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THE ROLE OF COMPUTER NETWORKS IN REMOTE SENSING DATA ANALYSIS*

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I. ABSTRACT

It has been hypothesized that computer networks can be used to make data processing facilities available to the remote sensing community both quickly and effectively. An experiment to test this hypothesis is being conducted by the Laboratory for Applications of Remote Sensing at Purdue University, with the participation of potential users at several remote sites. Initial indications have been highly favorable, although final evaluation awaits further experience and the accumulation of usage data.

II. INTRODUCTION

For remote sensing data analysis, a time sharing computer network offers several potentially significant advantages over dispersed, unconnected computer facilities. In order to evaluate the merits of such a computer network, the Laboratory for Applications of Remote Sensing (LARS) at Purdue University, under the sponsorship of NASA, has established a prototype remote sensing data processing system consisting of a central computer located at LARS and terminals located at organizations concerned with remote sensing. This paper discusses the rationale for such a system and some of the details of a project designed to provide an indication as to how computer networks might be used in the future to provide data analysis facilities to geographically dispersed users of remote sensing data.

One could consider a wide range of network configurations involving terminals with various levels of intelligence, each configuration having its peculiar advantages. For the purposes of this paper, however, attention is limited to a network consisting of a central computational facility and essentially nonintelligent teleprocessing terminals. The central computational facility is assumed to include the remote sensing data library. Each remote terminal consists of a typewriter, punched card equipment, and a line printer.

III. RATIONALE

One of the significant advantages of computer networks is the ease and speed with which the data processing capability can be made available to a dispersed community of users. Once the central facility is established together with the teleprocessing protocols, it is a relatively simple matter to add more terminals when and where needed. Furthermore, the capability can be made available in each user's shop, which provides for more frequent and more effective use of the facility.

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In general, if a relatively large and complex data processing capability is involved, it is less expensive to bring this capability to multiple sites by means of a remote terminal system than to replicate the central processing facility at every location where the capability is required. Looking at this from a different viewpoint, for a given level of expenditure which is available to provide data processing facilities at a number of sites, the remote terminal system allows the "lion's share" of the resources to be devoted to the central processing installation. This may make it possible to take advantage of economies and efficiencies of scale, increasing the power and sophistication of the processing capability available to all users.

Under this system configuration, the software is also centralized, thereby eliminating the need for the time-consuming and expensive dissemination and updating of many copies of software.

The principal form of data, in this case digital remote sensing imagery, is also concentrated at the central computer facility, which simplifies both the transmission and storage requirements. The centralized data facility can provide a much broader selection of data to the users on the system, which is particularly advantageous if the data are being used for research purposes.

Another characteristic of the remote terminal system results from the commonality of formats for data and results, terminology, processing algorithms, etc. In a very real sense, the users of the system are provided with a common data processing language dealing with the technology with which they are all concerned. It could be argued that this might lead to a narrowed view of the research problem and hence tend to stifle innovative research. However, the degree to which this might occur must be weighed against the advantages already mentioned and in addition the ease of communication and training which accrues from such a systematization. The rate at which new users can be put "on the air" and the rate at which new technology can be broadcast to all users of the network can be dramatic. Furthermore, the improved communication can be stimulating in itself.

IV. THE REMOTE TERMINAL PROJECT

Recognizing the particular applicability of the above rationale to the remote sensing research problem (including research into data processing systems for operational remote sensing data analysis), NASA approved and funded, beginning in 1970, the establishment of an experimental remote terminal system centered at LARS/Purdue. Specifically, the goals of the remote terminal project are to (1) investigate the feasibility of processing remote sensing data at field locations (as opposed to at a large central facility); (2) evaluate the remote sensing data processing technology developed at Purdue; (3) provide a training facility to potential remote sensing researchers and users; and (4) facilitate the communication of new remote sensing technology to remote sensing researchers and users.

HARDWARE AND CONTROL SOFTWARE

The remote terminal system on which the project is being carried out consists of an IBM System/360 Model 67 computer, operating under two time-sharing-oriented software systems: Control Program 67 (CP-67) and the Cambridge Monitor System (CMS). The hardware configuration (Figure 1) includes a central processing unit with a half million bytes of memory, a magnetic drum with 4 megabytes of storage, nine 1600 bpi tape drives, unit record equipment, and a transmission control system for supporting the remote terminals. The remote terminal equipment at each site includes a typewriter and a teleprocessing unit consisting of a medium speed printer and a card reader/punch. Communication is by means of dedicated voice-grade telephone lines with phase-delay compensation (studies have shown that dial-up lines are not economical under the expected level of system use).

CP-67 is a resource-sharing control system supporting each user with a "virtual machine" and "virtual memory". Each "virtual machine" is controlled by the CMS operating system which directly supports the remote sensing data processing software.

SOFTWARE

Software support for remote sensing data processing is provided by LARSYS (Phillips, 1973). LARSYS is a multi-image data analysis system consisting of eighteen processing functions which provide facilities for operating on multispectral and/or multitemporal image data. The primary inputs to the system are digital data resulting from measurements recorded by airborne and spaceborne multispectral sensor systems, and control instructions provided by data analysts.

The utility of the system as a research tool is enhanced by modular program structure, uniform data and control interfaces between processing functions, and simplicity of program control. The implementation of LARSYS on a general purpose computer with time-sharing and remote terminal support greatly increases the accessibility of the system to a wide community of users interested in both development and application of the remote sensing data processing technology.

The processing functions may be broadly categorized as serving three purposes: (1) utilities for manipulating and maintaining data and results files; (2) data display and evaluation facilities; and (3) algorithms for data analysis. The data analysis algorithms are based on pattern recognition methods utilizing statistical decision theory.

Great attention has been paid to the interface between LARSYS and the user. To begin with, an easily learned command language makes use of meaningful English words and a simple, uniform instruction syntax. Ordinarily, the instructions are punched on cards, although they may also be input directly from the terminal typewriter or disk files. Extensive facilities for error checking and error recovery are provided, both to minimize user frustration and to prevent the loss of intermediate analysis results.

Three modes of operation are available to the remote terminal user. He may operate LARSYS on-line in the "interactive mode"; submit jobs to be run in "batch mode"; or combine the best of both approaches by beginning his job in "interactive mode" and then allowing his job to run unattended to completion in "disconnect mode". These operating options not only make for increased user convenience, but tend to optimize the utilization of the remote terminal system resources, thereby enhancing its cost-effectiveness for remote sensing research and development.

EDUCATIONAL FACILITIES

One important step that can be taken in the direction of achieving a high usage rate is to provide an efficient mechanism for educating people in the use and capabilities of the computer network and its associated software. The educational challenge is one of providing materials which are geared to individual or self study and which are essentially self contained, i.e., they do not require the frequent intervention of a highly trained instructor. A high priority was placed on designing materials for individual study, as it was felt that this would be the most likely situation encountered in practice. One would expect to have only two or three people making initial use of the terminal. As their skills improved, other workers would be expected to join the effort. Students would be starting at random times and, depending on their backgrounds and other duties, would progress at different rates.

To meet the educational challenges presented by the remote terminal project, a series of mini-courses have been prepared (Figure 2). A mini-course is a set of instructional materials designed to take a student from an initial point, defined by the prerequisites of the mini-course, to an end point defined by the instructional objectives of the mini-course. Each mini-course provides a mechanism for information transfer, an opportunity for the student to practice or study the skills or ideas presented, and a problem or test situation so that the student can determine whether or not he has met the objectives of the mini-course.

A variety of media (Figure 3) are employed in the educational package depending upon the nature of the material and the objectives of each of the mini-courses. Decisions as to the best media to use were made after the instructional objectives of the unit were defined. Reinforcement of certain concepts may be found interwoven throughout the series of mini-courses. Examples are the multispectral concept, the fact that the classification algorithms are based upon a multivariate statistical approach, and the fact that ground cover classes of economic interest may not necessarily be spectrally distinct.

Another key to the success of the education effort is the concept of a "site expert". One or two people from each remote terminal site spend anywhere from several days to several weeks at LARS. While at LARS they have the opportunity to go through the training materials while working with a terminal identical to the remote site terminal. They also have an opportunity to observe operations in the computation center. The insights gained through this latter experience are invaluable in explaining to their colleagues at home the significance of various messages received at the terminal.

V. STATUS OF THE PROJECT

The central processing facility was established at LARS in early 1971, and has been gradually upgraded so that in its present configuration, it can support approximately ten terminals. A prototype remote site installation has been operating since late 1971 in a building a short distance from the central facility near the Purdue campus. This installation, used by LARS personnel for remote sensing research, has demonstrated the basic suitability of the hardware and software for supporting the remote terminal project. In late 1972, truly remote terminals were put on line (Figure 4) at Goddard Spaceflight Center in Greenbelt, Maryland, and at the Johnson Space Center near Houston, Texas; a third remote terminal at NASA's Wallops Island center in Virginia is expected to be operational by October 1973.

At this writing, it is too early to draw conclusions with regard to the degree to which the experiment objectives are being met. The outlook is already optimistic, however. More than 100 personnel have been trained using the remote terminals and are actively using the system for remote sensing data analysis. The users have indicated satisfaction with the educational materials and with both the hardware and software systems.

The "site expert" concept has proven an important one. One of the remote sites has had personnel for providing educational guidance and operational assistance much more readily available than at the other sites. As a consequence, the terminal at the former site has been utilized far more heavily and with fewer user-contributing problems. In fact, where such support is available to the terminal users and demand warrants, it appears reasonable to add a second typewriter to the remote site configuration, thereby allowing two users there to have simultaneous access to the system (the card/printer hardware can be shared; no additional phone lines are necessary). As long as the central computational facility is not overburdened, this can only increase the cost-effectiveness of the remote operation.

Experience and usage data accumulated on this system during the coming months will provide a definitive indication as to the role computer networks may be expected to play in future operational systems for remote sensing data analysis.

REFERENCE

Phillips, T. L., ed., "LARSYS User's Manual" (3 volumes), Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana, June 1973.

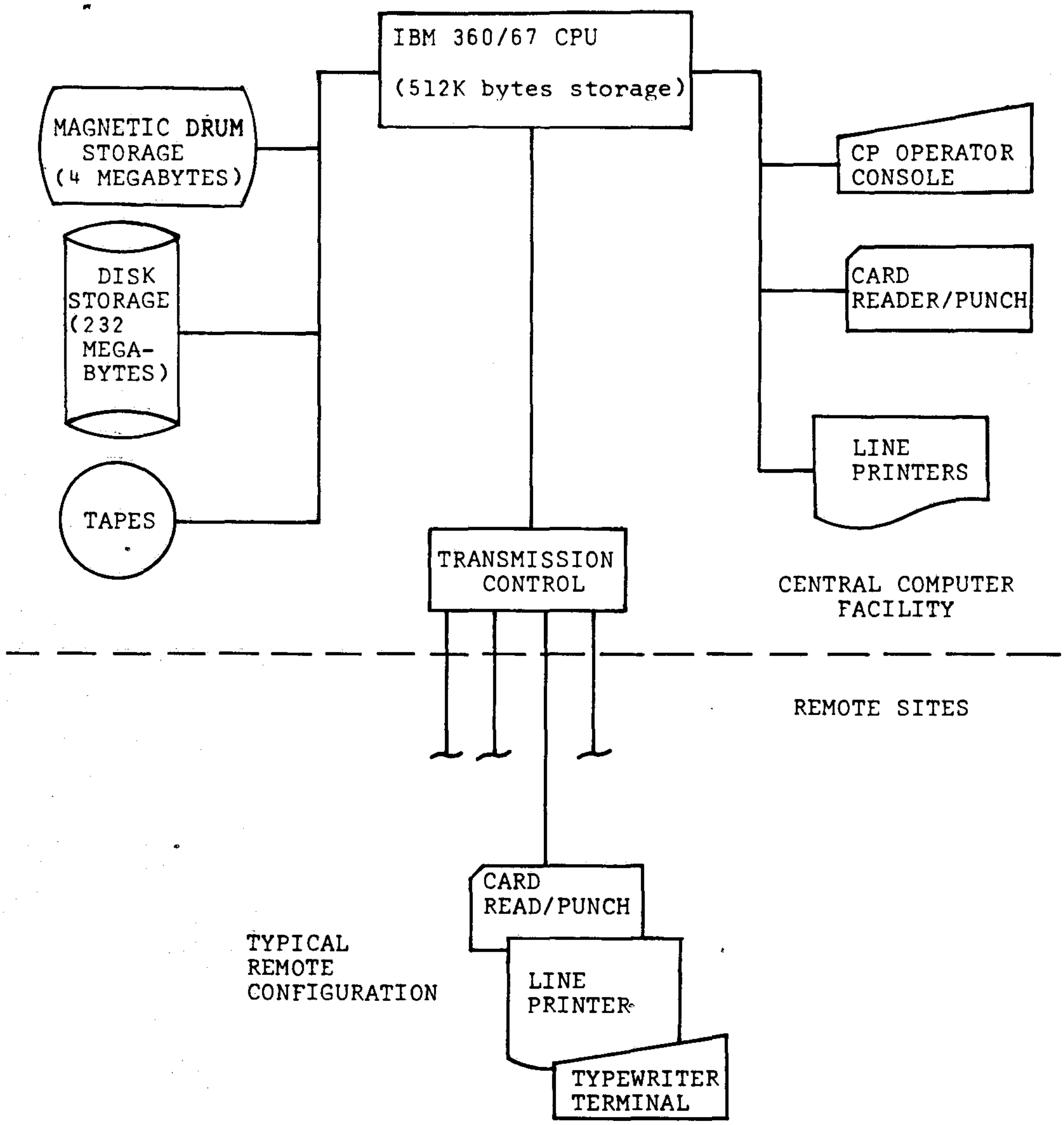

Figure 1. The System Hardware Configuration.

Title: Remote Sensing Analysis: A Basic Preparation Summary Objectives: Vocabulary building, orientation to remote sensing principles and pattern recognition ideas. Study time estimate: 4 hours	Programmed Text
↓	
Title: The LARSYS Software System - An Overview Summary Objectives: Orientation to software capabilities and following thru a typical analysis sequence Study time estimate: 2 hours	Illustrated Audio Tape
↓	
Title: Demonstration of LARSYS on a 2780 Remote Terminal Summary Objectives: Orientation to terminal hardware, terminal procedures. Study program output Demonstration time estimate: 1.5 hours Study time estimate: 1 hour	Demonstration by Site Expert
↓	
Title: How to use the 2780 Remote Terminal - A "Hands-On Experience" Summary Objectives: To transmit cards, receive punch and printer output, run a LARSYS program when given the control card decks. Preparation time estimate: 1.5 hours Estimated time at computer terminal: 2 hours	Self-Guided Session at the Terminal
↓	
Title: LARSYS Exercises Summary Objectives: Practice in using the terminal, writing and executing simple LARSYS processing runs. Time estimate: 6 hours	Short Problems in Terminal Use
↓	
Title: Guide to Multispectral Data Analysis Using LARSYS (with accompanying Example and Case Study) Summary Objectives: Analysis sequence philosophy, a detailed example and an analysis case study. Study time estimate: 10 hours Case study time estimate: 20 hours	Text, Exercises and a Case Study Problem

Figure 2. The LARSYS Educational Package.

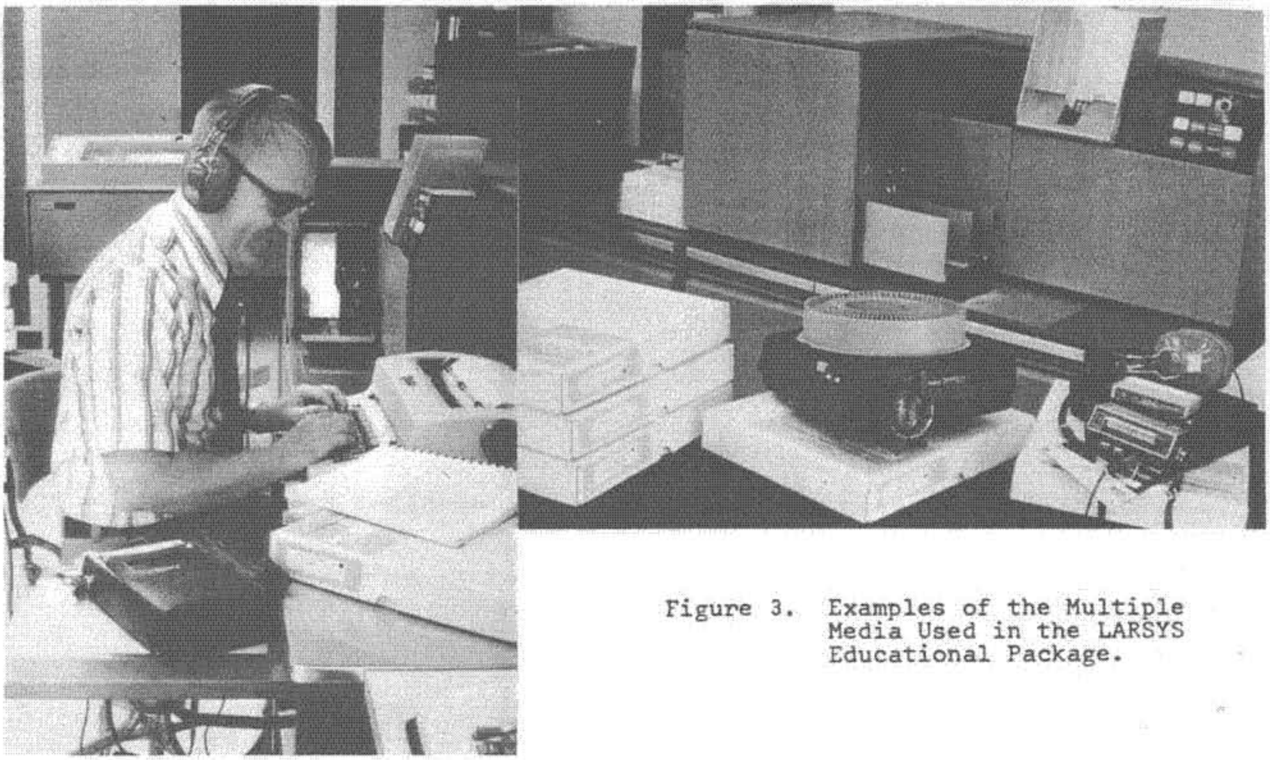

Figure 3. Examples of the Multiple Media Used in the LARSYS Educational Package.

Figure 4. Remote Terminal Network Centered at LARS/Purdue.