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GIS EDUCATION AND TRAINING OPPORTUNITIES AT MONTANA STATE UNIVERSITY

Montana State University has been able to incorporate geographic information systems (GIS) and remote sensing technologies into its programs of instruction, research, and extension during the past five years with the assistance of the M.J. Murdock Charitable Trust and the creation of a campus-wide Geographic Information and Analysis Center (GIAC). The Murdock grant provided sufficient resources to establish GIS and remote sensing facilities at several discrete sites and this approach coupled with the creation of the GIAC afforded the opportunity to avoid the college and departmental "turf" wars that often accompany new equipment acquisitions. The facilities now in place include 5 copies of workstation ARC/INFO and ERDAS and 18 copies of PC ARC/INFO and IDRISI. The instructional program includes a GIS/Spatial Analysis minor and emphasis in addition to two GIS courses based on the NCGIA Core Curriculum and several other courses with substantial GIS/remote sensing components. A number of innovative funding and cost-sharing programs have been implemented across campus to successfully promote the use of these technologies in research and extension programs.

BACKGROUND

Montana State University is a comprehensive, multi-purpose institution maintaining, in the land grant tradition, programs of instruction, research, and extension. The University currently has 10,300 students with an academic faculty of 550 and another 200 professionals engaged in research and extension activities. Instruction is offered through the Colleges of Agriculture, Arts and Architecture, Business, Education, Engineering, Health and Human Development, Letters and Science, and Nursing. The academic program emphasizes the professions of agriculture, architecture, business, education and nursing, along with strong support from the arts, humanities, biological, physical, and social sciences. The Department of Earth Sciences, as part of the

College of Letters and Science, offers bachelor's and master's degree programs in geography and geology, and in addition contributes significantly to the agricultural and engineering professional curricula.

The addition of two new geographic information systems (GIS) courses to the undergraduate geography program was accomplished during the past academic year as part of the switch from quarters to semesters. However, the efforts to acquire GIS and remote sensing software and related computer hardware to support these and other courses can be traced back to the submission of a proposal to the Instrumentation and Laboratory Improvement Program (ILI Program) at the National Science Foundation (NSF) in November, 1987. This proposal was funded in 1988 and led the university to expand the GIS initiative to include research and extension as well as the instructional program. A major grant from the M.J. Murdock Charitable Trust assisted with the acquisition of equipment and a campus-wide Geographic Information and Analysis Center was established by the Montana Board of Regents in March, 1989 to operate these new GIS and remote sensing facilities. The extension activities involve both the Office of Extended Studies, which administers and coordinates on- and off-campus instruction in the form of courses, institutes and conferences for individuals not regularly enrolled at Montana State University, and the Extension Service itself.

This paper describes the facilities currently in place and the ways in which they are used to support GIS education and training.

GIS AND REMOTE SENSING FACILITIES

The initial NSF-ILI proposal aimed to acquire GIS software and related computer hardware for use in several curricula at Montana State University. This proposal envisaged the purchase of single copies of ARC/INFO and PC ARC/INFO, two Tektronix 4207 graphics terminals (to be linked to an existing DEC MicroVAX II minicomputer), and a 9500-series Calcomp digitizer and 1043 GT plotter (to be linked to an existing Zenith 286 PC). However, this plan was expanded because of the advances in computer technology (i.e., local area networks and high performance workstations and PCs) that occurred during the 12 month delay in funding and the decision by the university administration to make a much larger investment in GIS facilities than initially proposed.

The facilities now in place consist of:

(a) A Student GIS/AutoCAD Laboratory with 10 Zenith 386 PCs, 10 Zenith 286 PCs, 20 Summagraphics digitizers, and 3 Hewlett Packard pen plotters running 20 copies of AutoCAD, 15 copies of IDRISI, and 10 copies of PC ARC/INFO. These facilities represent the main teaching facility and, as such, they support the laboratories and other "hands-on" components of the five GIS and remote sensing courses described in the next

section and are available to all Montana State University students 7 days per week, 18 hours per day.

(b) A Student GIS Laboratory in the College of Letters and Science with 2 Digital 3100 workstations, 1 Digital 486 PC, 2 Zenith 386 PCs, 2 Calcomp digitizers, 1 Houston Instruments scanner, 1 Calcomp pen plotter, 1 RasterGraphics electrostatic plotter, and 1 Digital laser and 1 NEC dot matrix printer running ARC/INFO, ERDAS (on workstations), PC ARC/INFO, IDRISI, and dBASE IV (on PCs) connected with a local area network (LAN). A Digital color film recorder and Tektronix color thermal-wax printer will be added to this network during the next three months. These facilities are available to 10-20 designated students (from any college) and are used primarily for thesis research, small group and one-on-one training, and student work experience programs.

(c) Two workstations (1 Digital 5000 and 1 Digital 3100 workstation) running ARC/INFO and ERDAS on the LAN described in (b) above in the GIS Technician's offices and 1 Zenith 486 PC running PC ARC/INFO and IDRISI in the author's office.

(d) A Student GIS Laboratory in the College of Agriculture with 1 Digital 3100 workstation, 1 Zenith 386 PC, 1 Calcomp digitizer, and a NEC dot matrix printer running ARC/INFO, ERDAS (workstation), PC ARC/INFO, and IDRISI (PC). These facilities are available to 5-10 designated students (from any college) and are used primarily for thesis research, small group and one-on-one training, and student work experience programs.

(e) A Student GIS Laboratory in the College of Engineering with 15 IBM-compatible PCs, 1 Hewlett Packard digitizer, 1 Hewlett Packard pen plotter, and 1 Hewlett Packard laser and 1 NEC dot matrix printer running 15 copies of AutoCAD and single copies of PC ARC/INFO and IDRISI. These facilities are available to 10-20 designated students (from any college) and are used primarily for thesis research, small group and one-on-one training, and student work experience programs.

(f) Two IBM-compatible PCs and a Hewlett Packard color laser printer running PC ARC/INFO and IDRISI in the USDA-ARS Rangeland Insect Laboratory. These facilities are available to USDA-ARS scientists and students and are used primarily for thesis research and student work experience programs.

(g) One IBM-compatible PC and a Calcomp digitizer running PC ARC/INFO and IDRISI in the Montana State Department of Fish, Wildlife and Parks (MT-FWP). These facilities are available to MT-FWP scientists and students and are used primarily for thesis research and student work experience programs.

The bulk of the GIS activities on campus are administered and sustained by the Montana State University Geographic Information and Analysis Center which is staffed by a director (the author) and two technicians with backgrounds in GIS/computer programming and GIS/ cartographic production. These technicians are supported by the university's instructional budget as well as from research grants. All three individuals have benefitted from extensive ARC/INFO

and ERDAS training during the past year as part of the university's expanded implementation strategy.

GIS AND REMOTE SENSING EDUCATION

The facilities described above support the "hands-on" components of five GIS/remote sensing courses as follows: (i) GEOG 305--Introduction to Geographic Information Systems, (ii) GEOG 410--Intermediate Remote Sensing, (iii) GEOG 411--Advanced Issues in Geographic Information Systems, (iv) GEOG 501--Landscape Analysis, and (v) P&S 417--Aerial Photograph Interpretation and Remote Sensing. The course descriptions listed in the 1991-1993 Montana State University Undergraduate Bulletin are reproduced in Table 1. These descriptions indicate the number of credits, prerequisites, and frequency of offering in addition to course content.

The author is responsible for the two GIS courses and graduate geography course listed above. The GIS courses more or less follow the National Center for Geographic Information and Analysis (NCGIA) Core Curriculum (Goodchild and Kemp 1990), and the laboratory component uses assignments from the NCGIA GIS Laboratory Exercises (Dodson et al. 1991; Veregin 1991) and the "PC ARC/INFO GIS Concepts Kit" published by Environmental Systems Research Institute, Inc. (ESRI 1991). These courses are intended to serve students with diverse backgrounds and they focus on GIS principles and concepts rather than the mechanical steps required to use one or more GIS software packages. The clientele for the GEOG 305--Introduction to GIS class taught this past Autumn Semester, for example, consisted of one faculty member (geology), six graduate students (three geography students and one each from geology, soils and wildlife management), 17 undergraduates (eight geography, three secondary education/social studies broadfield, two soils students and one each from computer science, electrical & electronic engineering technology, geology and range science) and three non-degree (i.e., second degree) students. The GEOG 411 course taught in Spring Semester was similar in that it attracted three graduate students (one each from geography, land rehabilitation and soils), six undergraduates (four from geography and one each from electrical & electronic engineering technology and soils) and one non-degree student. The NCGIA materials have been very helpful in that they have allowed the author to design courses that teach GIS concepts and applications and cater to the different strengths and weaknesses that such a diverse group of students brings to these classes. It would have taken several more iterations to achieve this goal without these materials.

Two other faculty members play secondary roles in that Dr. Gerald Nielsen teaches P&S 417--Aerial Photograph Interpretation and Remote Sensing and a new geography faculty member (Dr. Andrew Marcus) added during the past academic year will teach GEOG 410--Intermediate Remote Sensing. Both classes were offered prior to the acquisition of the equipment described in the previous section and they are being extensively modified to take advantage of the new facilities. The laboratory component of P&S 417 will make extensive use of the IDRISI software and the "hands-on" aspects of GEOG 410 will utilize the ERDAS software package.

TABLE 1. GIS and Remote Sensing Course Descriptions

GEOG 305 Introduction to Geographic Information Systems
Fall, 4 credits, 3 lecture, 1 laboratory
PREREQUISITE: GEOG 211--Cartography, CS 150--Computer Literacy; GEOG 301--Quantitative Methods in Geography recommended

Introduction to fundamental principles, data structures and basic functions used in GIS. Labs provide "hands-on" exposure to computer processing with a variety of GIS software packages.

GEOG 410 Intermediate Remote Sensing
Spring alternate years, to be offered 1993, 3 credits (lecture)
PREREQUISITE: ESCI 310--Aerial Photograph Interpretation

Earth analysis using satellite, thermal infrared and radar imagery and digital computer enhancement of remote sensing data. Makes extensive use of ERDAS image analysis software package.

GEOG 411 Advanced Issues in Geographic Information Systems
Spring alternate years, to be offered 1992, 3 credits (lecture)
PREREQUISITE: GEOG 301--Quantitative Methods in Geography, GEOG 305--Introduction to Geographic Information Systems

Students study several important GIS algorithms, data structure theories, advanced computational topics and analysis of error in depth. Operational and management issues arising from the use of GIS in scientific research, planning and resource management are also discussed.

GEOG 501 Landscape Analysis
Fall alternate years, to be offered 1991, 3 credits (recitation)
PREREQUISITE: One of the following: GEOG 306--Research Methods, GEOG 430--Mountain Geography, ESCI 307--Geomorphology

Application of field and quantitative methods, geographic information systems, remote sensing and computer modeling to the geography of landscapes. Research and management techniques applied to land, water and atmosphere as they relate to contemporary environmental problems.

P&S 417 Aerial Photograph Interpretation and Image Analysis
Spring, 2 credits, 1 lecture, 1 laboratory
PREREQUISITE: Junior standing and one of the following: P&S 201--Soil Resource, GEOG 101--Introduction to Physical Geography, GEOL 101--Introduction to Physical Geology, BIOL 303--Principles of Ecology

Obtaining airphotos, stereo viewing, image processing equipment, aerial reconnaissance for land management and land use decision-making. Remote sensing, earth resources satellites, infrared, multispectral remote sensing, and image enhancement.

These classes do not exhaust the education opportunities in that many students are interested in using GIS and remote sensing technologies as part of individual problems credits and/or their thesis research. Eighteen students have pursued these options to date and it is already clear that their computer and/or GIS backgrounds help determine the kinds of projects and problems they can handle. We have found, for example, that computer science majors and students with the introductory GIS class behind them can design and carry out modest projects of their own choosing with minimal direction and assistance. Those with strong computer backgrounds have found the "IDRISI Student Workbook" (Eastman 1990) and "Understanding GIS--The ARC/INFO Way" (ESRI 1990) materials easy to follow and helpful in learning about GIS concepts and applications when working on individual problems. Students from other backgrounds appear to require a great deal of direction and assistance and like graduate students wanting to use GIS and/or remote sensing in their thesis projects, they often require GIS and remote sensing training in addition to the educational opportunities described here. The GIS training component involves learning how to use the software products, themselves and is discussed in the next section.

The focus of the five classes and other education opportunities noted above exemplifies the university's land grant mission in that the effort is split almost evenly between the technology itself and the applications to which it can be applied. This same split is evident in the Spatial Analysis/GIS Emphasis and Spatial Analysis/GIS Minor offered by the Department of Earth Sciences (Table 2). The Spatial Analysis/ GIS Emphasis was designed for geography majors and is intended (as the name implies) to offer these students expanded opportunities to explore geographic skills and computer science topics that contribute to GIS and other kinds of spatial analysis. The Spatial Analysis/GIS Minor was designed for students with other majors (i.e., biology, computer science, geology, range science, soil science, etc.) and is intended to offer these students expanded opportunities to explore GIS and the other geographic skills that are often used in conjunction with this technology. Several students have already signed up for one or other of these options and we anticipate about a dozen students signing up for each option once semester enrollment patterns are established.

GIS AND REMOTE SENSING TRAINING

GIS training is offered to individuals not regularly enrolled at Montana State University as well as graduate students and others with projects that demand an in-depth knowledge of one or more software packages. The major vehicles used to offer GIS and remote sensing training to the first group consist of the 3-day Introduction to PC ARC/INFO course and special one-of-a-kind short courses and demonstrations that are usually offered in conjunction with other campus events. The PC ARC/INFO course was developed by ESRI, Inc. and is offered by the Office of Extended Studies two or three times per year. This course requires a 5 or 10-key PC ARC/INFO Lab Kit (305 Reid Hall) and a certified PC ARC/INFO instructor (the author). The other short courses and demonstrations that we have developed are mostly linked to agricultural applications. The Computing Mapping Seminar taught by the author and one of the GIS technicians as part of a Crop and Pest Management School for producers, county agents, present and future crop consultants and other agribusinesses in January, 1992 is a typical example of the kind of program

TABLE 2. Spatial Analysis/GIS Emphasis and Minor

Spatial Analysis/GIS Emphasis

Courses used here may not be used to fulfill geography advanced-elective requirements:

Required Geography Courses:	Credits
ESCI 310 - Aerial Photograph Interpretation	3
GEOG 301 - Quantitative Methods	3
GEOG 305 - Introduction to Geographic Information Systems	4
GEOG 306 - Research Methods	3
GEOG 410 - Intermediate Remote Sensing	3
GEOG 411 - Advanced Issues in Geographic Information Systems	3
Other Required Courses:	
CS 120 - Program Design	2
CS 140 - Pascal Laboratory I	1
CS 221 - Computer Science I	2
CS 222 - Computer Science II	2
CS 223 - Computer Science III	2
CS 224 - CS Laboratory I	1
CS 225 - CS Laboratory II	1
CS 226 - CS Laboratory III	1
STAT 217 - Intermediate Statistical Concepts	3
TE 230 - 2-D Computer Aided Drafting	3

Spatial Analysis/GIS Minor (Non-Teaching)

Required Courses:	
GEOG 211 - Cartography	3
GEOG 301 - Quantitative Methods in Geography	3
GEOG 305 - Introduction to Geographic Information Systems	4
GEOG 306 - Research Methods	3
GEOG 410 - Intermediate Remote Sensing	3
GEOG 411 - Advanced Issues in Geographic Information Systems	3
STAT 216 - Elementary Statistics	3
Take one of the following:	
CE 463 - Photogrammetry	2
ESCI 310 - Aerial Photograph Interpretation	3
P&S 417 - Aerial Photograph Interpretation and Image Analysis	2

that we have offered to date. We occasionally bring ESRI, Inc. and ERDAS staff to campus to provide special training seminars for faculty, graduate students and other collaborators as well.

The GIS and remote sensing training activities are also of interest to graduate students and others with projects that demand an in-depth knowledge of one or more of the software packages. These individuals are encouraged to obtain grant funds to cover the costs of GIS training (i.e., the 3-day Introduction to PC ARC/INFO course) and expert help from the GIS technicians throughout the duration of their projects. However, this approach favors those faculty and students with funded research projects and discourages new faculty and others looking to make use of this technology. The university has initiated two strategies to help alleviate these problems and increase access to GIS and remote sensing technology: (i) the College of Agriculture has funded part of the GIS technician's salaries so that they can assist agriculture faculty with GIS training and pilot projects that will increase the likelihood that these faculty members will obtain research and education grants that would utilize this technology, and (ii) the College of Letters and Science has funded part of the GIS technician's salaries from the university's instructional budget. This last step was taken so that these individuals can assist the author in teaching GIS laboratories and in providing training and other kinds of assistance to students with individual problems and thesis projects. The events of the past two years have demonstrated that this last type of support is critical if the author is to maintain his other teaching and research activities in addition to the administrative and public relations duties related to GIS.

The Geographic Information and Analysis Center also hires students to work on collaborative projects with federal and state agencies such as the USDA-Soil Conservation Service, USDI-Bureau of Indian Affairs, USDI-Bureau of Land Management, Montana Department of Agriculture, Montana Department of Transportation and Montana Department of Fish, Wildlife and Parks. Most of these projects to date have involved the development and editing of geographic databases and as such, they depend on a cadre of students who are skilled operators of ARC/INFO, ERDAS and other GIS and remote sensing software products. The GIS technicians are critical to this effort as well because they provide training and assist with project design, management and quality assurance. These kinds of projects offer the university and students four major advantages: (i) they provide students with paid employment while attending college; (ii) they help support small group and one-on-one training programs that some students want and need to strengthen their employment prospects upon finishing college; (iii) they help the university pay the computer hardware maintenance and software license costs that recur on an annual basis; and (iv) they facilitate regular contact with outside agency personnel that will (hopefully) lead to new research opportunities for faculty and students in the future.

THE FUTURE

Although Montana State University has made significant progress with the implementation of its expanded GIS and remote sensing strategy during the past three years, the most important work has in many ways just started. The university is now faced with the tasks of: (i) making the

facilities available to faculty and students for GIS and remote sensing education, training, research and extension activities; and (ii) providing funds to cover the technician's salaries, computer hardware maintenance and software license costs. It is already clear that GIS and remote sensing education, training, research and extension activities can and must complement one another for this endeavor to succeed and that it is expensive enough (annual costs are expected to run at about $75,000 per year) that it will fail without campus-wide support from all three university programs (i.e., instruction, research and extension). The establishment of a campus-wide center that crosses college and department boundaries, the partial support of the technician's salaries from the university's instructional budget, the faculty development and training program initiated in the College of Agriculture, the collaborative projects with federal and state natural resource agencies and the plans that are being formulated to return part of the indirect costs from research grants with GIS components to the Geographic Information and Analysis Center to help pay for the operation of the facilities are clearly steps in the right direction and their continuation will help to ensure the long-term success of this important initiative.

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