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THE LAND ANALYSIS SYSTEM (LAS)

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ABSTRACT

The Land Analysis System (LAS) is an interactive software system, available in the public domain, for the analysis, display, and management of multispectral and other digital image data. The system was developed to support the earth sciences research and development activities at the NASA Goddard Space Flight Center and the USGS EROS Data Center. Initially released in the fall of 1985, LAS provides over 240 applications functions and utilities, a flexible user interface, complete on-line and hardcopy documentation, extensive image data-file management, reformatting, and conversion utilities, and high-level device independent access to image display hardware. This paper summarizes the capabilities of the latest release of the system (Version 5.0). Emphasis is given to the system portability and the isolation of hardware and software dependencies in this release.

INTRODUCTION

The Land Analysis System (LAS) was developed by the Space Data and Computing Division and the Laboratory for Terrestrial Physics at the NASA Goddard Space Flight Center (GSFC) in cooperation with the U.S. Geological Survey EROS Data Center (EDC). The Transportable Applications Environment (TAE) [1,2] is used to provide a standard user interface and a unified environment for function development[1]. The LAS was originally implemented under the Digital Equipment Corporation[2] VMS operating system and installed on several VAX 11/780 computer systems at GSFC and EDC following the successful completion of acceptance testing [3] in August 1985. Since that time, the number of LAS installations has increased to over 80 sites to support research, production and education oriented image processing. A description of the initial release of LAS (version 3.2) can be found in an earlier paper [4].

The immediate objective in developing LAS was to satisfy the image processing requirements as identified by the science user community. The long term objectives were to: 1) develop transportable software that can be shared among government agencies and installed on a variety of computer systems; 2) incorporate a comprehensive user-friendly interface and array of executive services supporting raster data input, management, and display; and 3) provide a reliable, fully documented, and easily supported library of applications software functions that can be combined to support routine operational tasks, while maintaining a flexible environment in support of research for earth science data applications.

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1 LAS and TAE are available in the public domain through the Computer Software Management and Information Center (COSMIC) at the University of Georgia, Athens, Georgia.

2 Any use of trade names and trademarks in this publication is for descriptive purposes only and does not constitute endorsement by NASA or the U. S. Geological Survey.

There is an ongoing effort to further enhance the functionality and utility of LAS, not only through the development of new and enhanced applications functions and system utilities but also through the implementation of LAS on microprocessor based workstations running under non-VMS operating systems. The extension of LAS to the workstation domain provides a number of advantages: 1) allows greater flexibility in the configuration of hardware and software to meet the needs of a particular application; 2) lessens the potential impact of processing resource conflicts on users by placing a significant amount of dedicated processing resource directly under the control of the user; and 3) allows more efficient utilization of the host's computer's resources by distributing highly interactive data capture, display, and analysis tasks to the workstation. Also, the availability of LAS is expanded to a larger number of potential users.

APPROACH

To maximize the portability of LAS it was necessary to minimize and isolate dependencies on specific computer hardware, operating system, and peripheral devices. These portability requirements have had a major influence on the continuing evolution of LAS by dictating the development of highly transportable and functionally modular software as well as the utilization of hardware independent interfaces and integration techniques. The utilization of TAE inherently enhances the portability of LAS, isolating the user from the underlying operating system and assisting the applications programmer by providing such services as a common data interface for terminal access and communication, parameter definition and ingest, message handling, and session logging. In addition, TAE provides considerable flexibility in packaging software to meet the needs of a particular application by providing convenient mechanisms for user menu definition and allowing commonly used functions to be combined into single procedures or "procs." The availability of these services frees program developers from redundant design tasks and simplifies the development and integration of new applications functions.

The three major enhancements to the system which were requested by NASA users [5] will be incorporated in the Version 5.0 release. Details of these enhancements are presented in this paper. Two of the three enhancements are already complete: 1) removal of the file group implementation (in which each band is stored in a separate file) of the multispectral images; and 2) developing a portable implementation of the system. The third enhancement, improved catalog manager performance in file archival and restore, will be completed for the 5.0 release in December 1990.

SYSTEM OVERVIEW

The LAS provides a flexible and comprehensive environment for image processing by integrating the following software system components:

- the TAE user interface that is consistent, flexible, and can be used effectively by both novice and experienced users from an ASCII terminal or by mouse-driven commands on a graphics work-station;
- a comprehensive set of over 240 applications functions for input, analysis, and storage of a variety of digital image and geographic data in raster form;
- a uniform syntax for file naming spanning different operating systems;
- the Display Management Subsystem (DMS) to provide high level device independent manipulation of color image displays and 8-bit work-stations under X-Windows;
- interface routines to support data transfer between the LAS and optional, site-specific external software packages (e.g., geographic data entry and statistical analysis systems); and
- support routine libraries and documentation to facilitate the development of new applications functions.

The LAS is fully documented with hardcopy manuals and on-line help information under TAE. Image history and session logs are automatically maintained at the discretion of the user. Processing history information is maintained for all LAS images and includes image names, applications functions used, and parameter values. The user can elect to add comments to, list or delete records in the image history. The optional session log is kept for interactive sessions by TAE. It is a record of the pertinent user entries, program messages, and results appearing at the user's terminal. The user also has the option to print or delete the current session log before logging off the system. The tabular data interface provides flexibility in that appropriate interface functions may be modified to use different data base management, statistical analysis, and vector data processing systems. In addition, system manager documentation and release notes are provided for installing, running, and maintaining the system.

OVERALL DESIGN ENHANCEMENTS

The current release of LAS contains significant improvements to the previous release (Version 4. 1). The design and implementation of the entire system has been substantially changed while maintaining as much as possible the external appearance, functionality and operability of the original system. Many of the design changes were made in the interest of enhanced hardware and operating system portability. Moreover, the subroutine libraries were redesigned to provide simplified scenarios for applications programmers. The myriad special file formats of Version 4.1 were eliminated in favor of more system uniform file formats. In addition, an effort was made to use the ASCII file format wherever appropriate to allow users to directly create, list, edit or transmit such files over network and other distributed system environments.

A set of LAS coding standards for the C and FORTRAN languages was developed for the development of transportable software. The LAS library of system support routines for disk and tape access and data manipulation, originally written in the VMS MacroAssembler language was rewritten in C. The majority of the system is now implemented in the C programming language although there are still few components of the system written in the standard FORTRAN-77 language. The Image Input/Output subroutines were entirely rewritten to be based on the TAE "xi" image I/O package. A side-effect of this decision is an increased dependence on the port of TAE to a new operating system before LAS can be implemented in that same environment. All bands of an image are now contained in a single file (rather than a separate file for each band as in earlier LAS versions). This configuration allows applications to either process all image bands at once as if the data were stored in a band interleaved-by-line format or one band at a time, as deemed most appropriate and efficient by the applications programmer. Processing all bands at once has significantly improved wall-clock performance benchmarks for most LAS applications.

Image files (denoted by the suffix ".img") have logically associated history (suffix ".his") and data descriptor record (suffix ".ddr") files which are used during image manipulation to determine image size, data-type and other specialized information related to the image. Image geo-referencing is now carried throughout the LAS system by use of new entries in the ".ddr" files. Applications such as TM data magnetic tape ingest, geometric transformation, image concatenation and others now access the new fields in the ".ddr" files created for that purpose. For example, ingest of a TIPS format full scene from magnetic tape now places the latitude and longitude coordinates for the four comers of the image into the disk image's data descriptor record at the time of data ingest. The "lab.lab" file, of the LAS Version 4.1 and earlier, used the VMS exclusive Indexed Sequential Access Method (ISAM) format. This VMS dependency has been eliminated by the image associated files ".img", ".ddr" and ".his".

The Baseline library (i.e., the LAS support subroutines and the applications functions) has been built and tested under VAX/VMS on several different Digital Equipment Corporation computers, and under UNIX-based operating systems on SUN3 and SUN4 work-stations and a Powernode 9050 computer. Specific non-portable software modules are identified for potential users so that estimates of the level of effort required to port to new machines can be made more readily. Areas in which adjustments are known to be required for new system ports are in the area of the magnetic tape support library where operating system interfaces are necessary to manipulate magnetic tape drives and in many C language include files which define constant values such as the maximum and minimum range of values for data types such as float, long, etc.

Such areas as may need modification for untested operating systems are limited to the support software libraries rather than the application functions themselves with the exception of one or two specialized application functions which must behave differently depending on the host operating system.

The Baseline library can be used under any of the above named operating systems. The Contributed library is a collection of unsupported software from the LAS user sites that is available as part of the system release. The baseline version of the release has been configured into four separate directory trees called TAE, World, LAS and DMS. The LAS and DMS directories contain the unique applications and support modules which make up each system. The World directory consists of Applications and support routines which are required by both LAS and DMS users and programmers. This structure was created to avoid maintaining duplicate software for LAS or DMS users who may be interested in installing only one of these systems on their host computer. The TAE directory which is included in the release consists of the latest version of TAE currently installed at the user site and may be upgraded independently of the LAS, DMS, and World directories.

FUNCTIONAL ENHANCEMENTS

User Interface

User access to the LAS software is provided by the Transportable Applications Environment (TAE). The TAE was developed as part of a separate project at GSFC as a generic user interface and Environment for applications programs. The TAE provides: menu or command-driven function selection; an option for interactive prompting of function parameters; on-line help capabilities; interactive asynchronous and batch processing; and access to the host operating system without exiting from TAE. Additionally, users now have the option of using the system via keyboard on traditional ASCII terminals (using TAE Classic) or by mouse-driven commands on graphic workstations (using TAE Facelift).

Under TAE-Classic or Facelift, the LAS functions can be selected from menu screens or by command entry. Function parameters can be specified interactively using the tutor screens or by command entry. The functions can be selected from menus or by command entry and can be executed interactively, asynchronously or in batch mode. In the menu mode a user can search through a hierarchical structured menu tree to locate a specific function. The menu choices are either applications functions, commands, help, or other menus. In the command mode, the user can activate a function by entering its name and the required parameters. Under TAE-Facelift users can select application programs or open help windows for applications via mouse-button clicks. The user may switch from menu mode to command mode at any time during a session and TAE-Facelift users can enable or disable Facelift at any time from command mode. For a more complete description of the TAE see [1,2].

When an application is selected in menu mode, TAE automatically displays the tutor screens to prompt the user for the needed parameters. The user may also enter the tutor screens by typing "TUTOR" and the function name while in command mode. The TAE-Classic user enters values by typing the parameter name and its value e.g., "IMAGE=Harrisburg" and may obtain additional information on any parameter by typing HELP and the parameter name e.g., "HELP IMAGE". Most parameters may be abbreviated to the set of characters that makes them unique, e.g., if no other parameters had "I" as the first letter then "IMAGE" could be abbreviated as "I". Once all required values are given, the user may either execute the function or save the parameter values to a parameter file. The parameter file can be recalled, edited, and used to execute single LAS functions in batch mode. Alteratively, a procedure file can be created using the host editor to execute a series of functions in batch mode.

The TAE-Classic provides a number of additional capabilities that serve to minimize the amount of repetitive typing needed to execute a LAS function: parameters are validated prior to program execution and the user is re-prompted for invalid entries; spectral and spatial subsets can be given as part of the image name; meaningful default values are provided for optional parameters; function sub-commands limit the prompts in tutor mode to only those parameters that are relevant under the selected processing option.

On-line help information is available to describe TAE menus, TAE commands, LAS applications programs, and program parameters.

TAE-Facelift users are able to reduce typing commands to a minimum while retaining the conveniences and functionality of the TAE-Classic mode of operation. By means of mouse-button selections, graphics-workstation users can select parameter options and open several help and utility windows simultaneously while tutoring on the selected application. Input file names and other such entries must still be typed at the keyboard, of course, but the amount of keying is greatly reduced by the ability to select most parameter values from option lists and save or restore parameter selections, run the application and perform other TAE operations by mouse-button clicks alone.

Applications Functions

The LAS includes over 240 applications functions to process raster data in a number of data types, including byte, integer*2, integer*4, and real*4. The documentation for each function includes: revision date, purpose, parameters, algorithm, error messages, examples, prerequisites, processing limits (e.g., maximum image size, number of categories, and data types allowed), and references. The hard-copy documentation is generated from the on-line documentation and is accessible through the TAE help facilities. The original functionality of the LAS Version 4.1 was preserved or enhanced in response to user requests during the implementation of the Version 5.0 technical standards.

File Management

A simplified file management capability has replaced the catalog manager sub-system of the earlier LAS design. This, along with other system enhancements, has reduced the load on system management, run-time resources and wall-clock response time overall. The new system still provides the basic functions of the original system without the overhead in system resources and need for special attention by the system manager. The system now provides: 1) naming conventions that are independent of the host operating system; 2) an alias capability for the abbreviation of file names; and 3) utilities for the archival and retrieval of data files to and from magnetic tape.

Display Management Subsystem

The LAS display application functions use the Display Management Subsystem (DMS) to provide a device-independent interface to color image display devices. DMS minimizes application software dependencies on a particular display device by providing a generic set of image manipulation functions for device allocation, deallocation, and initialization; image transfer and setup; image viewing alteration; cursor manipulation; and image enhancement. At the lowest level, DMS is dependent on the characteristics of the particular display being used. The DMS libraries above this level can be considered to be transportable, meaning they are not dependent on the capabilities of a particular display. This transportability also applies to the display application functions that use DMS. Consequently, when a new display is to be used, only the lowest level, device dependent libraries must be modified. Like TAE, DMS can be used independently of LAS. For a more detailed description of DMS see Perkins et al., [6].

LAS image data can be displayed and manipulated using special hardware features such as panning and zooming. The modified image, image intensity mapping tables or graphics, and annotation information can be saved in disk files for later use. The LAS display functions use the DMS utilities to: allocate and deallocate a display; show display status information; load images to the display; save display images to disk; assign colors to intensity values; apply, modify, save, and restore graylevel and pseudocolor mappings; flicker series of images and look-up tables; perform operations on images including arithmetic, logic, rotations, zoom, and convolutions; define, enable, or disable the cursor, and return intensity values and coordinates at cursor position. The mensuration and graphics display functions allow the placement and editing of points, lines, polygons, and annotation on the graphics planes of the display. These graphics can be associated with a specific image (or image subset), such as training sites for supervised classification.

DMS has undergone extensive modifications with the result that the new subroutine libraries are no-longer compatible with earlier versions. An X-Window version of device dependent software has been developed which allows limited display capabilities on 8-bit graphic work-stations. This capability may be used for quick-look, pseudo-coloring, and control-point selection. The X-Windows device-dependent routines were developed under the MIT X11R3 protocol and are therefore compatible with release 3 and 4 of the X11 software.

The GSFC version of LAS will contain the DMS Version 3.0 as it's display system while the DMS Version 1.2 and earlier will be available from the contributed software library as a part of the release. Display applications will be documented as LAS Display Modules (LDM) in the LAS Version 5.0. The "Umbrella" version of the display applications will be released, however, such that all display modules will be run under a controlling, menu-driven, application module. This scenario provides speed in operation but at the cost of flexibility in inter-mixing DMS and LAS commands. The nonumbrella version of the applications will also be made available to users through the contributed software library. The Display Management Subsystem under TAE provides a high level, device-independent interface to display hardware. DMS uses the low-level libraries for display manipulation as provided by the respective vendors including vendor implementation of the X-Windows graphics protocol. Thus, DMS allows new display hardware to be used with LAS without modification to the applications functions.

Support Routine Libraries

A set of support routine libraries were developed for use by applications programmers. The libraries include: geometric coordinate translation, image input/output, data descriptor record (ddr) manipulation, pixel value manipulation, statistics and magnetic tape I/O, and others. The geometric coordinate translation routines are used to translate coordinate pairs between different map projections. The image I/O functions provide efficient read, write, and update access to image data independent of data type. The data descriptor record manipulation (ddr) functions are used to read, write, or update the LAS image labels. Pixel manipulation functions perform unary (e.g., logarithm), binary (e.g., arithmetic or logical), and miscellaneous (e.g., data type conversion) operations on image lines or line segments. The statistics I/O functions can be used to update, search, and delete information within the hierarchy of the LAS statistics files. A utility library provides miscellaneous capabilities such as for parsing input image names, printing messages to users and others.

CONCLUSIONS

The LAS is used at EDC, GSFC, and over 80 other sites to support production, research, and education oriented image processing and Version 5.0 satisfies the user requirements specified in [5]. The current system design allows the same body of LAS source code to be built (e.g., compiled and linked) under both VMS and Unix-based operating systems. The new release has been tested under the VMS, SUN3, SUN4, Gould Powernode 9050 and IBM AIX operating systems. Dependencies on proprietary software have been removed while system interfaces to statistical and other outside software packages have been preserved. Other enhancements include a simplified file management system, enhanced display capabilities, and operations through mouse or keyboard.

The functional advantages of the current release (version 5.0) can be summarized as follows:

- The system is no longer bound to the VMS operating system. The same body of source code can be installed under VMS or UNIX-based operating systems.
- The Catalog Manager has been removed from the system greatly reducing system overhead and increasing overall response time and replaced by the File Management System which provides a uniform file naming syntax independent of the host operating system.
- Multi-band images have been consolidated into a single file, eliminating the file group

construct of previous versions of LAS.

- Hard copy applications users guides are generated from the online documentation. Online and offline documentation is now identical.
- Single user interface, under TAE independent of the host operating system in which novice users can select functions from menus and be prompted for parameters, while experienced users can select functions and define parameters via terse commands on ASCII terminals or by mouse driven commands on graphic work stations.
- The LAS, DMS, WORLD, and TAE support libraries facilitate the integration of new applications functions.
- The Display Management Subsystem under TAE provides high-level device independent access to image displays and 8-bit workstations under X-Windows.
- Tabular data interface routines in the LAS Contributed Library facilitate data transfer between LAS and site-specific external software systems

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