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14. Abstract/Notes

The IDIMS (ESL Inc.), System 101 (STL/I2S), ARIES-II (Dipix Systems) and LARSYS (Laboratory for Applications of Remote Sensing - LARS) image processing systems are overviewed and compared in their software and hardware aspects. Emphasis is given to the application software.

15. Remarks

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1. INTRODUCTION

The idea of this document is to present the principal aspects of some of the existing image processing systems worldwide, in a way to facilitate the comparison among these systems. This presentation is not based on actual usage of the systems,but rather on manuals and advertisement material provided by the manufacturers and on the report USGS 77-414 of the United States Geological Survey. The classification of the application software used in this document is also taken from this last source.

The overviewed systems are:

- IDIMS (Interactive Digital Image Manipulation System), developed by ESL incorporated, a subsidiary of TRW Inc.

- SYSTEM 101, produced by the International Imaging Systems, division of Stanford Technology Corporation (STL/I2S).

- ARIES II, developed by Dipix Systems Limited.

- LARSYS, developed at the Laboratory for Applications of Remote Sensing (LARS) and distributed by Cosmic (Computer Software Management and Information Center), Georgia.

The presentation of the systems suffers from several problems. The first one is the disparity in the volume of data available on the systems. Another problem is that the gathered information is from several dates, and some may not be updated.

The format of the presentation of the systems is the following: in Section 2 the various systems are overviewed and in Section 3 the application software is presented in a tabular fashion so to make comparisons easy. Finally, Section 4 is devoted to a quick comparison of the presented systems.

2. AN OVERVIEW OF THE SYSTEMS

2.1 - IDIMS

The interactive Digital Image Manipulation Systems (IDIMS) (ESL Incorporated, 1981) is an image processing system based on the HP3000 series computers and subsystems for color image processing and display.

The basic configuration is shown in Figure 1. The computer can be configured with up to 2 Mb of main memory and nearly 1 Gb of disk storage. Data can be input to the system through magnetic tape, film recorder, microdensitometer or digitizing tablet. Results can be viewed/photographed from the display, output to a line printer to magnetic tape. Additionally, an ESL array processor may be added to the system.

The software of IDIMS is organized in two modules:

- Systems software.
- Functional software.

The system software is responsible for analyzing user commands in both interactive and batch modes. Three kinds of commands are presented in the command language:

a) processing function (manipulates the image data);

b) system control (deals with data management);

c) display control (displays images and manipulate the data stored in the refresh memories).

Also a MENU selection option is offered to the user.

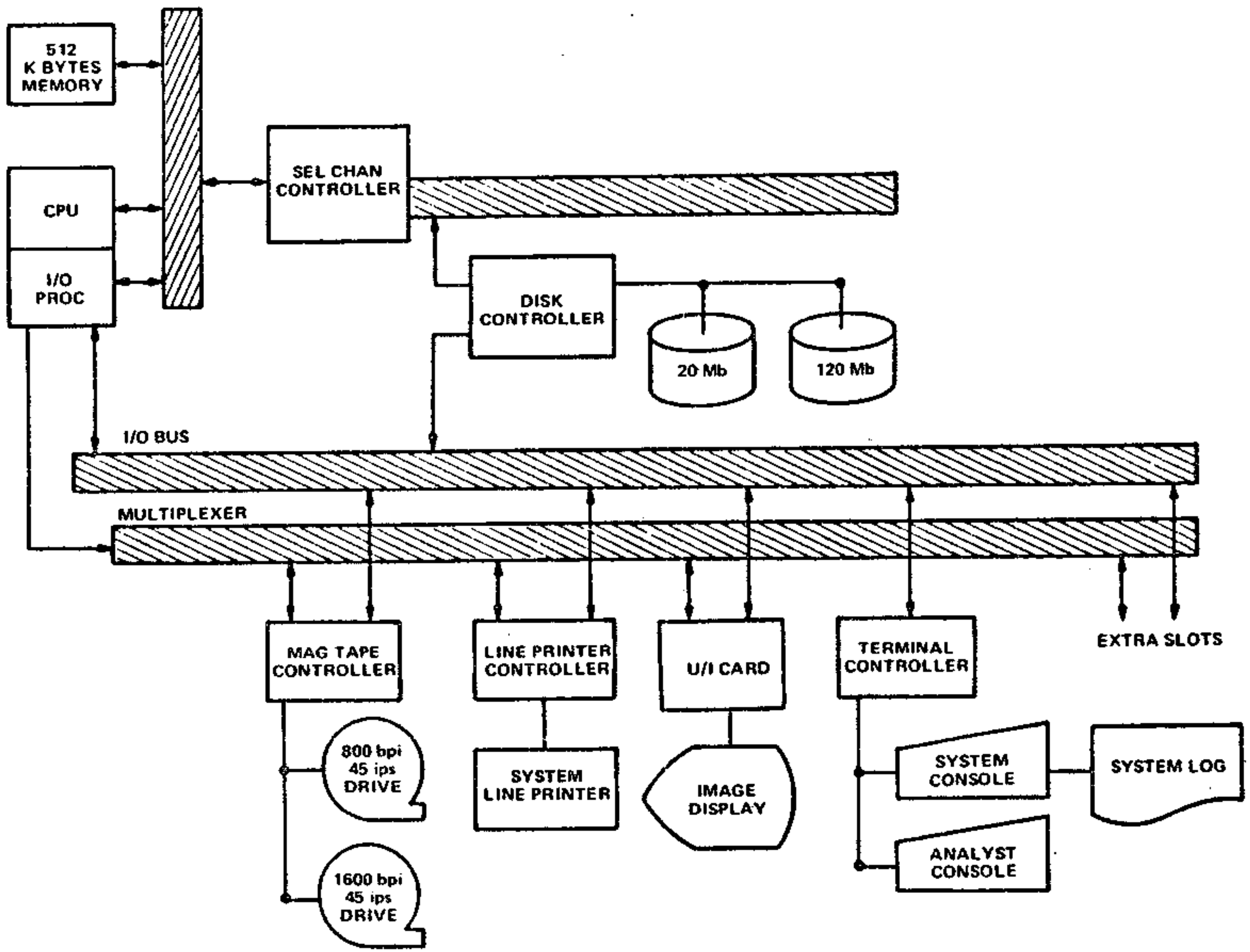

Fig. 1 - Basic IDIMS Image Processing System Configuration.

A file management system provides an interface between the user and the image data. The image input and output routines work with image pertinent information (line, band numbers, etc.), translating I/O requests in terms of record sizes, block factors, etc.

The functional software provides a set of processing functions that can be called by a processing command in the (general) format:

Input specification > Function specification > Output specification,

where in the input specification both spatial subsections and spectral band modifiers can be furnished.

2.2 - SYSTEM 101

The System 101 (International Imaging Systems, 1978) is an interactive, multi-user digital image processing system based upon a HP 3000 computer (16 bits). The hardware configuration (shown in Figure 2) includes also one or more video consoles (Model 70) which can process data at video rate, image input/output peripherals and an optional AP-120B Array Processor.

System 101 image software can be divided into three kinds of systems:

- Image processing operating system.
- Image processing application software.
- Array processor software.

The Image Processing Operating System consists of six distinct subsystems, as follows:

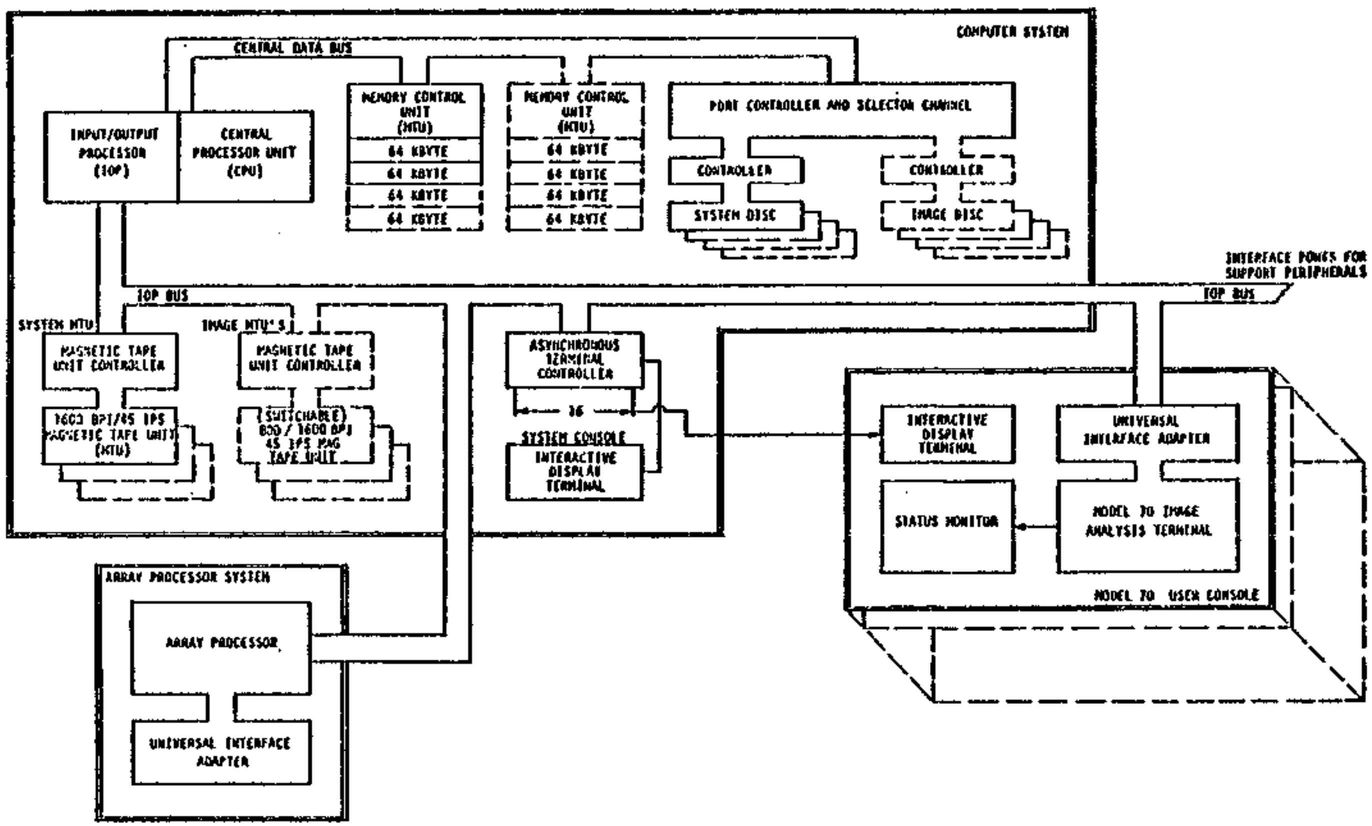

Fig. 2 - System 101 Hardware configuration.

1. Command Interpreter: controls all processing performed by the analysts. It reads user commands and passes the control to the appropriate subsystem.

2. Display Monitor: executes display oriented applications.

3. Applications Function Monitor: executes central processor application programs.

4. Parameter and User I/O: responsible for accepting parameters from the user and user communication.

5. Image I/O: handles all image I/O operations. Provides all subsectioning, spectral and temporal band selection and data type conversions for application functions.

6. Display Subsystem: collection of interface routines that permit communication with the Model 70 Image Analysis Terminal.

Figure 3 shows the software structure of System 101.

The communication with the system is performed through a command language with a uniform syntax. All commands are of the form[1]

$$\text{INPUT' IMAGE} \left\{ \begin{matrix} \hat{} \\ > \\ \backslash \end{matrix} \right\} \text{FUNCTION (P1 = ..., P2 = ..., ...)}$$

$$\left\{ \begin{matrix} \hat{} \\ > \\ \backslash \end{matrix} \right\} \text{OUTPUT' IMAGE}$$

The language allows the subsectioning, subsampling and subbanding of any input image.

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[1] $\{\ \}$ *denotes that any of the symbols inside the brackets can be used.*

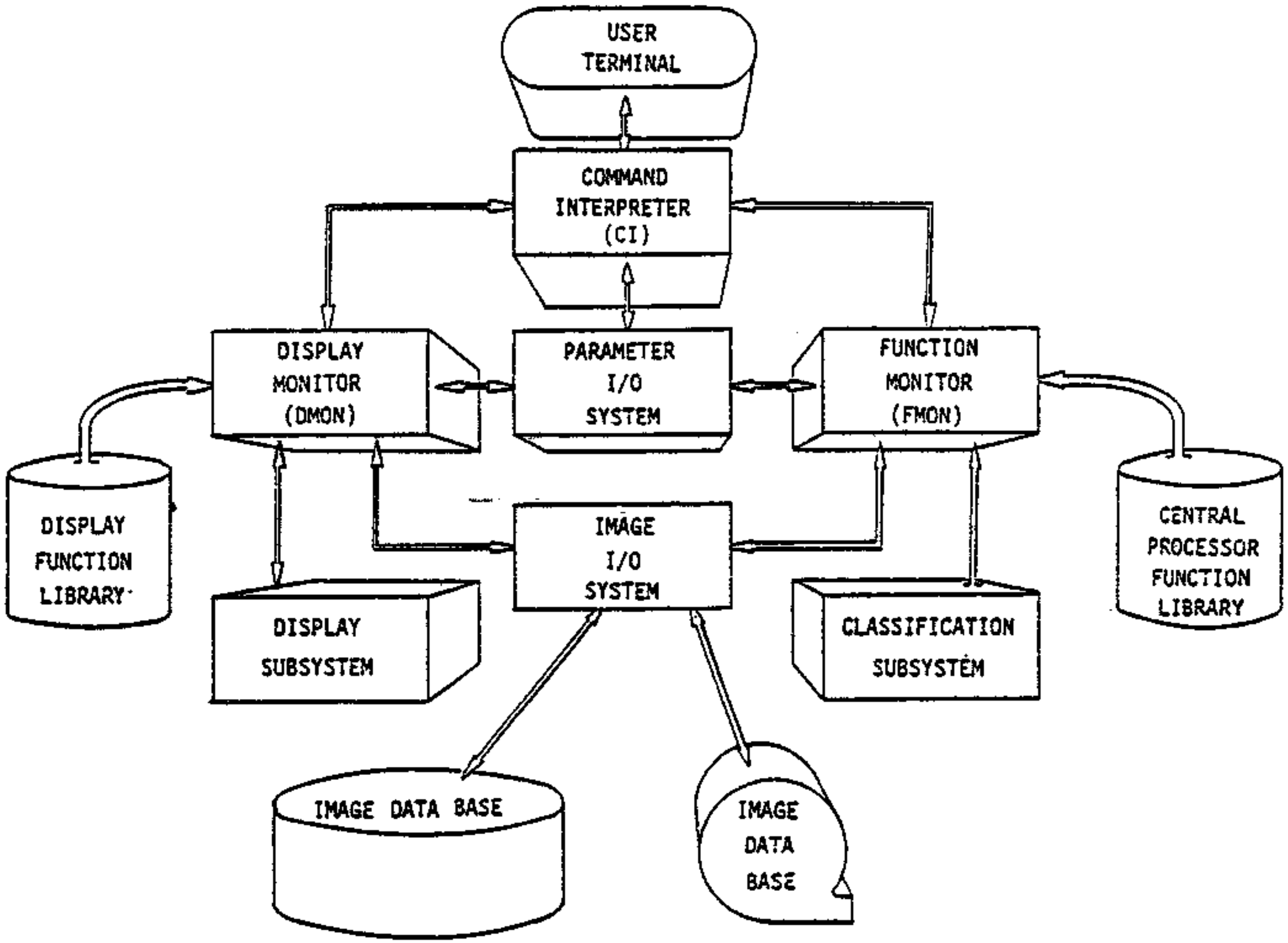

Fig. 3 - System 101 Software System Structure.

2.3 - ARIES - II

ARIES-II (DIPIX Systems Limited, 1980) is a family of digital image analysis systems and subsystems. Each member of the family is composed of various arrangements of modules augmented by optional peripherals. The Image Analysis Application Software is tailored for each configuration. The configuration for a large multi-user image processing system is depicted in Figure 4.

The Image Processing Subsystem (IPS) is the central control and processing element of ARIES-II systems. Various configurations of IPS are available, all based upon DEC computers (LSI-11, PDP-11 or VAX). In the case of the distributed processing configuration of Figure 4, the host IPS is responsible for the running of noninteractive tasks on any ISN request.

The Image Storage Node (ISN) stores all image and system data and can incorporate more than one disk drive.

Aries Image Display Sybsystem (AIDS) includes an operator's control tablet, video control computer and refresh memory (2 to 16 Megabit).

The Array Processor (AP) is an optional unit based upon the Floating Point Systems FPS-100 or AP 120B Array Processor.

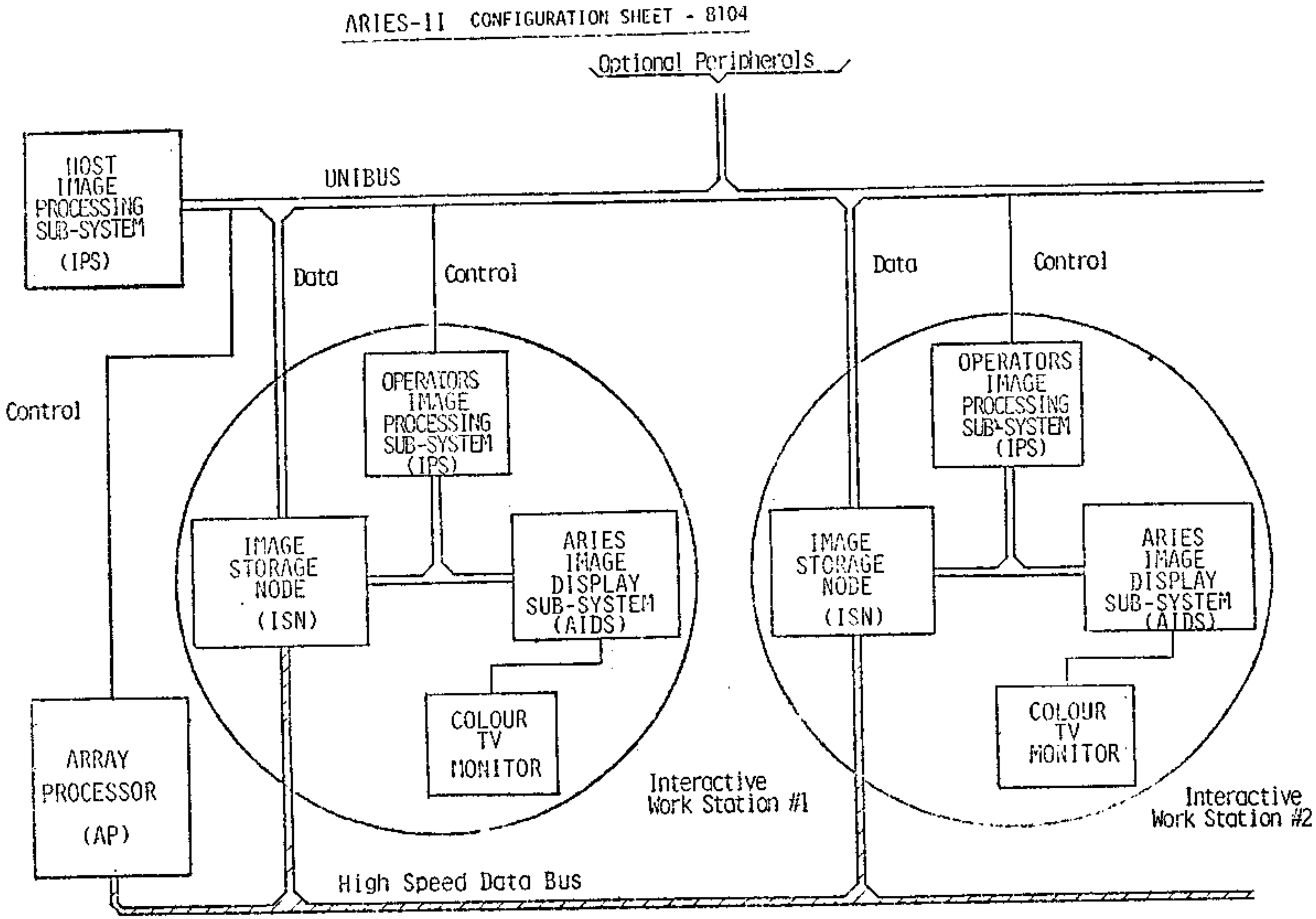

Fig. 4 - ARIES-II System Configuration.

Some of the possible configurations are:

1. Large scale multi-user image processing system (Figure 4), which can support up to 8 working stations.

2. Distributed processing for a production environment, similar to the configuration shown in Figure 4, with only one working station.

3. Stand-alone image analysis system. It consists of an IPS, an AIDS, color TV monitor, an ISN and an (optional) AP.

4. Costumer provided computer system configuration. Besides a DEC (LSI 11/23, PDP-11 or VAX) computer with floating-point, 96 k words memory, hard-copy terminal, a dedicated image disk and 10 Mb of system disk space, this configuration includes an AIDS, with a color TV monitor and an operator's console.

5. Microcomputer based image processing system. This configuration uses an IPS consisting of a DEC LSI-11/23 microcomputer, and simplified AIDS, ISN and a color TV monitor.

ARIES-II Application Software package provides a set of image analysis and manipulation functions that run on any ARIES-II configuration. The functions can be executed either on the local IPS, on the host IPS or on the array processor. The user interaction is done through the operator's console and the fact that different processes are being implemented by the AP or the host is transparent to the user.

User communication with the system is made using a MENU of the tasks which the system is capable of performing.

All accesses to the image disk are controlled by common routines.

2.4 - LARSYS

Purdue LARSYS (Carter and Billingsley, 1977) is a combination hardware-software image processing facility at the Laboratory for Applications of Remote Sensing (LARS) in West Lafayette, Indiana. System is used locally and also supports remote terminals via phone line. The software system (LARSYS) is primarily designed for multispectral classification, but also includes limited general purpose image processing.

Hardware is an IBM-360/67 plus an interactive console containing a black-and-white video display with facilities for black-and-white and color photographic output.

System hardware is not for sale, but several terminals are available throughout the country and at West Lafayette. System Software is available through COSMIC.

3. TABLES OF FEATURES

The application software, inputs, outputs and other features are presented in this section in the format of 5 tables. Table 1 covers general purpose image processing; Table 2 presents multispectral analysis; the possible inputs for the systems, in addition to computer compatible tape, are shown in Table 3; Table 4 shows both the volatile and hard copy outputs and Table 5 presents other features not covered by the previous tables.

The precise definition of the items presented can be found in Appendix A. The tables and the definitions were based on the work of Carter et al. (1977), updated for the IDIMS system and extended for the ARIES-II system.

3.1 - GENERAL PURPOSE IMAGE PROCESSING (TABLE 1)

3.1.1 - RADIOMETRIC CORRECTION

a) LANDSAT debanding, correction for 6 - sensor unbalance of MSS:

- average adjacent lines (all);
- notched filtering (IDIMS);
- Fourier, convolutional filtering (IDIMS, LARSYS);
- scanner angle correction (LARSYS).

b) Correction of photographic data:

- shading, focus correction (IDIMS, S 101[1], LARSYS);
- motion deblurring (IDIMS, S 101).

c) Others:

- Sun angle correction (IDIMS, S 101);
- atmospheric correction (none);
- finite aperture correction (LARSYS).

3.1.2 - DIGITAL LEVEL SLICING

a) continuum B/W to multiple discrete gray shades:

- N-level (IDIMS, S 101, LARSYS);
- completely flexible spacing (IDIMS, S 101).

b) Assignment of colors to discrete gray shades:

- arbitrary color assignment (IDIMS, S 101, LARSYS).

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[1] *S101 = SYSTEM 101 Of I2S*

3.1.3 - CONTRAST STRETCH

- linear, logarithmic, exponential (IDIMS, S 101);
- equal occupancy, flexible look-up table (IDIMS, S 101, LARSYS);
- piecewite linear (IDIMS, S 101, DIPIX).

3.1.4 - GEOMETRIC CORRECTION AND REGISTRATION

a) Internal sensor distortion:

- mirror scan velocity profile (IDIMS, S 101);
- roll, pitch, yaw (IDIMS, S 101);
- skew, aspect ratio, scaling (IDIMS, S 101, LARSYS);
- detector sampling delay (none).

b) External-projective geometry distortion:

- map projections (space oblique mercator, Alberts equal area, Polar stereographic, State plane, Lambert conformal, North American polyconic) (S 101);
- flexible rubber sheet, image rotation (IDIMS, S 101, LARSYS);
- UTM grid (S 101, ARIES-II);
- perspective correction (S 101).

c) Registration:

- manual control points (IDIMS, S 101, ARIES-II);
- computed block correlations (LARSYS);
- semiautomatic selection of control points (ARIES-II).

d) Geometric interpolation techniques:

- nearest neighbor (IDIMS, S 101, LARSYS);

- bilinear (IDIMS, S 101);
- cubic convolution (IDIMS, LARSYS);
- Sin x/x (LARSYS).

3.1.5 - FILTERING

- convolution arbitrary (IDIMS, LARSYS, ARIES-II);
- Gaussian, high pass, low pass, Wiener, homomorphic, directional (IDIMS, S 101);
- Fourier (IDIMS, S 101, LARSYS);
- Hadamard (S 101);
- Optimum constrained restoration, gradient (LARSYS).

3.1.6 - TRANSFORMS

- Fourier, Hadamard (IDIMS, S 101);
- Slant (S 101).

3.2 - MULTISPECTRAL ANALYSIS (TABLE 2)

3.2.1 - SUPERVISED CLASSIFICATION

- parallelepiped (S 101, ARIES-II);
- maximum likelihood (all);
- look-up table (S 101);
- Bayesian, minimum distance (IDIMS);
- sample classifier, multi-image layered classifier (LARSYS).

3.2.2 - UNSUPERVISED CLASSIFICATION

- spectral space clustering (all);
- automatic boundary finding/sample classification (LARSYS).

3.2.3 - INTERBAND MANIPULATION

- interband arithmetic functions (IDIMS, S 101, LARSYS);
- eigenvector (all);
- general axis rotation (S 101);
- Karhunen-Loẽve (all).

3.2.4 - STATISTICAL OPERATIONS

- training field selection (all) (IDIMS: polygonal, S 101: any shape, LARSYS: rectangle, DIPIX);
- optimum band selection (IDIMS, S 101, LARSYS);
- maximum number of bands (IDIMS: 255, S 101: 36, LARSYS: 30);
- maximum number of classes (IDIMS: 256, S 101: 64, LARSYS: 60);
- classification speed with array processor, 4 bands 512 x 512, 10 classes (IDIMS: 52s, S 101, 120s);
- post-processing (ARIES-II).

3.3 - INPUT DEVICES (TABLE 3)

- TV camera (S101, ARIES-II);
- microdensitometer (IDIMS, S101);
- LANDSAT digital tape (all);
- SKYLAB S192, analog tape, aircraft scanner (IDIMS, LARSYS);
- CCRS LANDSAT, JSC universal, VICAR (LARS);
- PCM (S101).

3.4 - SYSTEM OUTPUTS (TABLE 4)

3.4.1 - VOLATILE DISPLAY

- graphics (IDIMS, S101);
- 2-d graphic display:
  - cluster plots, pseudo 3-d, scatter-grams (IDIMS);
  - categorization accuracy table, status monitor (S101);
- annotation (all);
- CRT-display:
  - color (IDIMS, S101, ARIES-II);
  - B/W (LARSYS);
  - scrolling (IDIMS, S101).

3.4.2 - HARD COPY

- line printer, high quality film (all);
- overlays (raster) (IDIMS, S101);
- maps (line-plotter) (IDIMS);
- photographs of display (all).

3.5 - OTHER FEATURES

3.5.1 - SOFTWARE

a) Language:

- FORTRAN (IDIMS, S101: applications, LARSYS: 80%, ARIES-II);
- SPL-HP3000 (IDIMS, S101: system);
- System/360 assembler (LARSYS: 20%).

b) Interface mode to user:

- batch (IDIMS, S101, LARSYS);
- interactive-menu (IDIMS, S101, ARIES-II);
- interactive-command (IDIMS, S101, LARSYS).

4. CONCLUSIONS

Looking at the descriptions of the image processing systems in Sections 2 and 3, we note that some features were displayed by most of the systems. Among there features, one could mention:

- most of the display subsystems of the systems presented some kind of independent processing capability;

- the preferred form of communication with the user is through a command language, that can be suited both for batch and interactive processing;

- the image processing software was usually divided into an operating system module and a collection of application routines; also presented in most system was an image management and access subsystem that provided an interface between the image data and the remaining routines;

- to speed up the processing, the systems usually resorted to an array processor, that is absolutely necessary in a production environment.

Some good features presented individually by the systems were:

- distributed processing in ARIES-II system, where the actual computer that does the processing is transparent to the user;

- a quite complete set of applications software and a powerful command language, in IDIMS and System 101 systems, particularly the set of map projection routines of System 101.

Some limitations found in the systems were:

- a small number of application functions in ARIES-II System;

- in the LARSYS System there is no color TV monitor; this can greatly restrict the interaction with the user, which is an important factor in some applications.

- the IDIMS and System 101 systems rely on a 16-bit computer; this can be a severe limiting factor in some applications even if an array processor is used.

REFERENCES

CARTER, U.P.; BILLINGSLEY, F.; LAMAR, J. *Summary tables for selected digital image processing systems.* Reston, VA, 1977. (US Geological Survey Open-File Report 77-414).

DIPIX SYSTEMS. *ARIES-II information pack.* (Presentation, specification and configuration sheets) Ottawa, 1980.

ESL INCORPORATED. *IDIMS - interactive digital image manipulation system.* Sunnyvale, CA, 1981. (ESL-SR 337, Revision 2).

INTERNATIONAL IMAGING SYSTEMS. *System 101 - interactive multiuser, digital processing system.* Product description, s.l. 1978.

APPENDIX A

DEFINITIONS[1]

These definitions are generally arranged in the order in which they occur in the tables. Definition of all the terms used is not possible within the scope of this document.

GENERAL PURPOSE IMAGE PROCESSING (Table 1): The entire gamut of possible operations on a picture, including radiometric and geometric alterations, various diagnostic procedures and displays, image analysis, and enhancements such as contrast stretching and spatial filtering. This includes all of the processes leading to the extraction of useful information from an image such as mapping, radiometric information extraction, multispectral analysis and classification, calibration and application of calibration data (rectification), change detection, and image data base operations. This does not imply that all systems have all of these functions, nor that the list is necessarily complete.

Radiometric Correction - Application of calibration data or cosmetic cleanup to remove visible radiometric artifacts.

* LANDSAT debanding - LANDSAT imagery generally suffers from a banding effect due to unbalance in the various sensors. This may be mitigated by application of calibration data or by line-by-line cosmetic cleanup.

* Photographic Correction - Framing cameras produce non-uniformity of radiometric response over the face of the images. This shading may be removed if calibration data is available.

* Other - Pixel noise may be removed by frame-to-frame averaging. Atmospheric radiometric distortions require special procedures to estimate and correct.

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(1) *Copied from Carter et al (1977)*

Digital Level Slicing - Conversion of the brightness or digital number (DN) continuum to series of steps in each of which an assigned DN is substituted for a range of original DN. Each step may later be assigned a unique color.

Contrast Stretch - An alteration of the DN scale, usually to convert an input restricted DN range to an expanded output DN range. This may be linear or non-linear, as desired. Usually done by table lookup for computer efficiency.

Geometric Corrections - All sensors will produce images with some geometric warping. A primary example is the LANDSAT MSS, which, being a line scanner, requires 14 types of corrections.

* Internal - The principal MSS corrections required are those for intersensor pixel displacements, non-linearity of the scan itself and horizontal/vertical unequalities in the pixel spacing. Also, for framing cameras, raster, film, and lens distortions must be corrected.

* External - Correction for external effects such as spacecraft attitude and altitude, projection onto the round Earth, Earth rotation, and the various warpings required to register images to maps or to other images.

Geometric Warping - The geometric warping process is broken into two parts: determination of the warping function required over the face of the image, and the interpolations of DN required to generate the matrix of output pixels.

Registration - Determination of the geometric warping function.

* Registration Parameters - Determined either by a mathematical modeling of the warping desired, of by locating a series of control points (CP) for which the true locations (e.g., on the

ground "Ground Control Points, (GCP)" or in a reference scene or framework "Relative Control Points, (RCP)" are known both externally and by line and pixel.

* Mapping CPs to Scene - Specific location of the source of data for each output pixel is required. The relatively sparse group of CP locations over the face of an image are used, generally by some sort of interpolation or mathematical formulation, to generate the required continuous function.

* Temporal and Mapping - For temporal overlay, CPs are often determined by cross-correlation of areas in the new and reference scenes. For mapping, image-type references are not normally available, and CP selection must be manual.

Geometric Interpolation Techniques - Source location for an output pixel is rarely precisely at an input pixel location, so that some form of interpolation using a group of input pixels surrounding the required source location is required to estimate the DN of the scene at the source location.

Filtering - Spatial filtering is used to restore the high spatial frequencies which have been attenuated in the imaging process, to sharpen visible edges, to determine areas of high or low DN variance, to soften noise effects, to remove banding, or for numerous other functions. Spatial filtering is generally done by convolution, but may be accomplished by multiplication in spatial frequency space via a Fourier transform. Golay filtering minimizes isolated pixel noise in homograms (thematic maps).

Transforms - Normal image coding records the brightness at each discrete instantaneous field of view, IFOV, in the scene as the DN in each pixel. However, the energy in the scene may be grouped in other ways: the Fourier transform displays the two-dimensional energy content of the various spatial frequencies present in the scene; the

Hadamard transform displays a related quantity based on square-wave decomposition of the image. Other transforms are possible and sometimes used.

MULTISPECTRAL ANALYSIS (Table 2): That set of operations involving the analysis of multispectral data utilizing the spectral information. "Multispectral analysis" is often used synonomously with "multispectral classification", although it properly covers all of the required operations involving multispectral data. Multispectral classification is the recognition of areas of uniform ground cover through recognition of the spectral signatures (the multispectral vector of DN for a given material). Classification usually results in the substitution in each pixel of a "name" or color representing the ground cover class in place of the original data.

Supervised Classifier - The computer is instructed as to the identification of certain known materials in the scene by the use of "training areas". It is then given decision rules, and instructed to display all pixels matching the series of materials by unique codes (or colors).

Unsupervised Classifier - The computer first groups into a series of classes all of the pixels in the scene by measuring the tendency of pixels of a given material to cluster around a given location of multispectral space. Following this, the analyst identifies each material.

* Region growing - Pixels of a given material tend to form a series of groups of contiguous pixels (in image space). Thus, "All wheat pixels in the scene occur in a group of wheat fields, each of which is identifiable". Region growing is the computer process of gathering and displaying the pixels in the identifiable groups, after which the analyst may identify each.

Mensuration - the determination of areas in the image or designated subsection. This normally is done by simple pixel count, although for some purposes intra-pixel mixtures must be estimated.

Inter-Band Manipulation - For multispectral data, each spectral image is a "band". Operations between bands have been found to be useful for certain analyses.

* Functions - Various algebraic functions such as multiplication or division are non-linear, and produce data of a new kind. For example, division of a scene by a reference "flat field" scene, point-by-point, will tend to normalize against variation of sensor response over the face of the scene.

* Spectral Analysis - Analysis of selected data points to determine the optimum processes to be applied to the entire image. Examples are eigenvector analysis to determine the optimum band combinations to allow multispectral analysis, or the selection of optimum ratios to be used for display.

* Spectral Axis Rotation - Linear combination of bands, pixel-by-pixel, amounts to producing a new projection of the data onto a set of rotated axes. Rotation to the optimum angles following an eigenvector analysis (Karhunen-Loeve) is the most usual, but other rotation angles may be used for other purposes.

Statistical Operations - The set of processes and decisions required to carry out the multispectral analysis.

* Training Field Selection - Operator designation of areas of known materials or ground cover. May be done interactively or by off-line mapping.

* Training Statistics - Characterization of the group of pixels of the training area, usually as mean and variance in

multispectral space (covariance matrix). Other measures such as texture could be used as a derived multivariate analysis "band" for use with the multispectral.

* Number of Spectral Bands - Analysis time goes up as the number of bands used increases - but so may the classification accuracy. A tradeoff to be made by the analyst.

* Maximum Number of Classes - For some classifiers, the time for classification goes up with the number of classes. Another tradeoff, since the analyst may group classes together as desired.

* Optimum Band Selection - Some bands, including possible ratios between bands, will give better class identification than will others. Some software is available to aid the analyst in this selection.

* Speed - Schemes using full analysis can be extremely slow; table lookup methods can accomplish much the same task at greatly increased speeds. Decision as to "optimum methods" has not been made, and may not be possible; differences between methods is often secondary to differences caused by variance in the scene or the analyst choice of training.

INPUTS (Table 3): In addition to the computer compatible tape (CCT) input anticipated, other input devices will be useful for other than LANDSAT MSS data.

TV Camera - For scanning input images, a local TV camera may be useful. This normally will be a vidicon or image dissector.

Microdensitometer - For higher accuracy, either in spatial or in brightness quantizations, various forms of travelling aperture devices are used. These commonly take the form of either drum scanners or flatbed scanners.

Digital Tapes - The tape format expected for most MSS work is the "NASA LANDSAT". Others, many of which are similar, may be encountered. NASA and USGS are currently trying to define a universal tape format family which will encompass many of the present formats.

Analog Tapes - For some purposes, image data may be recorded on analog magnetic tapes. Special analog-digital conversion is required to utilize this data.

OUTPUTS (Table 4): These may be either volatile on a terminal display, or hard copy via line printer, image film, maps, or tables.

Volatile outputs

* Graphics - A number of graphics displays are available - these are normally used for alphanumeric conversations with the analyst during the analysis process.

* Two-Dimensional Graphics - Some graphics terminals have the ability to display line drawings, graphs, cluster plots, and other diagnostic aids.

* CRT for Image Display - When grey-scale or color images need to be displayed during the analysis, a special television-like terminal display is required. These displays must be continually "refreshed", requiring a special memory in the system to continually generate the required data.

* Annotation - Ability to superrimpose grids, alphanumeric data and other information on a displayed image.

Hard Copy Outputs

* Line Printer - The normal computer printer, which may also be used to generate a grey-scale image by character selection and

overprinting. For a printer having the normal 10 characters/ inch and 6 lines/inch, a 1/24.000-scale image will be produced if the pixels are interpolated to be 60.96x101.60 meters IFOV.

* Film - For most analysis, the desired output product will be high quality film, either in black/white (B/W) or color. The latter will normally be generated by photographic combination of three B/W films.

* Overlays - Film output requiring the ability to convert some set of data such as polygon vertices to rasters.

* Maps - Output implying the capability of driving line drawing devices.

* Display Photographs - Usually for quick look or reduced-quality permanent copy, limited in quality by the display device.

OTHER FEATURES (Table 5)

Microprogrammable Processor - Some of the analysis steps are very time-consuming, even with fast general purpose computers. A number of special purpose devices are available to perform specified process very efficiently. These are usually used as peripheral devices to the normal computer in the system.

Present Computer - The hardware systems discussed each are based on a modern minicomputer. Depending on the degree of interaction, number of terminals serviced, displays, and other features, the size required may vary considerably.

Software - Most applications programs are written in Fortran. Various higher-level languages may be used for parts of the system programs, and for some of the applications. The feature to look for here is the ability of the user to write and incorporate new programs as he wishes, since all functions cannot be defined at purchase time, and the state-of-the-art is continually advancing.

* Interface Mode to Analyst:

1. Batch - The analyst generates a series of commands, either at an interactive terminal or via card job entry. The entire series is run by the computer as a single job without further interaction with the analyst.

2. Interactive Command - The computer carries out each command as it is entered by the analyst, (usually) displays the results, and waits for the next command. In some cases, it may be possible to assemble or call a short series of commands (a procedure) which will be accomplished before receiving the next command.

3. Interactive Menu - As each command is entered by the analyst, the computer replies with a display which gives the analyst the choice of a number of options. These might be parameter entries, function options such as linear, log, table, or other defined types of contrast stretch, or entries relating to any multiple choice decisions the analyst must make. This mode is of particular value to the analyst unfamiliar with the details of the function being called, as it guides him through the required decisions.