

1-1-1975

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Reprinted from

Symposium on

Machine Processing of

Remotely Sensed Data

June 3 - 5, 1975

The Laboratory for Applications of
Remote Sensing

Purdue University
West Lafayette
Indiana

IEEE Catalog No.
75CH1009-0 -C

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THE IMAGE DISPLAY AND MANIPULATION SYSTEM (IDAMS)

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I. ABSTRACT

The Image Display and Manipulation System (IDAMS) is an interactive image analysis system consisting of a general purpose computer, a TV display and control console, and software. This paper describes the system features and capabilities. A scenario approach which simplifies the user interface is defined and is illustrated by an application of a scenario to multispectral classification. Included is a brief description of the Atmospheric and Oceanographic Information Processing System (AOIPS), a new interactive image analysis system currently being implemented at the Goddard Space Flight Center (GSFC).

II. BACKGROUND

IDAMS was designed and implemented in 1971 at GSFC to provide a tool necessary for research dealing with remote sensing of the Earth using images as the primary data source. At that time no system existed at GSFC with which to analyze digital imagery, yet volumes of LANDSAT data would soon be received. Such systems were not available for purchase; therefore, IDAMS was developed in-house. A timely development was essential to support LANDSAT prelaunch simulations and any analysis to be performed on the initial data received. Consequently, certain system design constraints were imposed in order to maintain a reasonable schedule.

III. SYSTEM CONFIGURATION

A. OVERVIEW

IDAMS consists of a general purpose computer, an interactive display and control console, and image processing software. A CDC 3200 computer was selected as the host computer because it was under our administrative control and

available for use several hours a day. The interactive console was developed in-house because a commercial product that would satisfy our requirements was not available. In-house personnel and personnel from the Computer Sciences Corporation developed the image processing software.

B. USER INTERFACE

A user interfaces with the system through the interactive console shown in Figure 1. Images are displayed on TV monitors in both color and black and white. An alphanumeric terminal (shown in the right foreground of the figure) displays tabulated data, questions to the user, diagnostic messages, and other information. With the keyboard and display, the user composes messages (commands, parameters, etc.) which are transmitted to the computer. The system also accepts batch jobs. A user can execute any of the processes contained in IDAMS from the terminal or from punched cards which have identical formats. Execution can be alternated between the terminal and cards by entering the command SWITCH. In this way a user can prepare lengthy parameter lists offline and enter them easily during an interactive session.

The TV automatically displays an image during processes such as the classification scenario, which is described later. In addition, there is a general purpose display process which enables the user to display color or black and white images. A variable size rectangle and a resseau can be superimposed over the image and positioned by a joystick to delineate areas or locate ground features. Typically, a user executes processes, views results, and makes decisions to execute additional processes.

C. HOST COMPUTER SYSTEM

The CDC 3200 host computer was delivered in the mid-1960's. It has 16,000 words, each word consisting of four six-bit bytes. Memory cycle time is about 1.1 microseconds; floating point arithmetic is performed in software. Peripherals include a card reader, a card punch, an eight-million-byte disk, a lineprinter, five high speed magnetic tape units, and an alphanumeric keyboard/CRT display which is used for communication between the computer and the investigator. The computer operating system is relatively simple; a data management system is virtually nonexistent. Table 1 summarizes these features.

The computer characteristics imposed several important design constraints. One is the use of tape for input and output for almost all processes. With a design criteria to process images with up to 5000 pixels per line and as many lines per frame that can fit on a tape at 800 bits per inch, the disk capacity was insufficient for use as data storage. This constraint resulted in much tape handling and increased the execution time for some processes.

Another constraint, imposed by the limited core and byte size, is the use of six-bit accuracy for most input and output data. Using half words (12 bits) to represent the image pixels would have wasted core during input/output operations and limited the core space available for computations. Internal computations use full word integer or floating point accuracy for most processes. Input data with greater than six-bit accuracy have to be mapped into six bits. An eight-bit byte computer is preferable and will be used in AOIPS (to be described later).

D. INTERACTIVE CONSOLE

The interactive console consists of both a color and a black and white TV monitor, a control panel for hardware manipulation of images, and disk storage for three TV size images (see Figure 1). The alphanumeric terminal is a standard computer peripheral with 20 lines of 50 characters each displayed on a cathode ray tube and a keyboard.

The computer is interfaced to the TV disk storage, and images are transferred from the computer to this disk. A reseau can be displayed on the monitors and positioned by the experimenter using a joystick to locate points in an image. A variable size rectangle can also be displayed and manipulated using the joystick.

This is used to delineate areas for additional processing.

The control panel operates independently from the computer so that some of the system features can be demonstrated even if the computer is not available. This independent operation has been an important feature for presentations to the many people who have visited the facilities. For example, by using the control panel only, any of the three stored images are displayed on the black and white monitor as positive or negative images. The images may also be alternated automatically in time sequence, a useful feature for detecting changes between images. Two variable threshold controls perform density slicing on an image. On the color monitor, a single image can be displayed in pseudo color, or three images in any false color combination of negative and positive images.

E. SOFTWARE AND PROCESSING FUNCTIONS

IDAMS began operating in January 1971 with a basic image manipulation capability using a combination of hardware and software functions. These include filters in the Fourier and spatial domains, contrast enhancements, simulation of sensor apertures, pseudo and false color display, density slicing, analog addition and subtraction, and alternation of images. Soon after, programs were added which perform geometric and radiometric corrections on LANDSAT Multispectral Scanner (MSS) and Return Beam Vidicon (RBV) images as well as shading corrections on the RBV images. Banding removal on the MSS images was added later. The geometric corrections are based on operator-selected ground truth landmarks and a model of the spacecraft and sensor motions which is fitted to these landmarks.

One useful function is ZOOM. This operation is similar to that of a zoom microscope which is adjusted to obtain a desired magnification. IDAMS performs this digitally, maintaining the multispectral registration, radiometric accuracy, and resolution inherent in the data. First, a large image is displayed on the TV screen at reduced resolution. Then via the joystick, a rectangle overlay is moved and sized to encircle an area of interest. When the ZOOM function button is pressed, this area is automatically expanded and displayed on the TV at higher resolution. If the selected area is too large to fit the screen, IDAMS averages contiguous pixels so that the selected area fits. Small areas are expanded to fit by repeating pixels. For example, one pixel can fill the entire screen. With ZOOM, fine detail is

discernable that could not be seen otherwise.

IV. MULTISPECTRAL CLASSIFICATION

A. BACKGROUND

A Multispectral Classification capability was first implemented in 1972 at GSFC by using a remote terminal connected to the Purdue Laboratory for the Applications of Remote Sensing (LARS) facility. The decision to follow this approach was based on several factors. First, GSFC experimenters were moving rapidly into the multispectral analysis field with LANDSAT-1 data and required an in-house capability. Second, LARS provided a staff of expert consultants as well as an extensive training package. Third, interest was growing to evaluate the use of remote terminals connected to a central facility for this application.

Experience was developed using IDAMS and the LARS terminal, and it soon became apparent that both functions should be combined into one system. IDAMS was selected for classification implementation because it had a powerful interactive terminal, it was accessible, and GSFC could experiment with the user interface in preparation for the AOIPS implementation. To simplify the interface for users who are not computer oriented, a "scenario" approach evolved.

B. SCENARIO APPROACH

In the scenario approach, requirements for a user or group of common users are defined and a set of operations implemented with a controlling program that automatically sequences from one operation to the next. The user interacts with the system as required to make decisions at branch points in the sequence. He is able to enter parameters required for each operation, to interact with the image locating ground features or selecting subimage areas such as fields, and to query the system for information needed to make some of the aforementioned decisions.

The first of several problems leading to the scenario approach is that discipline users are not good typists. Hunt-and-peck typing skills when combined with articulate computers have frustrated many users trying to perform a few simple functions. MINIMIZE TYPING. Another problem: providing too much flexibility. For many applications, a fixed set of functions are required. Presenting a user with 50 to 100 choices at each step in a sequence of operations

is confusing and unnecessary. LIMIT USER OPTIONS. A third problem: too much reliance on an operating manual during an interactive session. The system should lead a user through his sequence of operations. MAKE THE SYSTEM DO THE WORK. Every system has difficulties, but the aforementioned problems are major ones that can be minimized by using scenarios.

The user is led through a scenario by a set of questions from the computer or by a menu display of functions from which he selects his next operation. The menus are organized in a hierarchy. The first level allows the user to decide a general course of action, the second level allows the selection of more specific operations, and so forth. When a selection is made, a sequence of operations is initiated. When parameter values are required, the computer requests the necessary information on the alphanumeric terminal, and the user responds via the keyboard. Results of operations are automatically displayed on the alphanumeric terminal or the TV monitor.

C. CLASSIFICATION SCENARIO

The scenario implemented in IDAMS performs most of the functions found in other multispectral classification systems. The major difference is the user interface. The user is led through a sequence of operations with menus and questions which are presented on a display. He then responds with minimal typing or by using function keys.

Image data is prepared for the scenario using the standard IDAMS JOY-STICK routine to select areas of interest. These areas are usually reformatted for classification as a batch job to save time for the user. Reformatting functions were not included in the scenario because computer hardware constraints would have caused time consuming operations during an interactive session. Several TV size images (572 by 468 pixels) may be selected and classified sequentially.

Preprocessing functions may be performed on the images before they are classified. IDAMS has standard routines for ratioing, linear combining, geometric correcting, contrast stretching, filtering, and interpolation. Before classification, some users analyze their data using other standard IDAMS routines which pseudo color individual spectral images, generate histograms, or numerically list portions of the image. When the user has finished performing the necessary

preprocessing functions, he gives his formatted tape to the computer operator and sits down to begin his session.

Main Menu

The user types CLASSIFY and is first presented with the Main Menu shown in Figure 3. The primary image is automatically stored in the system when CLASSIFY begins, and it is saved throughout the session. A secondary image may be entered using (7) STORE SECONDARY IMAGE. Other secondary images may be entered similarly, but the previous secondary image is destroyed. When using (1) DISPLAY PRIMARY IMAGE or (8) DISPLAY SECONDARY IMAGE, the corresponding image is displayed in color and subsequent processing is then performed on that image. If time expires during a session, the user selects (6) SUSPEND OPERATIONS AND SAVE which enables him to continue at another time. Because (3) SELECT TESTING AREAS is similar to (2) SELECT TRAINING AREAS, it will not be discussed in this paper.

Training Menu

When the user selects (2) SELECT TRAINING AREAS, the Training Menu is displayed as shown in Figure 3. If previous training data have been selected during the session (or a previous session that was saved), a summary of classes, number of sites, and number of pixels are displayed below the menu as shown in the example. If the user is dissatisfied with his training data, he selects (1) CLEAR TRAINING SET, which clears all class names and training sites as if the scenario is starting at the beginning.

A user defines new classes, deletes classes, adds training sites, and performs other similar functions by selecting (2) UPDATE INTERACTIVELY. The Update Menu is displayed as shown in Figure 3.

When the Update Menu is displayed, the system automatically superimposes a rectangle on the TV image which defines all training sites. The joystick (see Figure 2) is used to shape, size, and position the rectangle around a training area. Two joystick features should be noted that are not generally available on other systems. First, the rectangle can be positioned by the joystick while the alphanumeric display of coordinates is being observed. In this manner, the user who does not opt to type can select specific coordinate values. The user also has the option of typing in coordinates using the SELECT function push button.

The second joystick feature is the enlargement of any portion of the TV image. Using the NOMINAL BOX function push button, the user sizes the rectangle for an enlargement factor ranging from two to ten. When the ZOOM function push button is pressed, the system enlarges the selected area by repeating pixels and displaying them on the TV. At this time the user selects training sites, and the computer performs all the bookkeeping to relate the position of the rectangle on the TV to image coordinates.

The Update Menu also allows the user to delete training sites, to combine similar classes, or to split a class into two or more separate classes. This is accomplished by referencing only the site number or class name. To assist the user with these decisions, there are class histograms available ((6) DISPLAY CLASS HISTOGRAM) for each spectral band and a display of the means and standard deviations ((7) DISPLAY SITE STATISTICS FOR CURRENT CLASS) for each site. During the latter display on the alphanumeric terminal, the rectangle is displayed on the TV image delineating each site. A function key is used to shift the rectangle from one site to the next.

With the Training Menu the user can define or update his training set from punched cards. This feature saves time during an interactive session and allows the repetitive use of training sites without having to enter each site as described above. Also, the user can request various statistics and other data such as class and site descriptions, divergence between classes, and the confusion matrix obtained once the training data has been classified.

Output Menu

The Output Menu gives the user several options for viewing the classified results. Each of these options has parameters which are typed by the user when questioned by the terminal. For example, the display and tape outputs can include a subset of all the classes. Also, subsections of the image may be selected for output by using the joystick to position the rectangle over an area of interest. The tape outputs are converted to film using a Dicomed film recorder.

One example of a black and white classified result from LANDSAT data is shown in Figure 4. In this experiment, to define water boundaries and areas, only the water class is displayed. This image was preprocessed before classification by interpolating between LANDSAT

pixels using a cubic polynomial. For comparison, Figure 5 shows each pixel of Band 7 represented by a rectangle of uniform density.

V. AOIPS AND THE FUTURE

AOIPS is a system currently being implemented at GSFC which will include most of the functions of IDAMS, but is designed around a powerful minicomputer system with interactive terminals designed for flexibility. The terminals include some hardware features that greatly accelerate some of the processes accomplished by software in IDAMS.

The computer system consists of two PDP 11/45 central processing units and an assortment of peripherals (see Table 2). The large disk storage capacity allows several LANDSAT size images to be stored simultaneously. Consequently, the execution time for displaying, selecting, and processing subimage areas will be considerably less compared to tape oriented systems such as IDAMS. Simultaneous program executions (i.e., time shared) permit efficient computer utilization. Background batch processes will be running while the interactive terminals are being used.

Two terminals are being installed, an IMAGE 100 terminal developed by General Electric and a Research and Development (R&D) terminal. Each one will operate essentially independently of the other. The two computers will share disk, tape, and core storage to exchange data base information. Since the IMAGE 100 terminal is a standard commercial product with considerable documentation, it will not be discussed here.

The R&D terminal consists of a TV display and alphanumeric display and keyboard. Five TV-size (512 by 512 pixels) images of eight bits per pixel can be stored and displayed.

Hardware design allows switching between any stored image and the display. Switching can be automated by computer control so that images are sequentially viewed in movie fashion. Five look-up tables provide contrast stretching or color enhancement. The look-up table outputs are coupled logically so that eight simultaneous parallelepiped regions are defined in feature space for classification. Many other features are not described here. However, one important design feature is that all operator switches are push buttons coupled directly to the computer which, in turn, sends commands to the terminal setting

the various conditions.

The user operates the terminal as follows. He pushes a button, and the computer responds by backlighting the button and setting the corresponding condition. However, at some point in a scenario, a particular display may be required. Then the computer overrides the conditions set by the user and configures the display for this requirement. In this manner, the scenario flows smoothly and relieves the user from trivial operations.

The AOIPS system design includes many of the better features of existing systems. In addition, special attention is being given to supporting scenarios and providing a functional interface to the user. A data management system being designed will overlay various data types at different resolutions.

VI. CONCLUSIONS

IDAMS contains a variety of application programs that are useful to a number of disciplines. Its interactive capability increases analysis throughput because results can be viewed and decisions made to continue other processes without the delays inherent in batch operations. IDAMS is supporting the research for in-house discipline users having digital images as one primary data source. Testing system concepts, user interface, and algorithms on IDAMS help build the design for the new AOIPS. The scenario approach for interfacing the user to the system has been tested and found to be highly successful.

VII. ACKNOWLEDGMENT

IDAMS was conceived, designed, and implemented through the joint efforts of Jim Billingsley, Lottie Brown, and myself of GSFC with Marty Szczur and staff at Computer Sciences Corporation providing software support. Karen Posey contributed to the implementation of the Classification Scenario.

<u>CENTRAL PROCESSING UNIT</u>
16K words of core 6-bit byte addressable 4 bytes per word 1.1 microsecond core cycle time floating point arithmetic in software
<u>PERIPHERALS</u>
5 7-track tape drives 8 million byte disk line printer card reader card punch alphanumeric CRT display and keyboard
<u>SYSTEM SOFTWARE</u>
scope 1.2 operating system Fortran compiler assembler scientific subroutines

TABLE 1. Salient Components Of The CDC 3200 Computer

<u>CENTRAL PROCESSING UNIT A</u>	<u>CENTRAL PROCESSING UNIT B</u>
<u>PDP 11/45 CPU</u>	<u>PDP 11/45 CPU</u>
48K words of core 8-bit byte addressable <1 microsecond core cycle time floating point hardware	32K words of core 8-bit byte addressable <1 microsecond core cycle time floating point hardware
<u>PERIPHERALS</u>	<u>PERIPHERALS</u>
2 9-track tape drives line printer card reader alphanumeric CRT display and keyboard ASR 35 teletype 50 megaword disk	2 9-track tape drives line plotter/printer card reader alphanumeric CRT display and keyboard ASR 35 teletype 2 1.2 megaword disks
<u>OPERATING SYSTEM</u>	<u>OPERATING SYSTEM</u>
RSX-11D	RSX-11D
<u>PLANNED AUGMENTATION</u>	<u>PLANNED AUGMENTATION</u>
64K words of core 0.5 megaword fixed head disk high density digital recorder 50 megaword disk	16K core shared with the Unit A

TABLE 2. Salient Components Of The AOIPS Computers



Figure 1. IDAMS Console including color and black and white TV display, control console, joystick/function buttons, and alphanumeric CRT/keyboard terminal.

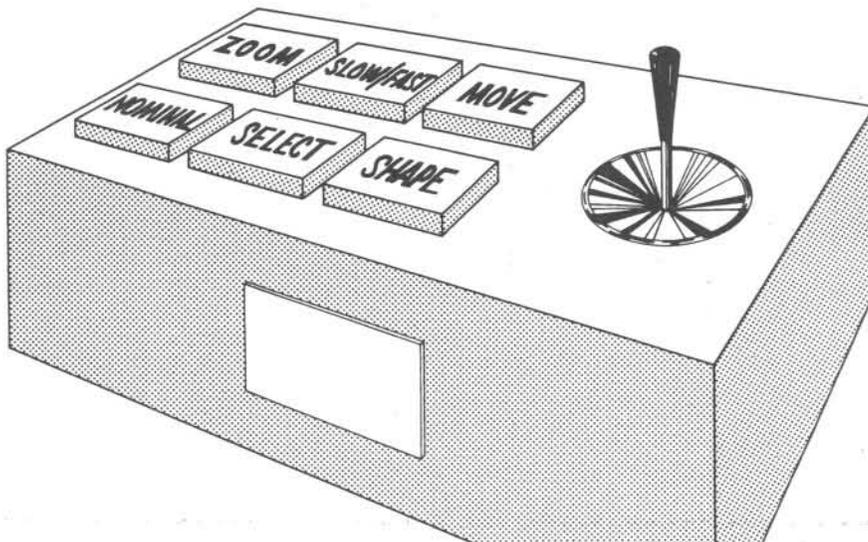


Figure 2. IDAMS joystick with function buttons labeled for the classification scenario.

IDAMS CLASSIFICATION MAIN MENU

- (1) DISPLAY PRIMARY IMAGE
- (2) SELECT TRAINING AREAS
- (3) SELECT TESTING AREAS
- (4) CLASSIFY THE IMAGE
- (5) OUTPUT CLASSIFIED IMAGE
- (6) SUSPEND OPERATIONS AND SAVE
- (7) STORE SECONDARY IMAGE
- (8) DISPLAY SECONDARY IMAGE
- (9) EXIT

LEVEL 1
MENU

TRAINING MENU

- (1) CLEAR TRAINING SET
- (2) UPDATE INTERACTIVELY
- (3) UPDATE FROM CARDS
- (4) DISPLAY OVERALL STATS
- (5) CLASSIFY TRAINING DATA
- (6) PRINT TRAINING REPORTS
- (7) RETURN TO MAIN MENU

DEFINED CLASSES	NUMBER SITES	TOTAL PIXELS	DEFINED CLASSES	NUMBER SITES	TOTAL PIXELS
CORN	3	126	SAND	2	87
WHET	4	59	BRLY	1	18
WATR	16	2130			
LAWN	1	33			
ROCK	1	15			
RICE	8	904			
TREE	9	431			

LEVEL 2
MENU

CURRENT CLASS - WATR SP SL NP NL
NO. SITES - 13 4103 804 39 66

UPDATE MENU

- (1) ADD TRAINING SITE
- (2) COMBINE CLASSES INTO CURRENT CLASS
- (3) SPLIT CURRENT CLASS
- (4) DELETE CURRENT CLASS
- (5) DELETE SITES FROM CURRENT CLASS

DISPLAY MENU

- (6) DISPLAY CLASS HISTOGRAM
- (7) DISPLAY SITE STATISTICS FOR CURRENT CLASS
- (8) RETURN TO TRAINING MENU

LEVEL 3
MENU

Figure 3. Classification scenario main menu with examples of levels 2 and 3 menus.

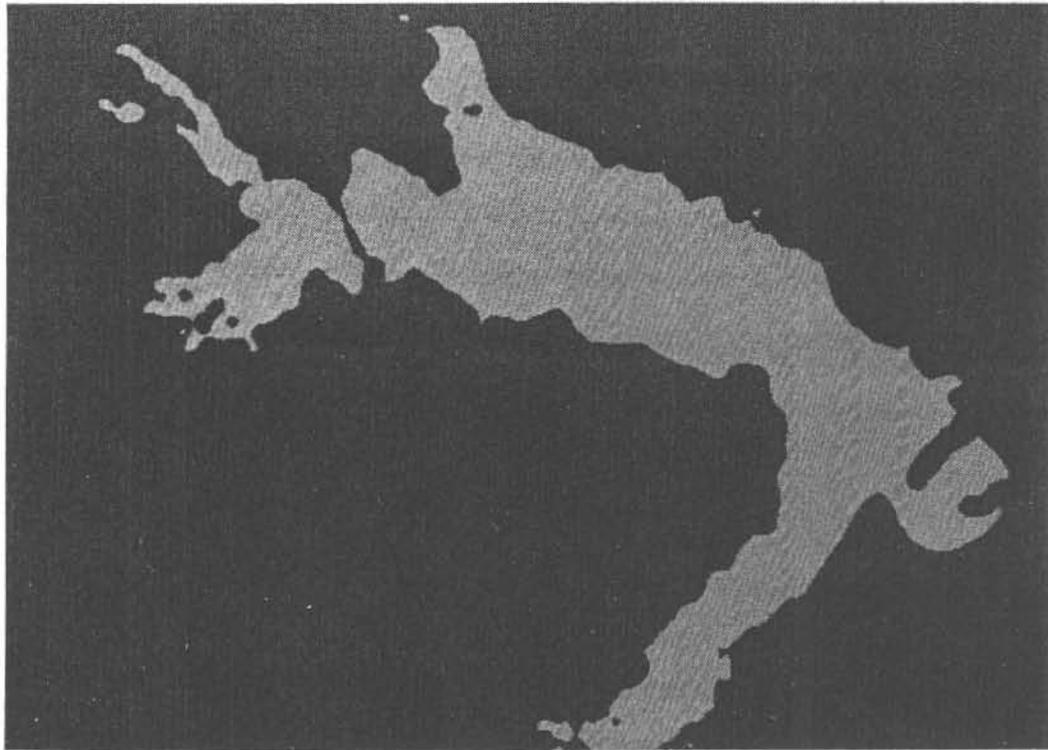


Figure 4. Water class using interpolated pixel values (not the same scale as Figure 5).



Figure 5. Band 7 showing each original pixel as a rectangle of constant density.