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THE LULEA IMAGE PROCESSING SYSTEM (LIPS)- A VERSATILE APPROACH TO EARTH RESOURCES DATA PROCESSING

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I.   ABSTRACT

The Luleå Image Processing System is presented in this paper. Some fundamental system design criteria are discussed together with some aspects of the actual implementation. The system is structured in two levels in form of a pseudo-overlay. The layout of the Image Data File is recognized as an integral part of system architecture. A number of major processing tasks discussed in detail.

II.   INTRODUCTION

Earth resources data processing has undergone a rapid development during the last decade. Especially the launch of the series of LANDSAT satellites by NASA has had a large impact on the development of concepts and methods for data processing. Already at an early stage the need for incorporation of automated image analysis systems has been pointed out by the staff of the Laboratory for Applications of Remote Sensing at Purdue University[1]. Some other aspects on the role of digital image processing systems for earth resources studies have been discussed by Landgrebe et al[2] and Phillips and Schwingendorf[3].

A number of image processing systems has been developed during the last two decades. Among those are what could be called the ancestors of image processing systems: VICAR[4] and LARSYS[3,5]. Both of these systems are very elaborate and complete in the sense that they contain an extensive set of basic as well as advanced image processing functions. Unfortunately, at least for users of minicomputers, these systems were designed for and originally implemented on rather large size computers. It is therefore not necessarily a simple task to try to implement these systems on mini-computers. In the mean time a set of image processing computer software has been developed at JPL for a PDP-11, which is known as Mini-VICAR.

There are systems that have been developed for small computers - e.g. KANDIDATS[6]. Another system has been developed by Jensen et al[7] for educational purposes.

There exist a number of image processing systems specifically designed for use with minicomputers. These systems, e.g. IDIMS, M-DAS, MDA etc., usually require the purchase not only of the software but of complete turnkey systems at considerable cost.

This paper will describe a software system which is being developed by the University of Luleå. The need for this development arose from the geographical position of the University of Luleå (1000 km to nearest image processing facility) and the lack of funds to purchase a complete turnkey system. Also, the University owns a relatively large and fast minicomputer of make NORD-10 which is suitable for on-site image processing.

The paper will discuss some of the basic criteria that guided the author in the design of the system. Also some aspects of the actual implementation will be discussed together with a short description of some of the key processors.

III.   SYSTEM DESIGN CRITERIA

The criteria that govern system design are by and large dependent on two factors: the actual hardware configuration and general principles of desired system performance. Another important aspect is a thorough analysis of the future user category of the system.

A. THE LULEÅ COMPUTING CENTRE

The computing centre of the University of Luleå is at present equipped with two computers of make NORD-10. The smaller of these machines is normally used for some administrative data processing and as an intelligent remote terminal to various large computers throughout the country. The larger system is used for in-house processing, both for educational purposes and for research. This system is configured as follows:

CPU Nord-10/S with 192 k 16-bit words solid state memory, 64 k words of which is user adressable plus 2 k words of fast cache memory; 2 disc drives with interchangeable 75Mbyte discs; 2 dual density tape drives for 800/1600 bpi and a maximum forward speed of 75 ips; line-printer (600 lines per minute) and a Versatec electrostatic printer/plotter. The system is operating under the real time operating system SINTRAN III[8]. Various subsystems, including editor and compilers for different programming languages, are available under the operating system.

B. IMAGE PROCESSING PHILOSOPHY

The use of computers in the analysis of images, in particular earth resources images, poses two fundamental problems in systems design:

1. The system must be capable of handling tasks of varying degrees of computational complexity. Possible image processing tasks include such simple tasks like copying parts of an image from magnetic tape to disc and such computationally complex tasks like two-dimensional Fourier transforms or clustering. These facts have already been pointed out by Haralick[6]. To perform satisfactory under these conditions rather complex software structures are required.

2. Especially in earth resources data processing there will be a rather in-homogeneous "user mix". This statement implys that one can expect the knowledge of the user about computers and computer programming to vary from nil to highly advanced. With regard this fact the system should be designed such that even the most unexperienced user can easily communicate with the software without having to learn anything about data processing.

In view of what was said above the following criteria were adopted to guide in the design of the software:

To accomodate the "user mix" the system should be *easy to use* and thus not require any other knowledge about the use of computers than how to logon and to logoff.

The system user should not be hampered by the access to printed manuals. The system should be completely *self-explanatory*. This can be achieved using conversational mode in system initialization or HELP-commands at different levels or a combination of both. The system should provide the user with a concise description of the function of each of the processing tasks and a list of the options available to run a specific task.

It is the authors opinion that an image processing system is never completed. Especially for a system in use at a University or other research oriented facility a system should provide a great degree of *flexibility*. Therefore, the system should be *modular* to enable easy implementation of new processing functions.

The system should be *portable* and *easy to maintain*. This means that the use of low level assembly languages should be avoided as far as possible.

At installations where a dedicated computer system is not available, as is the case in Luleå, the system should be running as a *background program* besides others in a time-sharing environment. Also the system should possess a high degree of *interactivity*.

Even though the usage of CPU time should not be a critical parameter in a research environment, the system should be *reasonably efficient* and insure acceptable turn-around.

Some tasks, like geometric correction of large images, reformatting of images, classification etc. do not require interactivity but an easy to use *batch capability*.

The hardware configuration described above displays a shortage of fast storage. The system should therefore be designed such that *magnetic tapes* are used as *main image storage* medium, with fast disc storage being used for intermediate storage during processing only.

Finally, the system must *accept map-* and other *ancillary data* in order to maximize the value of the information obtained from it as an aid in decision-making processes.

IV. SYSTEM IMPLEMENTATION

A. IMAGE DATA ORGANIZATION

An important part of the system design is the organization of the image data files on magnetic tape. We have chosen the following organization: Any image data file must include four types of records. The first type is a 256 byte header record which conforms to standards adopted by the Swedish Society for Image Analysis to facilitate exchange of image tapes within the country. In this header record we are at present only using the first four words, with the remaining 124 words set blank. There must always be one record of this type.

The second record is a 1000 byte identity record which contains pertinent information about the particular image, e.g., tape number, scene number, number of pixels per wavelength band, number of lines etc. This record is very similar to the ID-record used in LARS multispectral image tapes[5].

Following these two header records there can be an arbitrary number of records of variable length (maximum 2048 bytes) which contain the processing history and other information about the image in ASCII. The information in the history record consists of such information that is automatically written by the system during creation of a new image and of information which the user has input from the terminal.

The fourth record type, finally, contains the image data itself. Image data is stored in variable length records (maximum 4096 bytes), beginning with the line number (2 bytes), a control word (characters 'AA' in ASCII) and then the pixel values in line interleaved format. Only one format is permitted - grey scale values can only be quantized in the range from 0 to 255 and each pixel is represented by one byte.

This organization of the Image Data File makes it possible to treat any type of two-dimensional "grey-level" data as an image. Thus, an aerogeophysical map or a topographic map, soil or climatic information can be treated easily by the same processing functions.

B. SOFTWARE ORGANIZATION

The software is organized in two levels:

1. a control program (LIPS), with which the user interacts by means of command strings of length one to four words in plain English and

2. processing level programs which are invoked by the control program. The processing level programs communicate sith the user via a question- and answering scheme. Most answers preprogrammed with default values which are activated by a 'carriage reurn'.

The organization into control- and processing level simulates a conventional overlay, but it has theadvantage that the whole core memory space can be used for processing. Especially on minicomputers with restricted core memory this is of great value. A disadvantage in this structure lies in the fact that certain support routines have to be included in the generation of each of the processor modules. As each of the processor modules is a self-contained, independent unit it is possible to execute them individually without ever entering the control module. A check is made at the beginning of a processor if entry is from the control module or direct. At exit appropriate action is taken to either return to the control program or halt all processing.

The Control Module. The control module is the main interface between the processing level routines and the user. The control module provides all processing commands and five special commands. These commands are:

HELP - lists all available commands on either terminal or line-printer.

CATALOG - gives access to the image catalog file and can be used to check such information as tape number, scene number, image coordinates and so on.

DESCRIBE - provides for a description of a particular or all processing functions. The description can be obtained either in short format - i.e., not longer than one sentence - or it can be obtained in long format, containing a verbal description of the processing function and some of the options that are available.

NEWS - the command is used to check whether a file containing system news exist or not. If the file exists its contents will be displayed optionally on either the terminal or the line-printer. It is the responsibility of the LIPS system programmer to create a news file whenever any significant changes to the system have been implemented or when new processing functions have been added. The news file should be deleted after approximately one week.

EXIT - halts all processing.

Furthermore, the control module loads the processing module associated with a certain command and starts processing. A schematic view of the flow of control in the control module is given in Figure 1.

The Processing Modules. There is at present about 25 commands available in LIPS. After control has been passed from the control program to the processing level we have tried to adhere to certain standards with regard to processor organization and initialization of parameters. Throughout all processors it is a rule that only very little processing be done in the main program. Also, all input from the terminal is collected in one subroutine. In this subroutine all error checking on parameters is also performed. A schematic picture of the program flow in a 'normal' processor is given in Figure 2.

A complete list of the processing functions presently available is given in Appendix 1. We will restrict ourselfes here to discuss only a few of the processors in detail.

Preprocessing. Some of the LANDSAT images, especially early images, exhibit distortions in the radiometric quality of the images at regular intervals. This phenomenon is usually known as six-line striping. It has been established by Bernstein[9] that even sophisticated methods of correction do not completely remove striping effects. We have therefore chosen a simple method. Before reformatting the histograms of the different detectors are computed. A correction matrix is then established manually just in order to apply an additive correction to each of the detectors to equalize channel means. The six-line histograms are computed using the command LANDSAT-DETECTOR-TEST and the correction is applied in the reformatting processor, command REFORMAT-LANDSAT-IMAGE.

Hardcopy Image Output. We have put considerable emphasis in Hardcopy Image Output. The user can choose between shade-prints on a line-printer using either sympols or overprinting. There is also a possibility to obtain hardcopy from the Versatec plotter using integer dither matrices of size 4x4, 8x8 or 16x16[10]. This processor, PRINT-IMAGE, is one of the few with double function. As a histogram of the image has to be computed for display purposes it seemed unnecessary to create a separate processor for histogram computation. When the command

HISTOGRAM is issued the same processor is invoked.

Another possibility for hardcopy output is given through the command COLOR-IMAGE. Here optionally a pseudo-color image is created of one spectral band or a composit color image using three spectral bands. The hardcopy image is created using integer dither technique on an ink-jet color plotter.

Orthogonal Transforms. Three different types of transforms are possible at this moment - Fourier, Walsh-Hadamard and Haar transform. In the first mentioned real or complex images can be used. The heart of the processor is a fast matrix transpose algorithm developed by Eklundh[11]. Included in the processor are possibilities for filtering in the frequency domain etc. All three transforms are performed by the same processor, which is invoked using different commands (see Appendix 1).

Geometric Correction. At present there is no algorithm for precision correction of LANDSAT images using ground control points implemented. Geometric Correction is performed using a crude method described by Anuta[12]. The method has worked well for LANDSAT images taken at latitudes common to the Unit States. As we do have to rotate the images about twice the angle at 65° N as is necessary at 40° N we have to investigate yet if the accuracy provided by the method can be considered acceptable at least in every day use.

Classification. The command CLASSIFY-PIXELS will invoke a multispectral classification algorithm designed according to the method given by Eppler[13]. The Table Look-up approach was chosen as it has proven to give good classification results and is superior in efficiency as compared with a conventional Bayes classifier.

Estimation of Statistical Parameters. Means and covariance matrices for surface cover types can be computed using the command STATISTICS. Coordinates for one or several rectangular windows can be supplied by the user either through the terminal or from a disc file that has been prepared in advance. The histograms for each class and each channel used are printed. The histograms can be made unimodal by - using trial and error - thresholding away outlying points in one channel for each class. Thus, the final windows will not necessarily be rectangular and they can even have holes. An alternative method to estimate class-statistics is available

by use of the command CLUSTER. This command can be used to either cluster given data of one class into several subclasses or to partition a certain set of data into different ground cover classes based on minimum euclidian distances from given cluster centers. The clustering algorithm implemented is a variation of the ISODATA-algorithm developed by Ball and Hall[14]. Due to limitations in computer memory space our implementation is not only heavily compute bound but also I/O-bound as image data and cluster assignments are stored in random access memory.

C. LIPS AND THE DESIGN CRITERIA

In section II we have established a number of design criteria for the system. In the following paragraphs we would like to discuss these criteria in view of the actual system implementation.

The use of command strings at the control program level and the conversational modeused in the processing level functions insures, together with a multitude of default options, ease of use.

The existence of the HELP and DESCRIBE commands at the control level and the conversational mode satisfactorily fulfill the criterion that the system should be self-explanatory. One could wish for further provisions of explanations in the processing functions, but this would rapidly increase system complexity. The system is flexible in that it permits a multitude of different processing options inside each of the processors. The pseudo-overlay structure also makes it easy to add-on new processing functions.

The software is almost completely written in FORTRAN, which provides for portability and ease of maintenance. Ease of maintenance is further supported by the fact that all variables have names relevant to their meaning and that comments are used excessively throughout the software. Less than one percent of the system is written in assembly language. The system is presently installed as a background program. Both the operating system of the host computer and the system features give good interactivity.

At this writing there is not yet implemented a capability for preparing batch jobs inside the system. It is not very difficult though to prepare batch input files using the system manual and the batch capability provided by the computer. The drawback is, that this procedure requires some basic knowledge about the operating system of the NORD-10.

A user with very little knowledge will therefore not be able to use the existing batch capability.

Despite the fact that FORTRAN is the major programming language used the efficiency of the software is satisfactory. In some cases, e.g. geometric correction, we use fast random access memory as image storage medium in order to avoid time consuming movements of the input magnetic tape. For a similar reason, random access memory is used in the orthogonal transform processor. Else, all permanent image data is stored on magnetic tape in the format described in section IV A.

It is also obvious from the description of the data file organization that digitized maps and other two-dimensional discrete information can easily be uses as a complement to image data proper.

We can thus conclude that the system design criteria have been closely followed for the implementation.

V. OUTLOOK IN THE FUTURE

The system is at present being made available to users at the University of Luleå. Hopefully this will result in the implementation of new processors for image processing tasks even in other fields than earth resources data analysis.

Furthermore, the system will be expanded in the near future with a Color Digital Display System and thus give us the possibility to provide the user with real interactivity. Also, not in all cases are images readily available in digital form suitable for use in automated analysis. It is our hope to be able to complement the system with some kind of image reading device so as to further enhance its versatility.

In the mean time, we will proceed testing the system and try to get rid of any error that may have been overlooked in the testing phase.

VI. ACKNOWLEDGEMENTS

APPENDIX 1

Commands available in LIPS:

    HELP
    DESCRIBE
    NEWS
    EXIT
    CATALOG
    COPY-STRIP-TO-DISC
    DUMP-STRIP-FROM-DISC
    DUMP-STRIP-FROM-TAPE
    PLOT-A-LINE
    PLOT-A-COLUMN
    DUPLICATE-A-TAPE
    HISTOGRAM
    PRINT-IMAGE
    COLOR-IMAGE
    PRINCIPAL-COMPONENT
    FAST-FOURIER-TRANSFORM
    WALSH-HADAMARD-TRANSFORM
    HAAR-TRANSFORM
    SPATIAL-FILTER
    DETERMINE-LINEAMENT
    PRINT-LINEAMENT
    CLUSTER
    STATISTICS
    CLASSIFY-PIXELS
    REFORMAT-LANDSAT-IMAGE
    GEOMETRIC-CORRECTION
    LANDSAT-DETECTOR-TEST

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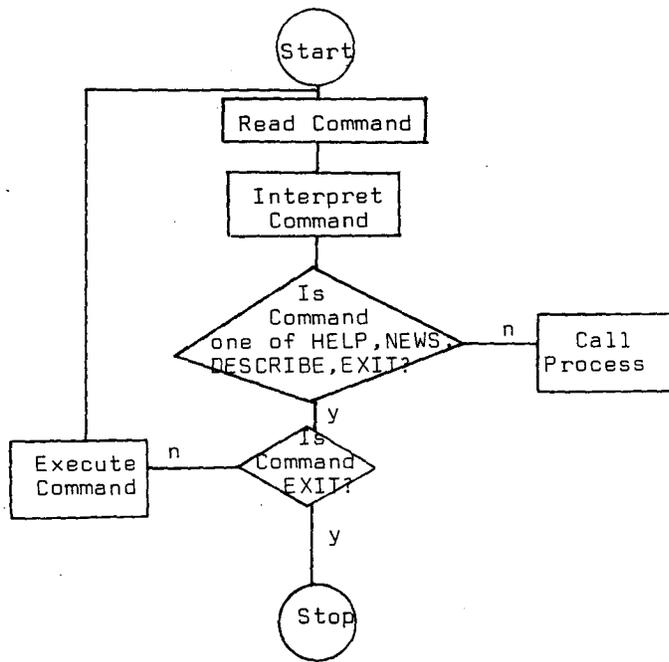
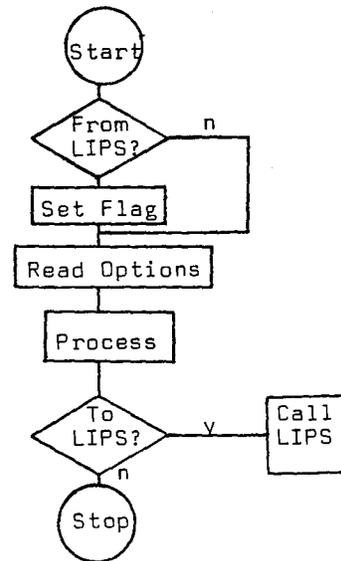Figure 1. Simplified flowchart for LIPS control module.

Figure 2. Schematic flowchart for arbitrary LIPS processor module.

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