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FY73 LARS PROJECTS

BY

THE LARS STAFF

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LABORATORY FOR APPLICATIONS OF REMOTE SENSING
WEST LAFAYETTE, INDIANA

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MAJOR MILESTONES OF RESEARCH
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Year	Major Thrust	Data Collection	Data Processing	Applications
1964	Feasibility Studies	Multispectral Camera (Aircraft) U. of M.	Photo Interpretation of Spectral Patterns	Identification of Natural Signature
1965	↓	DK-2 Laboratory		Laboratory Signature
		Definition of Single Line of Sight Scanner		
1966	Definition of Approach	Multispectral Scanner (Aircraft) U. of M.	Multi-level Slicing and Classification of Crops	Field Patterns
	↓	Slow Scan Field Instrument		
1967	Development of Approach	Calibration Techniques Definition	LARSYS Version 1	Crop Classification 5 square miles
	Over Increasing		Data Registration 1	
1968	•Areas		Feature Selection	Soils Classification
	•Disciplines			Water Quality Analysis
	•Techniques			
1969		Multispectral Camera (Spacecraft)	LARSYS Version 2	Crop Classification 10,000 square miles
			Data Registration 2	ASCS Program Definition
			Sample Classifier	Urban
1970	↓		Data Compression	Wheat Yield
		Single Line of Sight Scanner	Clustering	
1971	Test of Developments	Fast Scan Field Instrument	Operational Processing	Corn Blight Watch
			Remote Terminal Experiment	
1972	Improvement of Techniques			
1973			LARSYS Version 3	

I. APPLICATIONS TO HYDROLOGY, GEOLOGY AND GEOGRAPHY

WATER RESOURCES

Objective: Analysis of remote sensor data to determine the capability and reliability of water resource mapping.

Significance: Information on water resources is becoming increasingly important as more of this scarse resource is required. Remote sensing is a potentially valuable tool for obtaining this information on the location, quantity, and quality of water resources. The detection of chemical and thermal pollution is important to both public and private sectors of the economy.

Accomplishments: The locations of rivers, lakes, ponds, and streams have been mapped using ADP techniques on multispectral data. Development of a capability to calibrate thermal scanner data has facilitated the detection and mapping of small differences in water temperatures.

Future Prospects: Further development of capabilities in this area are expected to include classification of streams as a function of turbidity and correlation of spectral response with the amount of suspended solids.

Key Personnel: R. M. Hoffer, Associate Professor, Department of Forestry and Conservation.

GEOLOGIC FEATURE RECOGNITION AND MAPPING

Objective: Analysis of scanner data and digitized photography to determine rock type and geologic structure and relating this to general geologic mapping and to specific aspects of economic mineral deposits.

Significance: Applying the developing LARS analysis techniques to geologic studies allows us to determine the applicability of this automatic data processing to identifying types of unconsolidated and bedrock materials. Economic potential is enormous as ore deposits, sources of ground water, construction materials, etc. may be located in this way. Geologic material recognition is closely related to earth resources inventory and conservation.

Accomplishments: Several rock types have been identified and ground observation data extended by this analysis. Major structural trends such as faults have been indicated; one set is not shown on the existing geologic map and is yet to be verified in the field. The complicating effect of increased topographic relief on mapping techniques has been demonstrated.

Future Prospects: A combination of visible, reflective IR and thermal IR imagery over areas of known geologic conditions will facilitate the understanding of spectral properties of rocks and identification of rock type. Additional investigations into the effects of mineral composition and rock texture on spectral properties will improve the capability to identify rock types.

Key Personnel: Don Levandowski, Associate Professor, Department of Geosciences. Ray Frederking, Instructor, Department of Geosciences

FOREST AND WILDLAND RESOURCE INVENTORIES

Objective: Analysis of remote sensor data to determine the capability and reliability of forest and wildland cover type mapping.

Significance: Applying the LARS analysis techniques to forestry and wildland studies enables a determination of the applicability of these techniques to identifying and characterizing forests and wildlands.

Forest and land managers currently rely on aerial photography and field surveys to map and evaluate existing forest resources. Resource surveys are of paramount importance to ensure that a sufficient resource base exists to meet increasing demands for wood and fiber products. Since forestry involves management of extensive areas and has a very small margin for profit, there exists a need for inexpensive inventories of the forest resources over large geographical areas. Automatic data processing of remote sensor data offers a potential for meeting this need.

Accomplishments: Forests and wildlands have been identified from high altitude photography and multispectral scanner data. Key problems have been identified and efforts to solve them are underway.

Future Prospects: A capability to distinguish between coniferous and deciduous forest from other cover types will be developed. Area measurements will be incorporated into the analysis system.

Key Personnel: R. M. Hoffer, Associate Professor, Department of Forestry and Conservation.

R. P. Mroczynski, Professional Staff, Forestry

F. E. Goodrick, Professional Staff, Forestry

ATMOSPHERIC EFFECTS

Objective: To study the effect of atmospheric conditions upon aircraft and satellite remote sensing data and to apply the results of this study to the development of data correction algorithms.

Significance: Atmospheric corrections of remotely sensed data should enable detection of second order effects that might otherwise be obscured by atmospherically induced anomalies. Such a system makes usable a much wider variety of data than is frequently obtained under marginal weather conditions.

Accomplishments: A program which accounts for the scattering of under-aircraft haze layers has been developed and is being implemented. Correlation of radio-sun data and meteorological satellite data with atmospheric modelling studies is underway to develop a general atmospheric correction model of remotely sensed data.

Future Prospects: Results to date indicate that an easy-to-use software system to correct for atmospheric effects in both aircraft and satellite data is possible and should be developed.

Key Personnel: Jerald Jurica, Geosciences

II. SCIENCE, RESEARCH AND TECHNOLOGY

APPLICATIONS TO AGRICULTURE

LAND CLASSIFICATION AND SOILS ANALYSIS: LAND CLASSIFICATION

Objectives: The objectives are to

1) Produce useful soil and land classification maps by automatic processing of remotely sensed multispectral data;
2) Develop methods for utilizing these soil and land classification maps to supplement, implement, and replace conventionally produced maps to the extent possible;
3) Develop methods for utilizing computer-produced soil maps to increase the accuracy and speed of producing conventional soil maps;
4) Develop integrated land resource information systems which can be utilized by land use planners, industrialists, agriculturists and others in making wise land use decisions;
5) Cooperate with USDA personnel in the Indiana Soil Conservation Service in developing methods for updating the State Conservation Needs Inventory.

Significance: In the past 25 years many American cities and suburban areas have doubled or even tripled in population, creating an intense competition for space. As a result of this competition, subdivision developers, industrialists, transportation experts, recreation planners, agriculturalists and others have turned to the land use planners for help in making decisions regarding optimum allocation of the land resource for various uses. This decision-making process requires timely and accurate information regarding the current land use, and requires detailed knowledge of the capabilities and limitations of the land resource.

This information can then be combined with socio-economic factors for locating transportation systems and other public utilities. Sanitarians can also utilize current land use and land resource information to locate areas which are potential health hazards.

Accomplishments:

1. Developed a procedure for reliably classifying land areas into two categories without the aid of ground observations.
2. Produced multispectral maps from aircraft data which reliably delineated several soil types as mapped by conventional soil survey procedures.

Future Prospects: Using ERTS-1 data LARS will produce spectral maps of one or more counties which do not have conventional soil maps available and work with Indiana Soil Conservation Service state Soil Scientist and his staff in evaluating the usefulness of these maps in making land use decisions.

Spectral maps will be produced for one or more Indiana counties in which a cooperative soil survey is presently underway. These will be evaluated as to their utility as an aid to conventional mapping. Negotiations are presently underway to develop a cooperative project with the Marion County Planning Commission to evaluate the usefulness of remote sensing inputs into land use decision making.

Key Personnel: Marion F. Baumgardner, Associate Professor, Department of Agronomy

Jan E. Cipra, Research Agronomist

Stevan J. Kristof, Research Agronomist

LAND CLASSIFICATION AND SOILS ANALYSIS:

PHYSICAL AND CHEMICAL PROPERTIES OF SOILS

Objectives: The objectives are to determine the effects of physical and chemical properties of soils on spectral properties of soils and vegetation.

Significance: Establishment of such relationships facilitates recognition and mapping of physical and chemical properties from spectral data. These physical and chemical properties are dominant factors affecting the agricultural productivity potential of soils.

Accomplishments:

1. Found organic matter content to have an overriding effect on spectral response of soils and predicted organic matter content of soils from spectral measurements.
2. Developed a method for calibrating aircraft scanner data and successfully applied it to detection of variations in vegetation density.
3. Developed a procedure for improving the accuracy of recognizing Southern Corn Leaf Blight from spectral response as measured using an airborne multispectral scanner.

Future Prospects: In future research LARS will improve the capability to recognize crop and soil conditions entirely from spectral characteristics, that is, without the aid of ground observations at or near the time of flight. Some conditions which should be discriminable are severe nutrient deficiencies, some crop diseases, surface moisture content of soils, and surface roughness of soils. Detection of these conditions will be facilitated by comparison of spectral response over time and by results of experimental field research.

Key Personnel: Marion F. Baumgardner, Associate Professor, Department of Agronomy

Jan E. Cipra, Research Agronomist

Stevan J. Kristof, Research Agronomist

Forrest E. Goodrick, Research Forester

CROP PRODUCTIVITY INVESTIGATIONS

Objectives: The objective of crop production research at LARS is to develop a capability to effectively use remotely sensed data for making crop production estimates. The effort includes work on (1) the identification of crops and measurement of their acreage and (2) characterization of the condition and probable yield of crops using remotely sensed data. Current research projects include:

(1) Determination of the amount of spectral variation among and within crop types over a large area where different soils, weather, and management practices exist. Such information is essential to the design of ground data collection systems and will provide a measure of ultimate performance of remote sensing crop identification systems since spectral variability is the key to correct identification.

(2) Development of a statistical sampling model and analysis of ERTS-1 for making crop acreage estimates. The use of a sampling scheme is more efficient than classification of entire frames of data for this purpose.

(3) Analysis of field spectroradiometer data to characterize the reflectance and emittance properties of crops. Two major studies were conducted in 1972 with: (1) systemic and non-systemic stresses (two major types of stress) and (2) amount of ground cover and leaf area of corn. A better knowledge of the effect of these and other factors on spectral response will result in improved interpretation

of the spectral measurements made from aircraft or satellites. For instance, during the 1971 Corn Blight Watch Experiment it was not known whether mild blight infection could be detected by remote sensing. Likewise, the kind and magnitude of change in spectral response due to other factors causing changes in spectral response was unknown.

Significance: Information on agricultural crop production is collected and utilized by governments and private industry. Production estimates are a major determinant of market price and many decisions in managing the production, storage, transportation, and utilization of grain are based on these estimates. Improvements in the accuracy and timeliness of these estimates would result in significant social benefit to the country. For example, studies at LARS have shown that reduction in the error of estimate for corn, soybeans, and wheat production from three percent to two percent would result in 14 million dollars benefit. Satellites and aircraft offer a unique vantage point for collecting data for crop production estimates. If developed, this concept will provide more accurate and timely estimates than ground surveys now offer, as well as providing a more cost effective method of gathering the information.

Accomplishments: Work at LARS has shown that agricultural crops can be reliably identified from multispectral scanner data. The feasibility of this approach has been demonstrated over inceasingly larger areas. During the 1971 Corn Blight Watch Experiment, major crops were accurately identified from remote sensing data over the whole Corn Belt region. The cooperative work planned by ASCS and MSC is a direct result of the work at LARS on crop identification.

Recently completed projects are a statistical analysis and evaluation of the classification of corn blight as a part of the 1971 Corn Blight Watch Experiment. This analysis included a study of the relationship between remotely detectable blight classes and yield. The study showed that blight which could be detected remotely caused significant yield reduction.

Future Prospects: Results to date indicate that remote sensing offers a feasible alternative to complete reliance upon ground surveys for obtaining information on agricultural crops. In the near future it will be possible to make accurate area measurements of crops automatically. Development of procedures to improve estimates using correction factors based on the misclassification rates is underway and shows promise. Incorporation into the analysis system of a capability to utilize temporal and spatial information can be expected to further improve crop identification performance. As understanding of the relationship of the interaction of factors affecting yield and spectral response increases, it may be possible to obtain yield information directly from remote sensing data.

Key Personnel: Marvin E. Bauer, Research Agronomist
Ludwig Eisgruber, Professor, Department of Agricultural Econmics
Jan E. Cipra, Research Agronomist

SOCIO-ECONOMIC ANALYSIS I:

ECONOMIC ANALYSIS OF SAMPLING RATIOS FOR REMOTE SENSING APPLICATIONS

Objectives:

a. To develop and assess statistical models for various sampling plans for remote sensing application;

b. To develop empirical estimates of the variance components for sampling plans;

c. To derive cost coefficients for various sampling plans;

d. To assess the trade-off between increasing precision of estimates and associated costs in remote sensing applications.

Significance: Large-scale applications of remote sensing for the purpose of preparing crop estimates, natural resource inventories, pollution monitoring, and so forth, will, in general, involve questions of sampling since complete coverage of the total geographic region and subsequent analysis of data collected with complete coverage appear technically and economically infeasible. Thus, it is important to know about the relationship between less than complete coverage (i.e. sampling), precision of resulting estimates, and associated costs.

Accomplishments: A statistical model for a three-stage sampling plan was developed, and empirical estimates of the variance components of this model were derived for a given application. Cost functions relevant for this model and application were developed, and optimum sampling ratios were computed. The sensitivity of this optimum solution to changes in selected factors is being analyzed. Further development of a sampling scheme when the sampling ratio is a function of cloud cover is underway.

Future Prospects: No obstacles are foreseen to prevent the reaching of limited applications objectives.

Key Personnel: Dr. Ludwig Eisgruber, Agricultural Economics

SOCIO-ECONOMIC ANALYSIS II:

COST/BENEFIT ANALYSIS FOR REMOTE SENSING APPLICATIONS

Objectives:

a. To develop a theoretical framework for a remote sensing centered information system;

b. To ascertain user requirements for selected applications within such a system;

c. To devise empirical estimates of costs and benefits of selected applications;

d. To examine the distribution of costs and benefits to various user groups.

Significance: Public scrutiny of how public funds are expended is at an all-time high. This scrutiny is particularly intense with respect to funds expended towards "space technology". Objective cost/benefit analysis is not only necessary to meet such public scrutiny and to receive continued funding, but it can also aid in directing technology development towards areas of high (economic, social) pay-off.

Accomplishments: Based on classical concepts of social costs, social benefits, and the so-called inventory adjustment model, empirical estimates were derived of marginal social benefits resulting from improved precision in crop estimates. Implications were derived for remote sensing applications in this area. A study was completed on the impact of biased information and more frequently provided information of a given degree of precision on the commodity market. This study is currently extended to ascertain the beneficiaries of different types of information, such as remote sensing might provide. Work is also underway to examine the potential role of remote sensing in monitoring the extent of monocultures and associated resource patterns and socio-economic implications.

Future Prospects: In our judgement, this is one of the high pay-off research areas. The danger with this type of research is that it tends to approach the problem at extremes, i.e. either on too small or too large a scope. Either approach produces meaningless results, albeit for different reasons. For our own work, the danger lies in approaching the problem on too small a scope (for reasons of limited resources).

Key Personnel: Dr. Ludwig Eisgruber, Agricultural Economics

MEASUREMENTS

REFLECTIVE AND EMISSIVE PROPERTIES OF STRESSED VEGETATION

Objective: To study the reflective and emissive properties of vegetation, especially stressed vegetation, in order to better understand the physical aspects of the spectral and spatial distribution of reflective radiation from these cover types. To apply the results of these studies to the development of data preprocessing algorithms in remote sensing data processing technology.

Significance: During the planning and conduction of field experiments involving the measurement of reflected radiation from stressed vegetative canopies a strong interaction between instrumentation engineers and technicians and life scientists in other program areas at LARS takes place. In fact, the research scientist, who is a specialist on the particular vegetative canopy under study, participates in the direction of the on-site experiment. Such activity enhances both the natural and physical aspects of the experiment.

The results of these field experiments directly benefit the research scientist involved in understanding the spectral and spatial radiative characteristics of the vegetative canopies. However, an equally important benefit is the eventual application of the results of the experiment to the development of data preprocessing algorithms for the interpretation of aircraft multispectral data on stressed vegetation.

Accomplishments: Field data on systemic and non-systemic stressed corn canopies have been obtained during the 1972 growing season. In addition, data concerning the effects of percentage ground cover upon the spectral characteristics of stressed and unstressed vegetative canopies have also been obtained. These data were acquired under field conditions and represent the first complete data set of its kind that has yet been obtained over the wavelength region from .4 to 15 μm. These data are currently being processed and studied in order to facilitate the development of improved data preprocessing algorithms with regard to the classification of stressed corn canopies. The research is in relatively early phases due to the natural difficulty of carrying out accurate meaningful spectral measurements under field conditions.

Future Prospects: Experiments of this type will be expanded during the next growing season to include detailed goniometric measurements and to other cover types, such as wheat. The results of this work will aid in the improvement of the detection of stressed vegetation from aircraft and satellite altitudes.

Key Personnel:

LeRoy F. Silva, Associate Professor, Electrical Engineering

Barrett Robinson, Research Engineer

SPECTRAL AND EMISSIVE PROPERTIES OF SOILS

Objective: To study the spatial and spectral characteristics of soils in the reflective and emissive portions of the spectrum and to use the results of this research in the development of data preprocessing algorithms for remotely sensed soils data.

Significance: Spectral and temperature measurements on several soil types under field conditions have been made under the close supervision of soils scientists from the Agronomy Department of Purdue.

The results of this research will be used to improve the classification accuracies of soil types and to develop problem-oriented data preprocessing algorithms.

Accomplishments: A catalog of data on soil types over the wavelength range of .4 to 15 μm has been obtained over a wide variety of soil types that have been nurtured under field conditions. The effect of surface texture upon soil spectral characteristics has been carefully researched. Preliminary investigation of these spectral characteristics and their effect upon difficult soil classification problems has been undertaken.

Future Prospects: The separation of soil surface texture from the soil bulk properties appears to be one of the principal early future benefits from this research work.

Key Personnel:

Barrett Robinson, Research Engineer

LeRoy F. Silva, Associate Professor, Electrical Engineering

SPECIALIZED INSTRUMENT DEVELOPMENT

Objective: To develop laboratory and field instrumentation systems especially appropriate to the acquisition of data regarding the spectral and spatial characteristics of natural materials.

Significance: Activity in this particular research area is contained principally within the Measurements Research Area. However, frequent communication with potential users of instruments strongly influences the instrumentation system design, development and implementation.

The data produced in these specialized instrumentation systems are of direct use to research scientists from other program areas, and the results have a direct bearing upon data processing methodology that may be used in the preprocessing and reduction of remotely sensed data.

Accomplishments: The following instrumentation systems have been designed and developed:

i. An extended wavelength field spectroradiometer

A field spectroradiometer that covers the wavelength region from .4 to 14 μm has been designed, developed and implemented. This system can acquire data in the field under a wide variety of natural conditions, and it is so designed to permit goniometric spectroradiometric measurements. An accompanying software system is being designed to take the digitized data from the instrument and process it into a form suitable for analysis by the research scientist. The instrument may be fully calibrated under field conditions.

ii. Low-cost field spectroradiometer

A field spectroradiometer capable of operating under a wide variety of natural conditions over the wavelength region from .4 to 2.5 μm has been designed and developed and is being implemented. This instrument is capable of being constructed for a cost of less than $5000. Its intended usage is for those projects which desire an essentially dedicated field spectroradiometer setup.

iii. Portable digital field thermometer.

A high precision portable field thermometer has been developed and implemented that enables accurate temperature measurements of soil and water for both ground truth and research field use. These instruments are used frequently by research scientists in the other program areas, and the data used in their research as well as in the training of airborne multispectral data.

iv. Field calibration sources

Several inexpensive field calibrators have been designed and developed with suitable accuracy for the calibration of field instruments on the experimental site.

<u>Key Personnel</u>:

LeRoy F. Silva, Associate Professor, Electrical Engineering

Barrett Robinson, Research Engineer

Thomas Martin, Associate Program Leader

ELECTRICAL PARAMETERS IN SOIL MOISTURE MEASUREMENTS

Objective: To study the electrical properties of soils as a function of available moisture profile and to apply the results to the development of simple soil moisture measuring instruments and possibly extend the results to the technology of the remote sensing of soil moisture using radar systems.

Significance: Electrical engineers in this research program have been working closely with soil scientists at LARS and soil chemists in the Agronomy Department in a carefully researched and documented study of the electrical properties of soils as a function of moisture content.

Since soil moisture is an important parameter in agriculture and land use planning, measurements of this parameter are of direct benefit to research scientists working in this area and to the remote sensing community that is attempting to develop rapid low-cost methods to make large-scale measurements of this parameter.

Accomplishments: A coaxial probe has been developed that enables relatively accurate measurements of soil moisture in a wide variety of both laboratory and natural soil materials. Measurements have been made at radio frequencies and proper account taken for polarization effects. The results are being extended to higher frequencies, and a study of the transmission analogy is currently under way. At the very least, an instrument that is relatively easy to use will result that will make accurate field measurements of soil moisture.

Future Prospects: Whether or not the results of this research can be extended to the general measurement of available soil moisture profile using radar technology remains to be seen. This is a very difficult problem, but the results of the research described here will enable an intelligent assessment of the potential success of the program.

Key Personnel:

Floyd V. Schultz, Professor, Electrical Engineering

DATA PROCESSING

COMPUTER HARDWARE AND SOFTWARE:

HARDWARE AND OPERATIONS

Objectives: To research and develop concepts leading to hardware specifically applicable to the development and evaluation of remote sensing processing and analysis techniques.

Significance: Data processing hardware with software will be available to remote sensing research projects at Purdue and NASA locations. Specifications for hardware which enhance the development of Earth Resources information systems are also being developed through evaluation of this research system.

Accomplishments: In 1966 a digital data conversion system was designed by LARS personnel and delivered in February 1967. This system enhanced the researcher's accessibility to multispectral measurements recorded in an analog format by converting them to a standard digital data format available through a tape oriented data bank accessible on general purpose digital computers. Also, in 1966, a general purpose computer (IBM System/360 Model 44) was installed for implementing remote sensing technology and for providing access to that technology by the various researchers at Purdue. This capability (enhanced by the software support) became attractive to many researchers in the remote sensing community. Several research groups visited Purdue to evaluate the techniques for their own research efforts. These activities led NASA to request a proposal on how the capabilities could be expanded to other research locations. In January, 1971, the Model 44 was upgraded to an IBM system/360 Model 67 computer with a resource sharing software supervisor. This hardware and software supervisor provides the requested access at remote locations and allows evaluation of the techniques and concepts at these locations.

Another hardware concept developed early in the Purdue activity was the digital display. The major thrust of research into analysis techniques was that of machine processing. At that time, it was recognized that optimum human interaction with the data would be through an image format. This led to the design of a digital display which could be connected to general purpose computers for the input of numerical data and the conversion to gray scale images on a display screen. These concepts led to the design of several displays which are used at different research locations. Black and white displays have been used as well as color. A particular device constructed by IBM was installed late in 1970 at Purdue.

Future Prospects: The use of the Data Conversion System will continue to support the research activities with data. Further development of the use of the multi-terminal general purpose computer and the digital display are expected during the next year and in future years. A remote terminal has recently been installed at NASA Goddard and others are expected to be installed soon at NASA Houston and NASA Wallops. An outflow of technology is expected to these remote terminal locations. The concepts and techniques used for processing and analyzing data will be strengthened through the natural communications that will result from the use of this research system.

<u>Key Personnel</u>: Dr. Howard Grams, Systems Programmer
William Hockeman, Computer Operations Supervisor
Computer Operators

COMPUTER HARDWARE AND SOFTWARE: SOFTWARE SUPPORT

Objectives: To implement data handling and analysis techniques by methods which provide rapid and flexible access to the data bank and to the analysis capabilities for each research effort connected to the multi-terminal computer system.

Significance: Remote sensing tools are available to each type of researcher in the multi-disciplinary research situation. Such a system can be used for developing techniques, as an experimental system for testing techniques for their potential applications, and for evaluating the interaction of the subcomponents of an information system. The software coupled with the hardware addresses itself to the instrument and applied physics, preprocessing and analysis techniques, physical measurements, and applications researchers.

Accomplishments: In the late 1960's, a data analysis technique based on multi-variate pattern recognition was synthesized (LARSYS Version 1) and made available to the various researchers in remote sensing. Since that time research at Purdue has led to almost continual improvement of the capabilities of the original data analysis techniques. Significant advancements included: separability analysis and feature selection, cluster analysis and unsupervised classification, and sample ("per-field") classification. The utility of these techniques for accurately analyzing remote sensing data for a large variety of applications have been amply demonstrated by scientists from various disciplines.

The initial use of the LARSYS system was by LARS researchers, however, shortly after the first results were reported, other research groups began using the LARSYS programs at Purdue or at other research locations through implemented versions of the programs. Data formats and concepts first tested in LARSYS are currently becoming standards for multispectral analysis of data. NASA/MSC has evaluated this approach and found it useful to implement these techniques for their research.

Future Prospects: The LARSYS programs are expected to continue to evolve at a more rapid rate with the addition of terminals at other NASA locations. In February, 1973 a completely documented version of LARSYS (Version 3) is expected to be available to all terminal users and for export to other research sites.

Key Personnel: Terry Phillips, Project Administrator
Kay Hunt, Systems Analyst
Barbara Addessio, Computer Programmer
Jeanne Ethridge, Computer Programmer

COMPUTER HARDWARE AND SOFTWARE: DATA REFORMATTING

Objectives: To develop techniques which provide a data bank of multispectral images as a set of measurement vectors retaining their image orientation over increasingly larger portions of the earth's surface and in a digital format easily accessible for analysis.

Significance: Various research projects (at Purdue and other locations at NASA request) are provided with high-quality data sets from various sensors in a permanent non-changeable format. Data storage concepts for information systems are tested and a data base for evaluation of new analysis techniques is provided.

Accomplishments: The first 12-channel, multispectral-image, digital data set was generated at Purdue in 1967 from analog data provided by the University of Michigan optical-mechanical scanner. This data set, called Flightline C1, has been used by most earth resources research groups in the world to evaluate new analysis techniques and to test implementation of techniques. Machine analysis techniques were first applied to spacecraft acquired data after a cooperative effort by Optronics International and Purdue provided a registered digital data set taken over the Saltan Sea on Apollo IX. These digitization, reformatting, and data storage and retrieval techniques have also been applied to supporting data from the laboratory and field instrumentation systems.

Data from various optical-mechanical scanner systems have been digitized and reformatted for the evaluation of each type of system. These concepts were rigorously tested during the 1971 Corn Blight Watch Experiment when 300 square miles of digital data were created every two weeks for nine observation periods. Use of these techniques has led to decisions to use on-board digitization equipment on sensor systems such as the 24-channel scanner at MSC, Bendix scanner systems, and ERTS multispectral scanner system. Reformatting techniques to the standard format (LARSYS Version 2) have also been applied to ERTS multispectral data for analysis at Purdue and NASA/MSC.

Future Projections: Most future research data systems will be based on digital data banks such as these first tested at Purdue. The ERTS system is now generating digital data for many applications and plans for Skylab systems are progressing. The quality of data from these systems will improve due to upgraded calibration, registration, and other data handling techniques. These improvements are expected to come from the many centers of research including Purdue.

Key Personnel: Paul Anuta, Research Engineer
William Simmons, Research Engineer

DATA PROCESSING AND ANALYSIS RESEARCH

Objective: To conduct research into computer-oriented data handling and analysis techniques for remote sensing.

Significance: A well-defined need exists for the kinds of survey data which can be provided by remote sensing. The tremendous volume of data involved and the need for quantitative information require the application of effective and efficient computer-oriented techniques (at minimum, computer-assisted techniques) for analyzing the data.

Accomplishments: Early in its history, LARS adopted multivariate pattern recognition as a basis for multispectral remote sensing data analysis. Subsequently a large body of theoretical and experimental results has been obtained by LARS which has supported this early decision.

A pattern recognition algorithm utilizing a maximum likelihood decision rule and assuming Gaussian statistics has been established as a good trade-off between classifier power (discriminability) and processing speed. Theoretical and experimental studies of class separability measures have led to practical criteria for feature selection in multiclass classification problems. Various studies of distance measures both in the measurement space and parameter space have yielded algorithms for multivariate cluster analysis and for sample ("per-field") classification.

The effectiveness and efficiency of LARS has been amply demonstrated in a multitude of applications by scientists from related disciplines. NASA has chosen to adopt the LARS general approach to remote sensing data analysis for their research and keeps abreast of new developments by the LARS staff as they are shown to be useful.

Important results have also been achieved in other areas of multispectral image processing. A definitive study of the effects of various types of noise on informational content has been carried out. Theoretical studies of spectral and spatial basis functions have led to exotic yet probably very useful techniques for spectral and spatial data compression techniques. The implementation of image registration systems has provided a capability to perform multisensor and multitemporal studies of remote sensing data.

Future Prospects: Developing applications continue to try the limits of existing data processing technology in remote sensing. For example, given the scope and scale of the satellite imagery now being obtained, the development of an adaptive classifier which can track the slowly changing character of the scene over large geographical areas has become imperative and is being pursued.

The view from orbit has increased the magnitude of the data processing problem in many other ways. Means are being sought to cope with several of these. Boundary finding techniques are being sought to provide automatic scene segmentation in order to facilitate area mensuration and sample ("per-field") classification.

Methods for easing the training problem are being developed which apply cluster analysis to help establish appropriate classes and subclasses. The digital display is finding increasing utilization as an interactive device for speeding the data analysis procedure. And the image registration facility is being improved so that advantage may be taken of the multitemporal and multisensor coverage now readily available from satellites and associated underflights.

Finally, a key element in the evaluation of the utility of remote sensing is the precision of the information which can be derived from it. The models used in designing the classifiers and the accuracies obtainable in the analysis process. The data processing effort therefore includes a significant effort in cooperation with the applications scientists concerned with measuring the socio-economic impact of information derived from remote sensing.

Key Personnel: Philip H. Swain, Assistant Professor, Electrical Engineering

Gail F. Santner, Professional Assistant, Engineering Experiment Station

Paul A. Anuta, Professional Staff, Engineering Experiment Station

Paul Wintz, Professor, Electrical Engineering

C. D. McGillem, Professor, Electrical Engineering

REMOTE TERMINAL

Objective: Investigate the utility of remote terminal networks for remote sensing data processing; transfer LARS-developed technology to other remote sensing centers.

Significance: Hardware and software for remote sensing data processing are expensive. Transmitting to other centers the expertise developed at any given center in the use of remote sensing data processing is found to be difficult. The remote terminal experiment is an effort to demonstrate that both of these problems can be lessened substantially by centralizing the computational facility and the remote sensing data bank and providing geographically remote users access to these shared resources by means of appropriate teleprocessing equipment.

Accomplishments: LARS' time-sharing computer became operational in early 1971, at which time the remote sensing data processing software developed on a smaller system was successfully transferred to the new system. Since that time, the software has evolved to accomodate better the remote terminal mode of operation and the hardware has been upgraded to support the increased computational burden anticipated as a result of the connection of remote users. The "in-house" demonstration of the system (a terminal remoted to a building away from the central computer site) has been successful and the first truly remote terminal (at Goddard) is in final checkout.

A closely related activity is the development of educational materials for training remote terminal users. A package multimedia materials has been synthesized and used successfully in-house to train personnel with a wide variety of educational and technical backgrounds. This package is now available to support the remote terminal experiment.

Prospects for the Future: Now that many of the basic hardware and software problems have been solved, we are anticipating the connection of the projected number of remote users. A steering committee composed of NASA and LARS personnel will meet shortly to review and polish LARS' criteria for executing and evaluating the experiment. A successful conclusion of the experiment may suggest that NASA implement such a system on an operational scale to service the needs of the remote sensing research community.

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