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REMOTE SENSING INFORMATION SCIENCES RESEARCH GROUP

SANTA BARBARA INFORMATION SCIENCES RESEARCH GROUP
FINAL REPORT - YEAR 5

JUNE 1, 1988

PRINCIPAL INVESTIGATOR
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CO-INVESTIGATOR / CONTRIBUTORS
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF UNIVERSITY AFFAIRS
WASHINGTON, D.C.   20546

GRANT NO. NASA NAGW - 455

ISRG

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Introduction

John E. Estes and Jeffrey L. Star

University of California, Santa Barbara   **June 1988**

John E. Estes and Jeffrey L. Star

The Office of University Affairs of the National Aeronautics and Space Administration (NASA) has signed a grant establishing a Remote Sensing Information Sciences Research Group (ISRG) at the University of California, Santa Barbara (UCSB). This document represents an annual report of work conducted under this grant (Grant # NASA NAGW-455) during the period May 1, 1987 to May, 1988.

ISRG research continues to focus on improving the type, quantity, and quality of information which can be derived from remotely sensed data. As we look to the coming year of our research, we will continue to focus on information science research issues. In particular, we will focus on the needs of the remote sensing research and application community in both the United States and internationally, which will be served by the Earth Observing System (EOS) and Space Station, including associated polar and co-orbiting platforms. Research conducted under this grant has been used to extend and expand existing remote sensing research activities at UCSB in the areas of georeferenced information systems, machine assisted information extraction from image data and large spatial databases, artificial intelligence, and vegetation analysis and modeling.

As the world's human population increases, there is an ever expanding need for systems and techniques capable of acquiring, integrating, and analyzing information concerning the extent, use of, and changes in the major components of the earth's surface. NASA is playing an important role in the development of systems such as EOS which have significant data acquisition capabilities. To achieve the full potential of such systems, however, requires far-sighted fundamental research which is directed towards the scientific application of technologies upon which assessments may be made of both the current and changing status of the components of the biosphere, hydrosphere, lithosphere, and atmosphere.

The program of research which is documented in this progress report, is being carried forward by personnel of the University of California, Santa Barbara. This report documents our accomplishments in what we consider to be a multi-year effort to prepare to take full advantage of the capabilities of the platforms and systems associated with Space Station (in particular, EOS), and supporting other local to global scale databases and datasets.

Through this work, we have targeted fundamental research aimed at improving our basic understanding of the role of information systems technologies and artificial intelligence techniques in the integration, manipulation and analysis of remotely sensed data at local, national, continental and global scales. This coordinated research program is possible at UCSB due to a unique combination of researchers with experience in all these areas.

Efforts during this grant continue to focus on the integration of existing research activities at UCSB and the initiation and conduct of a number of research activities with a variety of NASA centers. We have also worked on background assessments of research and technology, as well as beginning steps towards design and implementation of the EOS Data and Information System (Eos-DIS) for NASA Headquarters. We continue to be involved in PLDS development efforts, largely through the Science Steering Group. In addition, UCSB personnel have been involved with the EOS Data Systems Panel, the Space Station Data User Working Group, the Space Station Operations Science Management Working Group, the Telescience Testbed Pilot Program effort (chairing the Earth Science consortium within this program), the Science and Applications Information Systems Working Group, the United Nations Environment Programs Global Resources Information Database program, the Committee on Data Management and Computation (CODMAC) of the National Academy of Science, the Academy's Committee on the Mapping Sciences for the United States Geological Survey, the National Research Council's Space Applications Board, and the Space Station Science and Applications Advisory Subcommittee.

We have also received a major grant from NASA Code EE/EC to study the concept of Browse of remote digital datasets, particularly as it relates to the data gathering capabilities expected in the EOS ERA, In addition, we continue to support system acquisition and operational activities of the United Nations Environment Programs (UNEP) Global Resource Information Database (GRID), at their facilities in Nairobi, Kenya and Geneva, Switzerland.

The first section following this introduction summarizes the research thrusts during the past year. The material which follows details ongoing work directly aided by this grant. Again, several of the projects used this funding as a catalyst to aid other NASA offices in the research, in the integration of remotely sensed and other data into an information sciences framework. The following sections discuss the details of the projects dealing with:

* BROWSE of Remotely Sensed Data in the 1990's

* Support of the United Nations Environment Program Global Resources Information and Database

* Image Processing Algorithm Selection

* Agricultural Monitoring and Econometric Modeling in an Information Systems Context for the Region of the Veneto, Italy

* Geographic Information System for Scholars

* Sensor Technology for Large Scale Vegetation Analysis

* Advanced Information Extraction Tools in Remote Sensing for Earth Science Applications

* Interpolation and Uncertainty in Geographic Information Systems   Model-

* The Earth Observing System for the 1990 and 2000 Decades

* A Knowledge Based Geographic Information System

These projects are discussed in some detail in the following sections. The appendices which follow contain material expanding upon work from various sections of the report, publications which have been funded (in whole or in part) by this grant, committees memberships held by our staff with direct relevance to information sciences, and symposia and professional society papers which have been presented, related to work on this grant.

Browse in the EOS Era

Jeffrey L. Star and John E. Estes

Full Text is Found in January 1, 1988
Progress Report and Proposal - Year 5

University of California, Santa Barbara   June 1988

John E. Estes and Jeffrey L. Star

We are in the midst of a several year research and development effort, titled "Browse in the EOS Era", funded through grant NASA NAGW-987. This project is based on developing a computer software testbed, through which we may examine different approaches to the problem of making remotely sensed science data available to the users. The issue specifically regards one of the key problems in science data management. This becomes an extremely important issue as we begin to prepare for the 1990's and EOS, with its extraordinary capabilities for multi-sensor data collection. This effort results from the discussions at and recommendations made by the ESADS meeting and EOS Data Panel reports.

A number of scientists are working with us to use our testbed, as well as contribute datasets and ideas to our staff. Collaborators outside of the University of California, Santa Barbara include researchers at Georgia Tech, Purdue University, San Diego State University, the University of Alaska, University of California at Berkeley, University of Colorado at Boulder, University of Rhode Island, and the University of South Carolina, as well as staff at NASA Ames Research Center and the Jet Propulsion Laboratory.

There are several areas we have emphasized in the past year of this effort. During our first year, we constructed a software testbed, in which a number of our ideas on spatial data management may be exercised. A key goal of the second year is to keep the testbed in operation, adding new datasets and users, to compile the user requirements discussed in the original proposal. Operating the testbed, including connections to appropriate nation-wide networks, has been a primary task in the past 6 months, and continues as a primary task for the second year.

Additional tasks for the second year fall into three categories. First, there are a number of planned optimizations to the current testbed for the second year. These include refinements in the user interface, a better-developed session history mechanism, and a revised electronic map model, based on a hierarchical data structure. In particular, the electronic map will be reworked, to reflect (1) a better understanding of user needs and network throughput capabilities, and (2) a locally-developed hierarchical data structure. Elements of all these components are now in the design and testing phases of development.

We intend to support both SPAN and Internet communications and browse file transfer available to the collaborators, to minimize the expense of working with us. We also were able to procure a 9600 BPS dial-up modem through another contract, to be able to compare Internet communications with a proprietary dial-up communications protocol. Early results suggest that the dial-up connection has superior reliability and throughput to the dedicated network, at least during prime-time hours.

Second, we have plans to investigate several new areas. These include distributed heterogeneous database query, 'intelligence' in a user interface to spatial datasets, and optimal compression of browse data. Distributed query involves moving the user's request from one database system on one computer to a different database system on another computer with a different operating system. Such an experiment is a reasonable model to the distributed archives in NASA, NOAA, USGS, and many universities, where database managers and operating systems are not standardized. We will examine this area by porting most of the functionality in our current VAX/VMS based testbed to a personal computer platform, and then developing an interface to permit heterogeneous database query. Intelligent user interfaces involve artificial intelligence technology; we wish to see how practical and expensive it will be to add such capabilities to the Browse testbed. Data compression questions include tradeoffs between data fidelity and communications speed and costs, as well as a determination of the data volume needed to provide useful scientific information about a single multispectral image.

Finally, it is important to involve the potential user community in our work, to insure that our results are a constructive contribution to the NASA information systems of the 1990's. To this end, we will continue to work with a science advisory group (as discussed in the original proposal), making our testbed as well as source code available for their use and consideration, as well as incorporating their input to our developments. As a new development, staff at the Marshall Space Flight Center and the National Space Technology Laboratory have expressed interest in out testbed efforts, and we will being to explore ways to collaborate with them in the coming year. In addition, we will continue to present our research at professional conferences during the second year, as well as continue to write articles for the professional journals in the field.

As appendices, we include abstracts of papers presented at national conferences during

the past six months, which detail our progress towards the goals described above. During the coming months, we will finalize the Build II configuration of the testbed software, and make accounts and user guides available to our collaborators.

TECHNICAL PAPERS
1988 ACSM-ASPRS ANNUAL CONVENTION
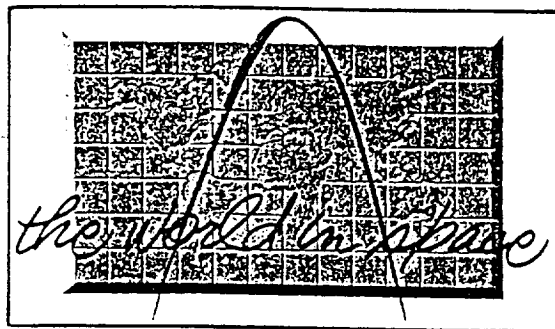
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ACSM • ASPRS/1988   THE WORLD IN SPACE
MARCH 13-18/ST. LOUIS

IMAGE PROCESSING/ REMOTE SENSING

St. Louis, Missouri
March 13-18
ACSM 48th Annual Meeting
ASPRS 54th Annual Meeting

KNOWLEDGE-BASED IMAGE DATA MANAGEMENT: AN EXPERT FRONT-END FOR THE BROWSE FACILITY

David M. Stoms, Jeffrey L. Star, and John E. Estes

Remote Sensing Research Unit
Department of Geography
University of California
Santa Barbara, CA 93108
(805)961-3845

BIOGRAPHICAL SKETCHES

David M. Stoms is a Ph.D. student in the Department of Geography at the University of California, Santa Barbara. Prior to graduate school, he worked 12 years with the U.S. Forest Service, primarily in land management planning. His current research interests are in browsing capabilities for spatial databases, knowledge-based approaches to spatial data processing and retrieval, and the value of improved spatial information.

Dr. Jeffrey L. Star is manager of the Remote Sensing Research Unit and Lecturer at the University of California, Santa Barbara. He received his undergraduate degree from M.I.T. and his doctorate in oceanography from Scripps Institution of Oceanography, University of California, San Diego. His research interests are in remote access to large archives of spatial data, merging artificial intelligence with geoprocessing technologies, and creation of a regional GIS for agricultural monitoring. Dr. Star has served on a number of national committees, including NASA's Earth Observing System Data Panel and the Task Force on Geo Information of the Research Libraries Group.

Dr. John E. Estes is Professor of Geography and Director of the Remote Sensing Research Unit at the University of California, Santa Barbara. He has authored more than 250 works on remote sensing and information systems, including 'Fundamentals of Image Analysis', a chapter in the *Manual of Remote Sensing*, which he coedited. He has served as senior scientist at the National Aeronautics and Space Administration and is a member of the Committee on Data Management and Computation of the National Academy of Science.

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ABSTRACT

An intelligent user interface is being added to the NASA-sponsored BROWSE testbed facility, developed at the University of California, Santa Barbara, Remote Sensing Research Unit. BROWSE is a prototype system to explore issues involved in locating image data in distributed archives and displaying low resolution versions of that imagery at a local terminal. The original user interface for BROWSE incorporated knowledge of the data base structure and query language. Users were questioned on their choice of sensors and other attributes, and then BROWSE would formulate the appropriate query. The new feature described in this paper provides expert consultation to researchers not trained in remote sensing concepts. Users are asked about their objectives, and the interface matches the objectives with the database domains of image attributes. Natural vegetation applications are the focus of the initial development. Expertise in remote sensing of forest and range land is being extracted from the literature for use in the knowledge-base. This paper describes work in progress on development of the expert system. Sharing of expertise should encourage a broader research community to utilize remotely sensed data.

INTRODUCTION

Launch of the Earth Observing System (Eos) sensor packages as part of the Space Station complex in the 1990's will magnify many of the image data management issues. Eos has been projected to generate an unprecedented terabyte of image data per day for at least a decade. Global science questions can then be meaningfully addressed by researchers in many disciplines, including some who have not been involved with remotely sensed data before. Even for experienced remote sensing scientists, finding the right dataset can be a significant investment of time. Furthermore, the data must often be ordered on the basis of a terse, sometimes unreliable, database record of their quality. One approach to these shortcomings has been to promote a browsing capability in the data systems (NASA, 1986; CODMAC, 1982; CODMAC, 1986; Billingsley, 1984).

Browsing is defined as the process of locating and viewing image data from a remote terminal (Star et al, 1987; Star et al, in press). A prototype browsing system for image data has been developed at the University of California, Santa Barbara (UCSB) under a grant from the National Aeronautics and Space Administration (NASA). The BROWSE testbed basically integrates a database management system (DBMS), a user interface, communications software, and an image display system. The user is expected to select the appropriate attributes and their values.

The Eos Data Panel, as well as other authors, have recommended the use of expert system technology to improve database access, particularly by new and infrequent users (NASA, 1986; Estes et al, 1986). An intelligent user interface, or front-end, is a program that will 'serve as an intermediary between a database and a user who has little or no knowledge of the database's architecture, language, or content' (Campbell et al, in press). NASA anticipates several modes of browsing for Eos data, requiring different types of interfaces. The first mode, handled by the initial version of BROWSE, visually confirms the quality and coverage of the image found in the Catalog. Other users will browse for spatial objects extracted from highly processed data. The third form of browsing will be by researchers who may not be experts in remote sensing but who need inputs derived from digital imagery. We are attempting to support this third group with a new intelligent interface. Specifically, we want to evaluate two objectives: 1) can expertise in remote sensing capabilities be formalized in a knowledge-base, and 2) would such a sharing of expertise be useful to non-experts in selecting image and spatial data? In other words, whereas the original BROWSE system incorporated only a low level knowledge of the data base structure and contents, the new interface adds a higher level of knowledge of the spatial, spectral, and temporal parameters suitable for a variety of tasks in a relatively limited domain.

Following a brief overview of the BROWSE testbed, the related concepts of browsing and intelligent interfaces in information science are reviewed. This explanation sets the foundation for discussing the intelligent user interface being developed for the BROWSE testbed. For prototyping, the initial application is remote sensing of forest and range land, where a large knowledge-base has accrued in the research literature. There are many potential parameters of vegetation that can be derived from image data, and a large number of image sources have been used in the past (Carneggie et al, 1983; Heller, 1985). Furthermore, many of the global science issues such as deforestation, desertification, climatic change, carbon cycling, and acid rain involve vegetative factors (Billingsley, 1984; NASA, 1984).

THE BROWSE TESTBED

The prototype BROWSE system was developed under the auspices of a NASA grant to explore formats most suitable for viewing spatial data by a range of multidisciplinary scientists. However, we have found the display of browse images is irrevocably intertwined with the process of retrieving appropriate data.

The hub of the BROWSE testbed is a relational data base management system. The CATALOG data base describes the attributes, or metadata, of each discrete image, such as its processing history, image quality, and so on. In the original prototype, a user interface was provided to guide a researcher in the query process. We took this approach to save the user from needing to learn the DBMS language and the structure of the data base. An investigator is presented a series of menus and prompts for selecting the query attributes. If a user finds an image that appears to meet their needs, based on a detailed record, they can transmit a browse file from the host computer to their local terminal for display. A fuller description of the BROWSE testbed, as well as some of the potential browse formats, are given in Star et al (1987 and in press).

After our experience with the prototype system and the reaction of our scientific collaborators, we feel that the display process can not be divorced from the query process when evaluating the effectiveness of a browse facility. For instance, our use of a multiresolution electronic map to interactively identify a geographic area of interest makes the overall browse process easier. (See figure 1 for an example of this graphic feature). For users who are relatively new to remote sensing, i.e., the wider constituency that NASA hopes to attract, an effective integration of locating and displaying data will be even more important. The original testbed version of BROWSE
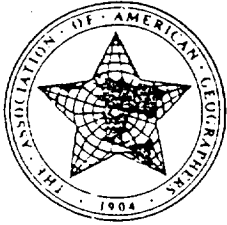
Association of American Geographers

1710 SIXTEENTH STREET, N.W., WASHINGTON, DC 20009
202-234-1450

Robert T. Aangeenbrug, Executive Director

August 28, 1987

Dr. David M. Stoms
Remote Sensing Research Unit
Dept. of Geography
University of California
Santa Barbara CA 93106

Dear Dr. Stoms:

The Association of American Geographers (AAG) is organizing and sponsoring the International Geographic Information System (IGIS) Symposium: The Research Agenda. This meeting is scheduled for November 15-18, 1987 at the Crystal City Hyatt Regency Hotel in Arlington, VA.The meeting will bring together professionals who supply or use geographic referenced data.

The Program and Science Advisory Committees have accepted your abstract for presentation at this symposium. We have reserved time in the schedule for you to address the audience on "Electronic Browsing for Suitable Input Data for a GIS" on Tuesday, Nov. 17 at 9:00am. We ask that you provide a biography and paper of 10 to 12 pages by October 15, 1987 (instructions are included). In order to finalize the schedule, we need your response by September 15, 1987. Please address your response to:

> E.H. Pechan & Associates, Inc.
> Attn:IGIS 87, Ms. Nancy Schiffman
> 5537 Hempstead Way
> Springfield, VA 22151

I hope that you can be a part of this exciting symposium. Please let the symposium contractor, E.H. Pechan & Associates, Inc., (703) 941-4450, know of your availability and any arrangements you may need.

Sincerely,

Robert T. Aangeenbrug

Enclosures

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Austin, TX 78712-1098	Madison, WI 53706	Washington, DC 20036	St. Paul, MN 55105	Washington, D.C. 20520

ELECTRONIC BROWSING FOR
SUITABLE GIS DATA

Jeffrey L. Star, David M. Stoms, Mark A. Friedl, and John E. Estes

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ABSTRACT

With the mass of remotely sensed data being collected, researchers are often unaware of what data is available and where it is stored. Data is frequently purchased on the basis of a terse database record describing, for instance, cloud cover and image quality. A better approach may be to allow analysts to preview spatial data, not just some salient facts about that data.

In a NASA-sponsored research program, the authors are developing a prototype system with browsing capability for data archives. The objective is to allow scientists, sitting at their local workstations, to access a network, to retrieve records of image and spatial data selected by user-specified attributes, to view low resolution versions of the data, and to place an order, if the data are satisfactory. The architecture and functioning of the BROWSE testbed is briefly outlined.

Surprisingly, the definition of BROWSE has found no consensus. This paper focuses on the on-going efforts to establish a definition that satisfies a broad range of scientific disciplines. Any operational definition will include the algorithms used to compress the raw data into a low resolution format. Preliminary algorithms being considered include single band subsetting, spatial subsampling, band ratios, principal components analysis, and linear combinations. Several browsing scenarios illustrate the complexities of selecting suitable data sets. An effective browsing utility will have benefits beyond NASA data systems and the Earth Observing System. Lessons learned from this project may be of value to other spatial data base designers.

1. INTRODUCTION

Effective information systems are an increasingly important aspect of spatial data analysis (Estes, 1985). Technical and social innovations provide a forcing function for improvements in the design of information systems, driven by the

GIS '87 • San Francisco

Department of Forestry and Resource Management • University of California • Berkeley, California 94720 • (415) 642-5170

Mon Jun 15 19:51:31 PDT 1987

Mr. Jeffrey L. Star
University of California
Santa Barbara, California

Dear Jeffrey:

The Program Committee for GIS '87 is pleased to inform you that your paper to be entitled:

Browse Capability for Spatial Data Bases

has been accepted for inclusion in the conference proceedings and you are invited to present the paper during the course of the conference.

Your paper has been assigned to Session T10 entitled *The Distributed Solution - GIS and Computer Networking* which will convene on Tuesday from 3:00 pm to 5:15 pm. Your session organizer is Mr. Kenneth Gardels. This assignment is preliminary and may change.

Due to the many papers that have been received and the Committee's desire to accommodate as many participants as possible, some sessions may been extended, or may convene at two different times. Final assignments of speaker times and places will be made, and you will be notified prior to the conference.

Enclosed please find:

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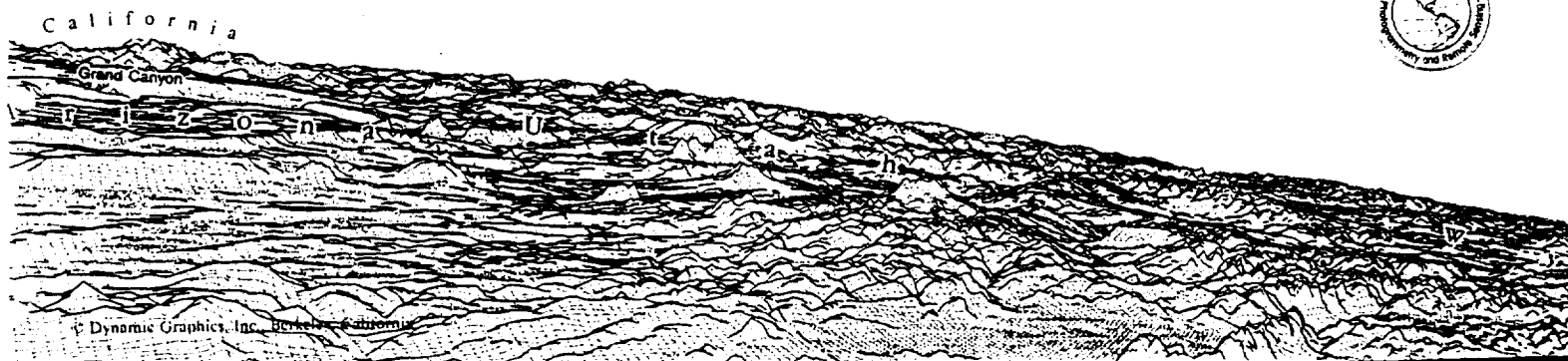- Assignment of Copyright
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BROWSE CAPABILITY FOR SPATIAL DATABASES

Jeffrey L. Star, Mark A. Friedl, David M. Stoms,
and John E. Estes

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ABSTRACT

A need exists to develop superior data management and information systems for remote sensing and other spatial data sets. This issue will become even more significant in the near future as remote sensing instrumentation continues to produce ever increasing volumes of data, and scientists attempt global scale earth science investigations. A testbed information system has been created to implement and evaluate some proposed solutions to future data management issues. In particular, strategies to maximize user access to a wide variety of data sources, and large scale spatial database design are being considered. By implementing a prototype system valuable insight will be gained for spatial information system design in the future.

INTRODUCTION

Earth science and related technology have progressed to the point where the conduct of global science now appears feasible (Estes and Star 1986). This is reflected by the growing interest of scientists from a wide range of disciplines in performing global scale investigations related to the dynamic coupling of the lithosphere, hydrosphere, biosphere, and atmosphere. A central element of such global scale studies is the utilization of advanced, high resolution remotely sensed data. An important component in this regard is the suite of sensors included in the Earth Observing System (EOS) planned for the space station complex of the 1990's (Arvidson et al 1985). This system will provide immense volumes (in the order of up to one terabyte of data per day) of high quality data to the scientific community.

A critical issue which needs to be addressed in this area is the effective management of data derived from EOS era sensor systems. Included in this domain are questions related to both technical considerations (ie. hardware and software) as well as strategic considerations dealing with the management of the data. Also, methods of incorporating image data and other non-image spatial data into a single database environment will be required for geo-based data management and analysis systems. Currently, much sophisticated database and information management

United Nations Environment Programme
Global Resources Information and Database

John E. Estes and Jeffrey L. Star

University of California, Santa Barbara   June 1988

John E. Estes and Jeffrey L. Star

During the past year, the University of California at Santa Barbara (UCSB) Information Sciences Research Group (ISRG) personnel have become increasingly involved in activities associated with the United Nations Environment Programs (*UNEP*) Global Environmental Monitoring System (*GEMS*) Global Resource Information Database (*GRID*) activity. These support activities, funded in part through this grant, include technical and scientific consulting to UNEP staff, as well as participation in management level program evaluations.

During September 1987, Dr. Star participated in a meeting held at the United Nations Environment Programme offices in Nairobi, Kenya. Particular emphasis at this meeting was on the information systems support that the GRID program will require as it becomes operational over the next several years. The invitation to join this working group came from Dr. Harvey Croze, GRID coordinator.

At this fall meeting, the working group reviewed the history, status, and future objectives of the GRID program. The pilot program, which began in 1984, was based on software and hardware donated or loaned to UNEP by government and private organizations in Europe and the United States. After two years of the pilot program, a decision was made by the UNEP in the summer of 1987 to begin an implementation phase for GRID. This next phase is to begin in early 1988 and continue for two years. Our meeting in September 1987 came out of this decision; we were to provide guidance for the start of this next phase.

We spent time with the GRID staff, as well as Dr. Croze and Mr. Wayne Mooneyhan, his counterpart at GRID/Processor in Geneva, Switzerland. We examined a number of current GRID database development projects, both in terms of in-country projects and continent-scale data collection and manipulation efforts. We spent significant time working with the staff to learn about the hardware and software systems now in place in Nairobi and Geneva, and about the workloads and projected data processing and storage volumes for the next few years. The scientific staff expressed the opinion that the software components now in use (the commercial geographic information system Arc/INFO, NASA/ERL's ELAS software system, and the commercial ERDAS image processing system) had adequate functionality to the problems being posed for the next few years.

Overall, the team brought to Nairobi in September was impressed with the quality and quantity of work done by GRID personnel. However, the hardware systems in place at both GRID facilities are some two generations old. This translates into extremely high maintenance costs, extremely limited data storage, and low processing speed. Further, the hardware now in place is difficult to interconnect, so that via networks, data and facilities are not easily shared. The software now in place, unlike the hardware, is considered state-of-the-practice by the working group.

The working group suggested that the two GRID laboratories strongly consider replacing their computer hardware, with an eye towards an eventual networked data system for GRID. We emphasized standard configurations wherever possible, and the long-term goal to of migration towards industry and international standards (particularly in terms of operating systems and communications) over the next several years. Networked workstations have several important advantages over the existing stand-alone minicomputer configurations. They have as much or more computational power than the computer systems now in place at GRID. Because of standard modular interfaces, they may be easily replaced, upgraded and expanded as processing and storage needs require. The redundancy in the networked systems provides greater safety in terms of hardware failures than the stand-alone single processors now in use. Further, current workstation costs permit GRID to gradually replace their computing resources at relatively low costs, with a planned phasing of new elements over time.

Finally, there are available systems which are compatible with the different software systems now used by the GRID staff. Instead of dedicating different processors to the different software systems, new hardware will be able to run all the software on all the hardware. We provided both a generic system outline for the two facilities, as well as recommendations for a specific hardware configuration, as guidelines for future acquisition. Based on these discussions, we understand that UNEP has placed purchase orders for new minicomputers, with delivery expected in Summer of 1988.

A second element of our discussions in September regarded long-term data management issues. At this time, there is a relatively small volume of data in the GRID system. Plans must be made to begin to develop ways to manage the future large data volumes, as well as provide means for users to access both the data itself as well as

descriptive information about the data. Dr. Star made a slide presentation to both the GRID staff and the working group on the BROWSE testbed activity, funded through NASA Headquarters. The BROWSE testbed, at a conceptual level, provides input to their planning in several ways. First, it demonstrates a way to index spatial data holdings in terms of prescribed attributes (geographic coverage, date of compilation, thematic information, etc.). These attributes are then freely searched by the users to identify relevant datasets. Second, since the BROWSE testbed includes capabilities to store limited image datasets, the same system provides limited access to the data itself. This is particularly useful in the case of the UNEP/GRID program, since there are, at present, no methods for charging users fees even to offset database duplication costs. A future system similar to BROWSE could provide electronic access to both data and data descriptions with no direct staff costs. Croze and Mooneyhan were extremely interested in our development. I have forwarded copies of the BROWSE user guide to them, and Dr. Croze has scheduled a visit to UCSB to see the testbed in action and have further discussions with us.

In addition to this first meeting, in January of 1988, Dr. Estes was on a panel of international scientists who evaluated GRID's pilot activities and made recommendations for GRID's near-term implementation phase. The report of this meeting is also contained as an appendix to this report. Based upon both of these meetings, and independent discussions with UNEP personnel, it is apparent that UNEP/GRID will move away from its current hardware and software configuration to either a networked DEC workstation based system, or a system employing IBM machines as yet to be determined. With this move, GRID will move a step away from its current support through the National Space Technology Laboratory at Bay St. Louis, Mississippi.

This move will not, however, lessen GRID's need for both scientific and technical information system support. Indeed, this need will only grow and become more EOS relevant in the coming years. At the present time, it is possible that GRID facilities will become an integral part of the International Geosphere Biosphere Programs Global Change activity. Should this happen, the need for effective and efficient science and applications data linkages to GRID will become even more important. These links need to interconnect both NASA center facilities and also to University scientists, as well.

With this background in mind, ISRG proposes to forge close ties to UNEP/GRID and

to work with and support GRID personnel as they move to understand the dimensions of their program activities in the coming year. It is our hope that this cooperation and support will move beyond a planning and technical support stage into a testbed and project demonstration phase after the coming year. In this effort we at the ISRG hope to couple our efforts conducted under this grant with research underway for Code EC in a testbed program in telescience. In addition, we see that elements of our joint Code EE and EC funded Browse in the EOS Era project will also prove valuable in this effort. Indeed, since it is our hope to refocus the Earth Science portion of this testbed effort to more directly support Earth Observing System Data and Information System (Eos-DIS) activities at NASA/GSFC.

The tie is all the more important within the framework of this grant. It is our feeling that this activity is a natural extension of the combined research thrusts of ISRG, and that both NASA and UNEP can benefit significantly from our work in this area. Specific areas of support for UNEP might include the technologies of both image processing and advanced Geographic Information Systems, as well as specific science project support.

Abstracts of the reports which were developed for the UNEP by the two meetings described above are reproduced in the appendices to this document.

GRID
GLOBAL RESOURCE INFORMATION DATABASE

GRID

INFORMATION SERIES

NO. 12

NAIROBI

NOVEMBER 1987

Report of an Ad Hoc Expert Workshop
on GRID Systems and Software:
Nairobi, 14-18 September 1987

Weber, J.D. ed.

GEMS

GLOBAL ENVIRONMENT MONITORING SYSTEM

UNITED NATIONS ENVIRONMENT PROGRAMME

EXECUTIVE SUMMARY

As a result of successful demonstration of the feasibility of a distributed global database system capability during the pilot phase of GRID, UNEP decided in June of 1987, to enter into a two-year implementation phase for the GRID project. To consider the optimum systems and software which should be employed in this, and future phases of the GRID project, an international group of hardware and software experts met in Nairobi, 14-18 September 1987.

The group found the primary computing systems currently employed at both the Nairobi and Geneva facilities to be inadequate to meet the future processing requirements of the GRID project, and found that these systems would become increasingly difficult and expensive to maintain, due to systems obsolescence. The group found the primary software systems to be adequate for near-term GRID activities, but suggested additional software tools which should be considered. While the applications software expertise of the scientific staff of GRID was found to be appropriate, a lack of systems and operating software expertise resident in GRID was noted.

Based upon these findings, the working group reached the following conclusions:

Perkin-Elmer and Prime computer systems currently employed by GRID should be replaced as soon as such changes can be effected with minimal impact upon GRID activities.

Although a major investment in electronic communication should not be made at this time, the need for inter-node communication via conventional modems was recognized.

ELAS, Arc/Info, and ERDAS software packages currently in use should not be replaced at this time.

GRID staff should be augmented by the addition of personnel qualified in hardware and operating software trouble shooting and maintenance.

A specific recommendation was made that existing systems be replaced with a networked modular systems approach built around Digital Equipment Corporation's Microvax series microcomputers, workstations, and servers. It was recommended that existing software be modified to be compatible with these systems. The group specifically recommended that one operating systems specialist be added to the GRID staff as soon as possible to provide in-house trouble-shooting and maintenance capability.

GRID
GLOBAL RESOURCE INFORMATION DATABASE

Jeffrey L. Star

GRID
INFORMATION SERIES

NO. 15

NAIROBI
JANUARY 1988

Report

Meeting of the GRID Scientific and Technical Management Advisory Committee

UNEP, Nairobi, 18-21 January 1988

GEMS

GLOBAL ENVIRONMENT MONITORING SYSTEM

UNITED NATIONS ENVIRONMENT PROGRAMME

1. Introduction

The Global Resource Information Database (GRID) was established within the Global Environment Monitoring System (GEMS) in 1985, in response to the increasing number of environmental data being available within UNEP and the world scientific and planning communities.

The intention was to give users access to harmonized and integrated geographical data sets of known quality.

An important tool for the capture, storage and retrieval of such data was the introduction of suitable computing techniques.

The introduction of GRID within UNEP took place in the form of a pilot phase during the two and a half years from mid-1985 to end 1987.

It was envisaged that a critical review of the Pilot Phase be undertaken prior to the implementation of a next phase.

The review of the GRID system Pilot Phase was the task of this Expert Group, (see meeting Agenda, Appendix 1, and list of participants, Appendix 2).

The group was further charged with the responsibility of offering guidelines for a possible Implementation Phase. For this task the Expert Group has also relied on the report of an Ad hoc Expert Workshop held in Nairobi 14 - 18 September 1987 (see GRID Information Series No. 12, 1987).

Dr. M.K. Tolba, Executive Director of UNEP, in his opening address, challenged the Group to make certain that GRID could be used to provide information to decision-makers in a way which helps to influence their decisions. Dr. Tolba expected that an important ingredient in this would be the establishment of regional GRID nodes, and the future creation of national nodes compatible with the GRID system, and he invited advice on how to accomplish practical results.

2. An Evaluation of the Pilot Phase

2.1.   Original objectives

The pilot phase objectives of GRID have been summarized in GRID Information Series No. 14, 1988:

    - Objective 1: development of a Geographical Information System (GIS) capability for constructing, manipulating and making available to users global environmental data sets for the purpose of conducting environmental analyses and assessments

    - Objective 2: demonstration of GIS capability to combine global and national datasets for resource management and environmental planning applications at national level

- Objective 3: establishment of a framework for cooperation and data exchange between relevant international and inter-governmental organizations

- Objective 4: exposure to GIS technology to scientists and resource managers from developing countries, including training.

2.2. Expert Group Evaluation - available material.

The Expert Group has evaluated the GRID Pilot Phase in light of the above objectives. For this evaluation the Group has had access to the Final Report prepared by GRID staff (GRID Information Series No. 14, 1988), demonstrations presented by GRID staff in Nairobi during this evaluation (see Appendix 3), and auxillary knowledge possessed by individual members of the Group from previous visits to the GRID installations in Nairobi and Geneva. Members of GRID staff from Nairobi and Geneva were present during the evaluation to provide additional information, together with the GEMS Director and - at the start of the evaluation - UNEPs Executive Director, Dr. M.K. Tolba.

2.3. Evaluation - Objective 1 (GIS capability).

2.3.1. General effects of the funding procedure

The funding procedure of the GRID Pilot Phase entailed that GRID during this period has been built around donated or highly discounted hardware, software and basic installations. Furthermore centrally placed staff have been made available on a secondment basis from UNEP member states, in addition to more permanently employed UNEP staff.

The creation of GIS capability within GRID has therefore been subject to considerable constraints, some of which in retrospect may be seen to have caused some suboptimality in systems design and execution. However, the Expert Group is well aware of the realities of UNEPs funding, and wishes to reinforce the gratitude expressed by UNEPs Executive Director to the institutions and commercial firms that in fact made a GIS system possible. It is also obvious to the Group that GRID acquired very competent people through secondment and similar support during this Pilot Phase. It is obvious to the Group that considerable progress was indeed made during the Pilot Phase in systems implementation and operation and that this has led to the successful demonstration of GRID technology in a number of important areas.

2.3.2. Two-installation strategy (Geneva and Nairobi)

A principal strategy during the Pilot Phase has been the installation of two closely related systems, a larger one in Geneva, Switzerland, and a somewhat smaller one in Nairobi, Kenya. The rationale for this must be seen in the light of two factors:

- the proximity that a GRID Geneva installation would have to other important international agencies (re:. Objective 3, see 2.5 below)

- the availability of high-quality support facilities for the computer system.

The Expert Group concludes that the (near) duplication of systems in Geneva and Nairobi has had a positive effect on the execution of the Pilot Phase, both from an operational point of view and also for international contact-building. The firm commitment of Swiss authorities to GRID operations may also set an example for other countries. The presence of a system at UNEP Headquarters in Nairobi has undoubtedly facilitated more general GRID acceptance both among

Image Processing Algorithm Selection

R.E. Crippen

Full Text is Found in January 1, 1988 Progress Report and Proposal - Year 5

University of California, Santa Barbara   **June 1988**

R.E. Crippen

The following section is based on the doctoral dissertation research of Robert Crippen, who is completing a joint degree in Geology and Geography here at the University of California, Santa Barbara. As a part of his research, he has investigated two important areas in image processing, which revolve around the problems of selecting algorithms for selected tasks. This work has resulted in the submission of two manuscripts to the International Journal of Remote Sensing: *The Relationship of Band Ratios to Spectral Curves*, and *The Dangers of Underestimating the Importance of Data Adjustments in Band Ratioing*. Copies of the submitted manuscripts follow this introduction.

The Relationship of
Band Ratios to Spectral Curves

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Abstract

The potential utility of band ratio images has often been estimated by evaluating slope differences among the spectral curves of the materials that are to be distinguished. This letter shows that band ratios are not functionally related to any measure of spectral curve slope. It also shows that a functional relationship between ratios of recorded radiance and reflectance spectral curves exists only after adjustment of the band data to compensate for the additive terms of recorded radiance.

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The Dangers of Underestimating
the Importance of Data Adjustments
in Band Ratioing

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ABSTRACT

The practical importance of simple data adjustments for path (atmospheric) radiance and sensor calibration offsets prior to band ratioing has often been overlooked or misjudged. This paper describes and demonstrates the critical nature of data adjustments for the production of useful ratio images, including ratio images derived solely from long-wavelength bands. A simple bispectral graphic model is used for illustrating and evaluating the impact of data offsets upon ratio images. Orthogonal indices, used as alternatives to band ratios, are shown to be sometimes less sensitive to topographic influences than ratios of unadjusted data but not less sensitive than ratios of properly adjusted data.

1. INTRODUCTION

Band ratioing is a standard image processing routine that is used to suppress radiance variations that are proportionally constant between bands (and are generally attributable to terrain illumination, ground albedo, and look-angle effects) in order to enhance spatial radiance variations that are proportionally inconsistent between bands (and are generally more informative as to surface composition). Although the theoretical need for data adjustments prior to ratioing to compensate for path radiance and sensor calibration offsets (collectively termed "data offsets") has been widely acknowledged, too often the practical importance of the adjustments has been overlooked or misjudged, and adjustments have not been implemented. The purpose of this paper is to clarify the importance of data adjustments by presenting (1) examples of image data for which adjustments are clearly critical and (2) a simple bispectral graphic explanation of the role of data adjustments in band ratioing.

2. IMAGE EXAMPLE: SHORT-WAVELENGTH BANDS

Figures 1a and 1b are band 1 and band 4, respectively, of a Landsat Thematic Mapper (TM) scene of the Eagle Mountains in southern California. The area is rugged

Agricultural Monitoring
and Econometric Modeling in an
Information Systems Contest
for the Regione del Veneto, Italy

Principle Funding Agency:
Dipartimento Foreste, Regione del Veneto

Joseph Scepan

University of California, Santa Barbara   **June 1988**

Agricultural Monitoring and Econometric Modeling in an Information Systems Context for the Regione del Veneto, Italy

Joseph Scepan

The Regione del Veneto has instituted a cooperative research program with the University of California with the goal to develop regional scale crop determination procedures and production and yield estimation techniques to support agricultural resource management. This project is a part of an integrated environmental monitoring program being implemented for the Regione. Accurate crop yield prediction capabilities can increase the efficiency of agriculture in the Regione as well provide useful environmental data on the use of water resources and the use of chemical fertilizers and pesticides. Accurate, systematic crop inventory and yield and production estimation techniques are being developed for six principal crops grown within the Regione: small grains (wheat and barley), soybeans, sugar beets, corn, vineyards and orchards. UCSB's ISRG funding has provided modest matching funds for this work, mainly through the funding of graduate students and their M.A. thesis research projects.

Developing a system of crop inventory in this area presents some particular challenges. The Regione del Veneto contains an extremely complex mix of land uses and land covers. In addition, agricultural production in the Regione is characterized by small field sizes, a diverse crop mix and multiple cropping in some areas.

Initial work in this study has demonstrated that both crop identification and crop yield modeling are data dependent. Accurate crop identification requires careful selection and timely acquisition of satellite data. Agrometeorological based crop yield modeling is dependent upon complete and accurate historical yield and weather datasets. We are developing a proposal at this time for the second funding period of this research, and will submit it to the regional administration during Summer 1988.

Geographic Information for Scholars

Jeffrey L. Star

University of California, Santa Barbara   June 1988

Jeffrey L. Star

The Research Libraries Group, Inc. (RLG) is a non-profit corporation owned by major universities and research institutions. The creation of RLG is an effort by research universities to manage the transition from locally self-sufficient and individually comprehensive collections to a system of interdependencies that will preserve and enhance our capacity for research, and improve our ability to locate and retrieve relevant information. RLG was established in 1974 by Harvard, Yale, and Columbia Universities and the New York Public Library. There are now roughly 40 owner-members, and numerous associates and special affiliates. Its goals are:

- to provide research institutions a structure through which common problems can be addressed

- to provide scholars and researchers with sophisticated access to bibliographic and other forms of information

- to enable libraries to manage their catalogs in an automated mode and in the context of an automated union file of all member collections

- to promote, develop, and operate cooperative programs in collection development, preservation of materials, and shared access to research materials

RLG owns and operates a major automated information system, running on dual Ahmdahl mainframe computers which are housed at Stanford University. Users can search over forty specific indexes, in addition to conventional search procedures. Information about some 18 million books, 2 million periodicals, and significant collections of maps, archives, and film are on line. The system supports simultaneous users around the world. The information system also forms a mechanism for shared catalogs, interlibrary loan, and collection management. The system also supports non-Roman alphabetic scripts, such as Cyrillic and Chinese.

One of the most recent RLG efforts has been the creation of a Task Force for Geoinformation. Dr. Jeffrey Star is the UCSB science representative to this task force. This new group has met several times to begin to understand the problems of managing and retrieving spatial data. Representatives from NASA Headquarters, (M. Devirian), NOAA (J. Hoake), and USGS National Center (T.M. Albert, D. Wiltshire) have attended these meetings in the past and given the group encouragement.

Funding has been provided over the last years by the Keck Foundation to develop a detailed system design, to be able to add geographic data to the RLG database. RLG has hired a full-time person for the task, Dr. Cecil Bloch. UCSB has been chosen as the first site for testbed activities in this newly-funded effort. A series of position papers have been created, and reviewed by a selected team of both science users and information management staff. Some of the key issues to be addressed include the development of standardized descriptions of spatial data elements, and arrangements for inter-institutional catalog access. These issues are directly parallel with those faced by the NASA pilot data systems, and the ESADS and EOS-DIS activities.

We continue reviewing detailed program plans, and are now beginning to develop and test standards for describing spatial data. The UCSB Browse testbed is directly relevant to this effort, and we have been in regular contact with the RLG members about our parallel research and development efforts. Dr. Bloch has been our guest at UCSB to discuss a first-phase implementation plan with us, and to review progress in allied areas (including the Catalog Interoperability and Data Systems Lexicon activities within NASA). We believe that the community of remote sensing researchers, in NASA and university laboratories as well as in the private sector, will directly benefit from this effort. We will continue to act as liaison between the RLG system developers and our colleagues, providing leverage between our NASA funding and the RLG private foundation resources. Presentations at professional meetings about the RLG activities for better managing spatial data resources are in the planning stages; we will continue to report on this exciting effort in our reports to NASA headquarters. The external system design document will be reviewed during the summer of 1988, with proposals to be developed for first phase implementation to follow.

Endangered Species Habitat Analysis

Joseph Scepan

University of California, Santa Barbara   **June 1988**

Joseph Scepan

Preliminary cooperative research activities between the Condor Research Center (CRC), Ventura, Ca. and the Geography Department, University of California (UCSB) have begun. The activities center on data compilation and implementation of an automated Geographic Information System (GIS) for use in identifying and analyzing remaining potential habitat for the California Condor (*Gymnogyps californianus*) within the state of California. Essential condor GIS data layers, including a land use and land cover classification system for use with multispectral satellite data, are identified and grouped hierarchically in a four part system.

A pilot study to construct a digital database for storing mapped information on potential habitat of the California Condor has begun. Digital maps of land use, vegetation, water bodies and roads were compiled for a 3600 sq km test site in southern California. These maps were co-registered with condor field observation data and satellite multispectral data acessions. These diverse datasets were stored and manipulated using geographic information system software available on the ERDAS (Earth Resources Data Analysis System) image processing system.

This pilot program has led us to consider the more general problem of species richness mapping, and the scientific and technical problems of determining appropriate characteristics for multi-species preserve sites. Several manuscripts are in preparation on these subjects, and grant proposals are in preparation for a follow-on to this work.

Sensor Technology
for Large Scale Vegetation Analysis

Jeffrey L. Star and John E. Estes

Full Text is Found in January 1, 1988
Progress Report and Proposal - Year 5

University of California, Santa Barbara   **June 1988**

This past year we completed a unit of work funded by NASA's Goddard Space Flight Center, under contract NAS5-28697, titled *An Evaluation of Current and Proposed Sensor Technology for Large Scale Vegetation Analysis*. The research we have conducted under this program has focused on the potentials of remote sensing technology for large-scale ecological studies. A portion of the funds for this work came from the current year's funding under NAGW-455.

The final report which was submitted to the agency under this contract had several sections. Following a brief introduction, we reviewed our research in field sites in the Boreal Forests of North America. This research is the culmination of several year's work, bringing together collaborators with expertise in botany, biogeography, and remote sensing. Through this research, we have begun to identify some of the processing algorithms that may be of use with present and future sensor systems, for a remote analysis of vegetation characteristics over large areas. The background for this work is a hierarchical investigation of four study sites in North America, examining sensors from helicopter-mounted spectroradiometers to the AVHRR multispectral imager.

The next section of the final report described an investigation in progress. We have proposed a series of research activities at a site in Santa Barbara county, where the regional toxic waste dump is located. We had hoped for repeated coverage by aircraft sensors, which was not possible for several reasons. The overall work plan focuses on the regional characteristics of vegetation, and how these characteristics may be impacted by the waste site. This work is continuing at this time, in collaboration with D. B. Botkin (also of UCSB). The report describing a portion of this work consisted, in part, of an M.A. thesis by one of our students, which explains our overall scientific approach, and a portion of the monitoring and research program we hope to develop in the coming years.

In a section of the report titled *Image Processing Algorithms for Natural Vegetation*, we presented copies of three published papers. These all revolve around the problem of classifying natural vegetation, based on remotely sensed data.

In a section of the report titled *Monitoring Waste Sites*, we presented a portion of a M.A. thesis, funded in part through this contract. The emphasis of this thesis is on a geographic

information systems approach to the management of hazardous waste sites. In this manuscript, remotely sensed data is a key input for monitoring the sites, to detect impacts off-site. The major emphasis in such monitoring is to track the flow of materials, via groundwater, surface, and airborne transport pathways. Sensitivity of vegetation to hazardous materials is an assumption; we therefore base a significant portion of the monitoring on remote sensing of regional vegetation condition. The student who worked on this research, Kenneth McGwire, continues working in our laboratory as a candidate for the Ph.D. degree.

COORDINATING HAZARDOUS WASTE MANAGEMENT ACTIVITIES USING GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT

This paper describes a framework for the role of geographic information systems (GIS's) in the monitoring and management of hazardous waste sites. Compilation of required information, incorporation of existing waste monitoring strategies, analysis of these data in a GIS environment, and the integration of computerized models for transport processes are discussed. Examples for the analysis of spatial data using cartographic overlay techniques and the implementation of geostatistical methods on monitoring data are provided from work in progress by the authors. These examples are set in the context of developing a fully integrated monitoring and management system utilizing GIS technology.

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Advanced Information Extraction Tools in Remote Sensing for Earth Science Applications

Mark A. Friedl, John E. Estes, and Jeffrey L. Star

Full Text is found in January 1, 1988
Progress Report and Proposal - Year 5

University of California, Santa Barbara   **June 1988**

Advanced Information Extraction Tools in Remote Sensing for Earth Science Applications

The following is a copy of a manuscript which has been submitted to <u>AI Applications</u> in <u>Natural Resource Management</u>. The manuscript is based on work we have conducted under this NASA grant, and considers the prospects and opportunities for merging artificial intelligence with modern geographic information systems.

University of California, Santa Barbara

Advanced Information-Extraction Tools in Remote Sensing for Earth Science Applications: AI and GIS

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Abstract. Remote sensing, the science of collecting information about objects with systems not in direct contact with them, is a powerful technology for gathering data about the earth. Most current computer-assisted information-extraction techniques for remotely sensed imagery are slower and less accurate than human interpretation. Techniques from artificial intelligence could alleviate a number of data analysis problems currently reducing the usefulness of remote sensing as an analytical tool. Geographic information systems (GIS) may also be coupled with these techniques to enhance their overall utility for resource applications. Computer vision approaches to image analysis and expert systems are suggested as key tools for development of knowledge-based image analysis systems for remotely sensed data. GIS can be used within this framework to provide site-specific information and collateral data to an expert image analysis system. The combination of techniques from the fields of artificial intelligence, remote sensing, and geographic information systems holds significant promise for enhancing the utility of remotely sensed imagery for natural resource management tasks.

Remote sensing is the science of collecting information about objects or phenomena by systems not in direct contact with those objects or phenomena. Remote sensing systems employ electromagnetic energy (e.g., light, heat, and radio waves) to detect, identify, and measure target characteristics (Sabins 1987). These systems have been coupled with space science technology to allow observation of the earth's land masses, oceans, and atmosphere with instruments carried on earth-orbiting satellites. A serious limitation that has reduced the overall utility of remote sensing as a tool in natural resource management has been the failure to develop accurate and efficient computer-assisted techniques to extract information from remotely sensed images. In this paper, we consider techniques from the domains of artificial intelligence (AI) and geographic information systems (GIS) that we believe may alleviate a number of the limitations of current computer-assisted information-extraction techniques.

The objectives of this paper are: 1) to identify the limitations of current computer-assisted image analysis techniques in remote sensing; 2) to review and assess the development of AI techniques in remote sensing for image analysis; 3) to consider how the emerging technology of GIS can be combined with AI techniques to improve image analysis; and 4) to identify avenues of research that hold particular promise for natural resource management applications. Although a comprehensive discussion of the full range of impacts of AI upon remote sensing and natural resource management is beyond the scope of this paper, we have attempted to identify issues especially pertinent to the stated objectives. Specifically, the problem of information extraction from remotely sensed imagery is emphasized.

Remote Sensing

History and terminology. Aerial photography, the first form of remote sensing, has been used extensively since before World War II for mapping and monitoring of natural resources. Technological developments in the 1950s and 1960s provided two key advances that enhanced the utility of such imagery. First, developments in remote sensing instrumentation ex-

Interpolation and Uncertainty in Geographic Information Systems Modeling

Kenneth C. McGwire and John E. Estes

Full Text is Found in January 1, 1988 Progress Report and Proposal - Year 5

University of California, Santa Barbara   **June 1988**

Interpolation and Uncertainty in
Geographic Information Systems Modeling

Kenneth C. McGwire and John E. Estes

The following paper was presented at the International Geographic Information Systems Symposium, Crystal City, Virginia, in November of 1987. Mr. McGwire, the first author, is one of the students whose M.A. thesis research has been funded in part by this continuing grant. The paper discusses an important computational problem in spatial data processing, that of interpolating surfaces from limited point data. This work is an outgrowth of our investigations into merging disparate data sources with remotely sensed data. Mr. McGwire continues his work in our laboratory, and has joined our department's Ph.D. program.

University of California, Santa Barbara

Interpolation and Uncertainty in GIS Modeling

Kenneth C. McGwire and John E. Estes

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University of California, Santa Barbara

ABSTRACT

This paper discusses the incorporation of data taken from point samples with area covering data types found in a geographic information systems (GIS). The authors provide examples for two methods of interpolating point data to area covering surfaces and statistical methods for characterizing error for these surfaces. The moving averages technique of interpolation is found to be computationally efficient, however, establishment of optimal interpolation parameters is difficult and only a simple error statistic can be generated for GIS data layers created using this method. Kriging, a geostatistical technique, is a more demanding method for interpolation of surfaces and may be appropriate for certain environmental variables. Kriging is shown to provide valuable estimations of error throughout the surfaced data layer, reflecting spatial positioning of samples and variance observed in those samples. Techniques for the estimation of error in GIS data layers, such as those discussed in this paper, must be implemented in operational GIS's in order to provide information products and confidence measures that will form the basis for effective decision making with spatial data.

1. INTRODUCTION

This paper presents examples and analysis of the implementation of moving average and geostatistical interpolation techniques in a GIS environment. As the legitimacy of analysis using a GIS is inherently dependent on input data quality, the uncertainty associated with synthetically derived datasets must be characterized in order to determine the limits of data application. This paper limits itself to examining the use of two interpolation techniques for a GIS in the context of providing a product with known error characteristics. These techniques were chosen to represent methods for meeting two different levels of accuracy and error characterization requirements for interpolated products. The "jackknifing" method (Mosteller and Tuckey, 1977) is applied to assess the accuracy and stability of interpolated products generated by moving averages. Benefits of geostatistical methods in optimizing interpola-

The Earth Observing System
for the 1990 and 2000 Decades

Alexander J. Tuyahov, Jeffrey L. Star, and John E. Estes

Full Text is found in January 1, 1988
Progress Report and Proposal - Year 5

University of California, Santa Barbara   **June 1988**

The following is a draft of a chapter which will be published in the monograph, "Our Role in Changing the Global Environment", to be published by Academic Press. This chapter is designed to explore the space-based systems we expect to be able to use to examine the Earth in the next few decades. The monograph is directed towards a general audience, including environmental scientists interested in large-area problems, as well as other scientists working on interdisciplinary research programs involving the Earth as an integrated system.

University of California, Santa Barbara

The earth observing system for the 1990 and 2000 decades

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INTRODUCTION

An understanding of Earth as a system requires that research be conducted from an interdisciplinary focus. Such research must be directed toward the processes operating across the boundaries between the atmosphere, oceans, and land surfaces, as well as on man's impact on these processes. Examples of such cross-boundary problems include the increase in atmospheric carbon dioxide, the anticipated depletion of the ozone layer and deposition of acid rain. Study of these Earth science processes must be approached in quantitative terms, on a unified, global basis, and over time scales ranging over several decades. The purpose of this paper is to review the historical trends leading to the current interest in interdisciplinary Earth science, and the development of present the current status of concept development for an Earth Observing System (Eos), a planned United States National Aeronautics and Space Administration (NASA) Space Station related program for the 1990 and 2000 decades. Eos will provide the observational and information system capabilities needed to significantly contribute to an understanding of Earth processes, with an emphasis on those global processes that operate at or near the Earth's surface.

The newest and most important initiatives in the U.S. civilian space program currently revolve around the Space Station complex. The Space Station complex includes not only the station itself, but also its associated co-orbiting and polar satellite platforms. This proposed suite of platforms and support systems offers a unique potential for facilitating long term, multi-disciplinary scientific investigations on a truly global scale.

The man-tended systems which are proposed for these future platforms

will have new and unique capabilities to provide a wide range of data from both operational and research sensors. The large volumes of multispectral, multitemporal data expected from these systems, if supported by efficient and effective data systems, may provide a continuity of data which has been substantially lacking from previous systems, operating on independent free flying platforms. The challenge to the remote sensing community is two-fold. The first challenge is to prepare for the large volumes of data which will become available in the late 1990's. The second challenge to the scientific community is to bring the tools we are developing to a broader constituency, in the service of what we call global science; or as discussed by Botkin et al, (1984), "The Science of the Biosphere". The biosphere is the large scale planetary system that includes and sustains life.

For those scientists concerned with the earth's surface, the most important component of the Space Station complex is the Earth Observing System (Eos) (NASA, 1984a; NASA, 1984b). Eos, based on the current design concept, has both active and passive earth surface sensor systems as well as atmospheric sounding systems (Table 1). Eos is an evolutionary step in our efforts to remotely sense the earth, and may provide a large scientific community with data in support of multidisciplinary research on an unprecedented scale. Unlike the previous generation of satellites, designed for relatively limited constituencies (such as the Landsat series for the land scientist and Seasat for the oceanographic community), Eos has the potential to provide an integrated source of information which recognizes the scientific interest in investigating the dynamic coupling between the oceans, land surface, and atmosphere.

In the same way that Eos represents an evolution in earthward-looking satellite technology, we believe that Eos may help begin an evolutionary improvement in our understanding of our planet. Traditional branches of the earth sciences have been limited in scope to modest areas, and to relatively narrow ranges of biophysical, geochemical and socioeconomic processes by the extent technology to measure map, monitor, and model those processes. It is our hope that Eos will foster and expand collaboration between scientific disciplines, continuing recent trends within the remote sensing community toward interdisciplinary science on an international scale.

Historical Perspective

The history of science and technology shows a general trend towards specialization, with individuals developing greater expertise in

A Knowledge Based Geographic Information System

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A Knowledge Based Geographic Information System

Terence R. Smith

The research and development cycle of the Knowledge Based Geographic Information System (*KBGIS*) has been documented in these reports over the past three years. Funded principally through the U.S. Geological Survey, with additional help from NASA and the National Science Foundation, KBGIS represents a new approach to geographic information systems, by merging modern developments in software engineering, artificial intelligence, and data structures.

In the past years, we have developed a second build of the system, which is principally a proof-of-concept tool. This version (*KBGIS II*) was delivered to the USGS in summer of 1987. The system has been run successfully using a variety of realistic queries that included learning as well as basic queries. As a result of these demonstrations, several areas for further research were identified, particularly in relation to the spatial database. During the past year, most of the research and development of the system has concentrated on redesigning, rebuilding and testing the database, although continued development of the high-level constraint-satisfaction query-answering system has also proceeded.

New areas of development and research , described below, are now underway. By June 1988, version KBGIS-III will be available, which will be a "usable" system. By June 1889, we expect to have a much more extensive and powerful version, KBGIS-IV, available.

Research during the year 1987-88 has involved three major developments:

The reconstruction of the quadtree database with the use of bit-parallelism to speed up processing. This has permitted great speed-up in query answering, particularly with such operations as Boolean Overlay.

The use of bit parallelism has also been accompanied with the exploitation of the space efficient Autumnal Quadtree. The new system has been implemented in C instead of Lisp and runs very quickly.

The use of Relatively Addressed Compact Quadtrees in the database, which are very space efficient structures. This memory management scheme has proved to be very efficient.

The continued development of Multicomponent Object Search using Constraint Satisfaction. Although this problem is at least NP-hard, our strategy of pruning the space and searching for objects in a component-wise fashion has proved very successful.

The three major developments have been implemented in a testing mode, and have resulted in system speedups of up to two or three orders of magnitude. The results of the research are written up in three manuscripts that have been submitted for publication.

The following developments are planned for the following year:

The addition of image processing capabilities into KBGIS-IV, using the same database structures as in KBGIS-III.

The ability to link the system to more standard vector based systems, such as ARC-INFO, to obtain the capabilities of both types of systems.

The development of a powerful graphics front end.

The conversion of the high-level query answering system into an object-oriented system.

The recoding of the system to run under a UNIX environment on systems

such as SUN 350's.

These developments will occur over the next year, and should result in an extremely powerful system. A proposal to the USGS is now pending for the majority of the funds needed for these new efforts. The accompanying paper by Smith, Peuquet, Menon and Agarwal discusses some of the accomplishments of the development team in the past years.

KBGIS-II

A knowledge-based geographical information system

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Abstract. This paper describes the architecture and working of a recently
implemented knowledge-based GIS (KBGIS-II) that was designed to satisfy several
general criteria for GIS. The system has four major functions, query-answering,
learning, editing and training. The main query finds constrained locations for
spatial objects that are describable in a predicate-calculus based spatial object
language. The main search procedures include a family of constraint-satisfaction
procedures that use a spatial object knowledge base to search efficiently for complex
spatial objects in large, multi-layered spatial data bases. These data bases are
represented in quadtree form. The search strategy is designed to reduce the
computational cost of search in the average case. The learning capabilities of the
system include the addition of new locations of complex spatial objects to the
knowledge base as queries are answered, and the ability to learn inductively
definitions of new spatial objects from examples. The new definitions are added to
the knowledge base by the system. The system is currently performing all its
designated tasks successfully, although currently implemented on inadequate
hardware.

1. Introduction

A geographical information system (GIS) may be viewed as a data base system in
which most of the data are spatially indexed and upon which a set of procedures
operates in order to answer queries about spatial entities represented in the data base.
In a previous paper, Smith *et al.* (1987) suggested five design requirements that a
general, large-scale GIS should satisfy, as well as suggesting and describing four general
principles that may be employed in order to meet these requirements. In the current
paper, a knowledge-based GIS (KBGIS-II) is described whose design and implement-
ation are based on the five requirements. These requirements and principles are briefly
summarized in this section before a detailed description of KBGIS-II is provided in the
remainder of the paper.

1.1. *Requirements and principles of GIS design and implementation*

Previous research suggests that the following general requirements should be
satisfied in the design and implementation of most GIS:

(*a*) an ability to handle large, multi-layered, heterogeneous data bases of spatially-
indexed data;

(*b*) an ability to query such data bases about the existence, location and properties
of a wide range of spatial objects;

(*c*) an efficiency in handling such queries that permits the system to be interactive;

(*d*) a flexibility in configuring the system that is sufficient to permit the system to be
easily tailored to accommodate a variety of specific applications and users; and

(*e*) an ability to 'learn' in a significant way about the spatial objects in its
knowledge bases during use of the system.

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