystem will be enhanced with sophisticated pattern detection techniques and complex measurement functions.

The microcomputer framework has proven to be a flexible support for the development of image processing applications and the system is expected to be useful to a great number of users in a large number of fields.

4. REFERENCES


