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# THE KEYS FOR REMOTE SENSING EDUCATION

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## ABSTRACT

Difficulties related to remote sensing education include: a shortage of facilities at academic institutions; incomplete remote sensing data sets; prohibitive costs of data processing; and only a small number of operational remote sensing programs.

Textbooks and courses covering the principles of remote sensing and data analysis characteristics are readily available and numerous references exist in the published literature.

"Seeing is believing" is the most effective way to teach and micro-computers are contributing to this approach. Furthermore, the remote sensing curriculum would be naturally increased if the remote sensing data could be distributed in various media such as floppy disks or video disks. For that purpose, mass data reproduction technologies must be developed, and are expected to be realized in the near future.

The most important factor is to have properly trained teachers and to establish methodologies to extract applied information from remotely sensed data. This situation is analogous to that of medical doctors. Now every medical doctor knows what a chest x-ray image is, how they were taken, and how to apply the information to medical diagnosis. Previously, older doctors never had access to x-ray technology and relied solely on a medical diagnosis based on experience. In other words, we need to educate the students with new attitudes and new perspectives. There is a need for each specialized discipline to have experts trained in remote sensing technology so that remotely sensed data can be applied for specialized problem solving.

## I. INTRODUCTION

The successful launch of Landsat 4 (with the TM sensor) heralds a new era in remote sensing technology. Associated with this new advance in technology and ten years of scientific development and application is the need to provide more information on global envrionmental resources. Engineering accomplishments in terms of satellite and sensor design, hardware development, and communication technology have been impressive. However, the application of satellite remote sensing technology has been limited, in large part, to its sophisticated engineering, physical science, and computer-related designs.

Understanding the highly technical aspect of satellite remote sensing can only be accomplished through educational programs in the university environment. Increasing the number of trained personnel in this arena is necessary for applications of this technology to proceed. It is pertinent to now review remote sensing educational trends.

## II. REMOTE SENSING EDUCATION

Generally, there are three major disciplines associated with remote sensing education at academic institutions: engineering and technological; scientific applications; and technical training for problem solving. Although the three disciplines are significantly different, there are numerous common basic and fundamental concepts.

One of the major problems encountered in a remote sensing course is the fact that the class consists of students from several disciplines. Therefore, scientific and mathematical competence is highly variable. For example, most will have familiarity with non-parametric statistics, but multivariate analysis is often not as universally understood. Others might have a well developed physical science background and easily understand radiometric concepts, but have no biological orientation and fail to appreciate phenological significance of vegetative analysis. Such circumstances make it very difficult to develop an effective course curriculum that will provide sufficient background information so all students can communicate at the same level. Table 1 shows the profiles of students under the guidance of the principal author (J.I.) in Japan. Although they come from very different disciplines, the common interest is "remote sensing."

Based on our collective experiences in teaching remote sensing, student difficulties are encountered with the following concepts: units of radiometry; radiance; radiometric properties of the atmosphere; reflectance in association with digital data; effects of azimuth and solar illumination; radiation and thermal temperatures; and spatial resolution and resolving capability of sensors. Although these concepts are often novel to the interdisciplinary course, they are described in detail in most textbooks and the literature. Therefore, the burden of exposing the students to these often complex areas does not necessarily fall solely upon the teacher. Nonetheless, the educator must be capable of developing a general class appreciation of these fundamental principles, or an integrated approach to remote sensing will be lacking.

In our experience, the most efficient mechanism for understanding remote sensing concepts and applications is to have students gain hands on experience on an image processing system. Student interaction with a system reinforces the fundamental concepts of electromagnetic energy, reflectance, birghtness, pixel size, resolution, etc., since image processing requires at minimum, a comprehension of these concepts. Our experience emphatically shows that such access to a digital image processing system is mandatory, and lectures alone cannot integrate the broad subject effectively. Satisfactory image processing starts with the knowledge of spectral response of targets and mechanisms of interaction between targets and electromagnetic waves. Appreciation of the products of satellite imagery can only be possible if this relationship is understood.

Furthermore, the above properties of sensor principles must be linked to biological, structural and cultural phenomena on the earth's surface. For example, estimation of evapotranspiration in a specific area requires some knowledge of the physical evapotranspiration process, plant physiology, and vegetative phenology. If crops are involved, one must also know the crop calander, tilling techniques, method of fertilizer application, etc.

The above example illustrates the point that each scientific discipline has its own inherent specializations that are not necessarily easily conveyed or transformed to remote sensing requirements. Consequently, remote sensing applications are feasible only if the scientific knowledge of a discipline can be matched to remote sensing technology. Once again, the burden falls upon the educator to successfully interpret contemporary scientific knowledge and relate it to remote sensing data.

Spectral response of particular vegetative phenomena is highly dependent on temperature, rainfall, soil characteristics, and evapotranspiration. Remote sensing as a discipline is relatively new and students must be exposed to the complex relationship between these parameters and in situ measurements. Perhaps it is advisable to focus more effort on how to gather data on the spectral characteristics in a standardized procedure.

## A. COMPUTER TECHNOLOGY AND REMOTE SENSING EDUCATION

In the past, access to machine processing of satellite data was restricted to a small number of institutions that had expensive mainframe computers. Although such large computers are still required for advanced remote sensing applications, recent advances in large scale integrated (LSI) circuits have provided low cost microcomputer systems for digital image processing. Several software packages for remote sensing applications are now available and one can now order Landsat data on 8 inch diskettes, direct from EROS. In addition, user-friendly language is a standard component of such systems, enabling utilization of these hardware/software systems by non-computer programming personnel.

Different institutional requirements will dictate to some degree specific demands for memory capability, but a general configuration of requirements are listed in Table 2. Although the costs associated with some microcomputer systems are now relatively low, we are concerned about recent cost increases of Landsat data.

## B. RESOURCE REQUIREMENTS FOR REMOTE SENSING EDUCATION

The basic requirements for remote sensing education are: 1) appropriate remote sensing images, 2) data processing facilities, and 3) good instruction. Selection of images to be used in the course should focus on the particular interests of the students. In a Remote Sensing of Natural Resources course at the University of Maryland, the second author (K.M.G.) uses conventional aerial photography, Landsat MSS, and TM, and extensive ancillary information to produce general land cover/land use maps of the campus area. Natural Resources is the broad unifying discipline in this course, so image processing centers around forest/wetlands of the nearby Chesapeake Bay. These data sets include chronological as well as seasonal differences.

Generally, in a small introductory class, data processing is mostly a demonstration procedure using both the microcomputer and IMPAC system as well as the more elaborate $I^2S$. It is our experience that in an introductory level course, there is insufficient time for the students to actually gain hands on experience. For efficient learning of image processing capabilities, we prefer that the students each have the opportunity to sit and interact with a hardware system. At the University of Maryland, a software image processing package (ASTEP), is reasonably accessable to large numbers of students through remote terminals on the UNIVAC central computer. However, we feel this type of approach is of limited value in an introductory course because there is no color graphic interaction, only a line printer product. An overview of these three remote sensing systems is available in Figure 1.

A critical component for a successful remote sensing course is a qualified teaching staff who are familiar with remote sensing principles, hardware/software image processing systems, and conduct active research in their particular disciplines. Such a combination of talents requires an interdisciplinary approach to remote sensing. Again, we draw an analogy to educating medical doctors. Learning x-ray technology does not necessarily also yield expertise in medical diagnosis. The physician combines his medical experience with x-ray images to improve diagnosis. Similarly, the scientist should use remote sensing imagery as a tool to assist in his/her research or management decisions.

### C. SUBJECTS AND TEACHING METHODS

The design of a remote sensing course can be divided into the following four areas: 1) the physical interpretation of remote sensing, 2) data processing, 3) information extraction, and 4) applications and modeling. The level of intensity for teaching can be considered from two levels: a general overview approach, or a more detailed analysis. This depth of teaching is generally related to the scientific interests and training of the students. Our experience indicates that this is a challenging task for the educator. If one immerses the students too deeply into the theory of atmospheric properties using scattering theory and correction functions, most of the students will become discouraged. This is particularly true for those students who have only a weak academic background in physics and engineering. Nonetheless, proper exposure to these problems is necessary to provide the students with a clear appreciation of the limitations and potential of remote sensing technology. Table 3 shows a general outline of the two levels of approaching this course.

Table 4 presents the outline used in the course taught by K.M.G. at the University of Maryland. Digital processing of Landsat data is conducted in the second half of the course, so that fundamental concepts, that are for most students learned for the first time ever in the beginning of the course, can be reinforced. The IMPAC system is extremely condusive for learning purposes because the student can perform classification by invoking a command file and following procedural messages on the screen. Several parameters exist that are discussed by the instructor and a color display and line-printer output are produced for further analysis. Throughout the course, field trips are used to reinforce the classroom and textbook material. Ancillary information for several localities is used in conjunction with the Landsat derived products. The objective of such a process is to provide the students with an understanding of how the digital data compares to more conventional maps and aerial photographs.

The remote sensing course conducted by the senior author (J.I.) in Japan begins with an initial orientation on remote sensing (6-12 hours). In this phase, principles, physical meaning, and interpretation of remote sensing are covered. Data processing for these students is available through guidance from senior students who have previous data processing experience, and demonstrate land use classification using MSS data. Ordinarily each student will process a different area of the same scene. After obtaining their results, each student presents their findings in a small seminar. Experience shows that this procedure assists the student in comprehending not only the function of data analysis, but also how to select the training fields, the sequence and rationale of parameter selection, modification of parameters from intermediate results and interpretation of results. Class review of histogram or similar statistical output of data distribution is necessary at this point. At the completion of this phase, each student has an understanding of the benefits and limitations of processing techniques. After this basic education, independent research subjects are assigned to each student according to their interest and study objectives. Generally, this phase requires weekly review by the instructor, who assesses satisfactory progress and with the student helps plan further analysis. Continued experience with data analysis increases remote sensing competence of the student so that he/she can proceed independently in further remote sensing applications.

## III. CONCLUSIONS

As mentioned above, difficulties with remote sensing education vary according to background disciplines of students and the resources available for digital processing at each institution. In summary, we conclude the following from our own experiences:

1) The teaching staff must have an appreciation of the potential and limitations of remote sensing and technology.

2) Examples of remote sensing data are required to cover a broad selection of discipline areas.

3) Data analysis must proceed within a context of scientific rationale.

4) There is a need to stress scientific applications of remote sensing to satisfy growing needs across disciplines.

5) Each discipline area requires a re-orientation so that data collection becomes more compatible to remote sensing technology.

6) Provide standardized low cost facilities for data analysis, such as microcomputer systems.

7) Promote the availability of data media such as video disk, floppy disk, and digital video disk for analysis with low cost hardware systems.

8) Improve guidelines for extraction procedures of remote sensing data as they relate to each scientific discipline.

Table 2. Computer Systems for remote sensing

A. Microcomputer basis:

basic configuration (5 students/$5000 or less)

- standard 8 bit microcomputer
- graphic image printer
- 8' floppy disk x 2
- color monitor (TTL level)
- BASIC/FORTRAN
  - options
    - graphic digitizer
    - color plotter
    - color display (256 x 256, 512 x 512, 12-16 bits plane)

medium range (5-15 students/$10,000-$40,000)

- multi terminals (16 bits multi task)
- large disk: fixed hard disk 10m-50mbytes
- color hard copier

B. General purpose:

large capacity computer (>10 similutaneous users)
- data base function
- geographic infomation system combination with graphic capabilities
  - functions
    - map output
    - photoprocessing
    - mosaic enhancements

Table 1. Student disciplines and special research applications in remote sensing courses

| Discipline | Independent Study Subjects |
|---|---|
| Fishery Science | - sea-surface temp./sea current front<br>- analysis of fish catch in relation to sea surface temperature |
| Architecture | - urban environmental changes<br>- greeness index of urban areas<br>- comparison major cities in the world |
| Image Technology | - texture extraction<br>- directional feature enhancement |
| Physical Oceanography | - texture patterns of clouds in conjunction with sea currents and fronts |
| Geology | - linear feature extraction by spatial filtering<br>- geological similarity in frequency domain |
| Computer Science | - interactive image editing<br>- image data base<br>- ground truth data base |
| Agricultural Engineering | - soil mapping<br>- preprocessing for vegetation classification |
| Forestry | - forest type classification of Mt. Fuji area using preprocessed MSS data |

Table 3. Two levels of intensity for a remote sensing course

| | Level I<br>Introductory/General | Level II<br>Advanced |
|---|---|---|
| PHYSICAL CHARACTERISTICS | - definition and terminology of physical parameters:<br>reflectance<br>radiance<br>CCT count vs. radiance<br>- sensing system<br>data type<br>- how to use annotated data<br>- meaning of spectral response and its significance<br>- relationship between digital pixels and remotely sensed data<br>- effects of image enhancement and usage<br>- image display methods<br>- basic image handling<br>- basic classification principle<br>- how to use classification functions of computer<br>- differences of supervised/unsupervised procedures | - Solar environment<br>atmospheric properties<br>preprocessing for atmospheric correction<br>radiometric normalization of temporal data<br>- algorithm resampling method<br>- image smoothing (banding, etc.)<br>- advanced color display method (RGB/HUE conversion)<br>- texture analysis<br>- geometric correction and mapping<br>- image processing<br>- system concept<br>- graphic data manipulation |
| INFORMATION EXTRACTION (CASE STUDY) | - how to set up training fields<br>- usage of ground truth data/how to use and interpret the ground information<br>- how to interpret statistics of spectral data | - relationships between target phenomena and remotely sensed data<br>- method to develop required preprocessing |
| APPLICATION STUDY | - how to evaluate computer generated outputs<br>- regrouping of classes<br>- interpretation of spatial relationships<br>- significance of spatial relationships | - correlation analysis with target information and analyzed results of remotely sensed data<br>- model building (discipline oriented) |

Table 4. Remote sensing course example

Class name: Remote Sensing of Natural Resources
(Includes 3 field trips)

| | |
|---|---|
| Lect. #1 | Introduction to Remote Sensing |
| Lect. #2 | Photographic systems remote sensing |
| Lect. #3 | Airphoto Interpretation/Landuse-Landcover |
| Lect. #4 | Applications and characteristics |
| Lect. #5 | Characteristics of MSS |
| Lect. #6 | Classification Training |
| Lect. #7 | Graphic Products |
| Lect. # 8 | LANDSAT |
| Lect. # 9 | Image Interpretation |
| Lect. #10 | Terrestrial Ecosystems |
| Lect. #11 | Aquatic Ecosystems |
| Lect. #12 | Natural Resource Monitoring and Inventory |
| Lect. #13 | Global Issues and satellite sensors |

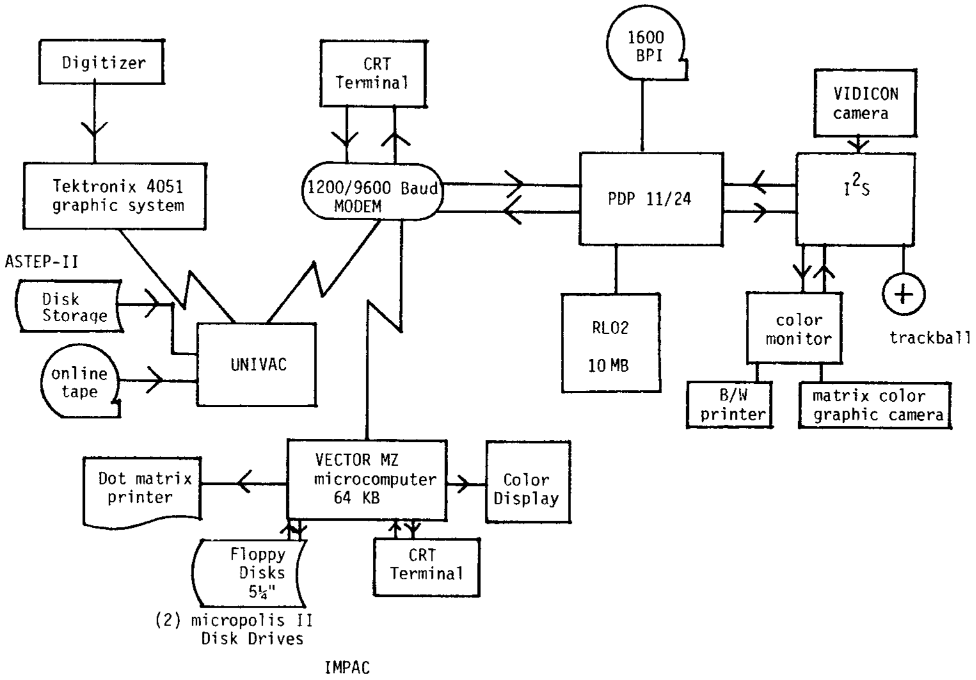

Figure 1. Image processing and computer systems support at RSSL