Reprinted from

Symposium on Machine Processing of Remotely Sensed Data

June 27 - 29, 1979

The Laboratory for Applications of
Remote Sensing

Purdue University
West Lafayette
Indiana 47907 USA

IEEE Catalog No.
79CH1430-8 MPRSD

TRANSFER OF REMOTE SENSING COMPUTER TECHNOLOGY TO THE DEVELOPING WORLD - CASE EXAMPLES

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I. PROBLEMS IN TRANSFER

A. LEVEL OF COMPLEXITY

Computerized image processing represents a level of technology sufficiently advanced that the Agency for International Development (AID) has had years of problems attempting to set up the necessary equipment support. The theory of pattern recognition and various software algorithms, such as maximum likelihood, k th nearest neighbor, and supervised clustering, are difficult to teach to remote sensing resource managers and technicians with limited education in mathematics. Computer hardware is relatively complex and, in addition to requiring programming skills, both procedural level, as well as operating systems, also requires training in electronic "trouble-shooting" and computer maintenance to keep systems in operation.

B. EXPERIMENTAL NATURE OF TECHNOLOGY

Landsat is regarded by the U.S. Government as an experimental system. Because there are no governmental agencies nor private groups which have been willing to take over an operational Landsat system, the user community can expect a continuation of significant changes in satellite sensors, progressing from the present Multi-Spectral Scanners (MSS) through the Thematic Mapper (TM) to Multiple-Linear Arrays (MLA). These changing bands, spectral ranges, quantization levels, and other sensor features require fundamental changes in the few computerized image processing systems which AID has developed in the Third World. We are thus in a position of having to assist in modifications to these systems every time new sensors are flown after Landsat-3.

C. VARIATION IN TAPE FORMATS

The Landsat ground station managers' working group notwithstanding, Computer Compatible Tape (CCT) formats are not uniform among all Landsat stations. In particular, this very university (Purdue) hosting this Symposium has been under contract to me to write software converting Brazilian tape format to NASA Goddard format in order that the LARSYS package operating in Bolivia will process Brazilian CCT's. With foreign Landsat stations springing up everywhere (in addition to those operational in the U.S., Canada, Brazil, Italy, and for a time in Iran, ground has been broken for stations in Argentina, Sweden, India, and Australia, funding is approved or obtained for stations in Thailand and Japan, and serious discussions are under way for stations in Mexico and Upper Volta), variations in CCT formats make it extremely difficult and expensive for AID to assist Less Developed Countries (LDCs) in developing computer technology for image processing.

D. LACK OF PHASED APPROACH

Because computer classification for the most part is limited to the spectral domain and generally ignores spatial relationships of land uses, inferring resources, especially those beneath the earth's surface, requires a certain degree of visual analysis, or eye-brain correlations. Thus the best interpreters are those well grounded in basic air photo interpretation and who have, since this training, mastered the fundamentals of computer interactive image processing. Many LDCs entering the remote sensing arena are oversold on computer technology and, in their enthusiasm to acquire these image display devices and progressive-looking computers, completely bypass the hard, sweaty work of manual interpretation training. It is the author's considered opinion that the worst misuse of remote sensing technology, as well as the major reason for sophisticated equipment sitting in disuse or disrepair, is the short-cutting by a user of a necessary phased approach to digital image processing through visual analysis to analog equipment.

E. RELATION TO MINERAL EXPLORATION

The application of remote sensing to mineral exploration requires the extraction of the maximum informational content from multispectral data. Minerals can generally be inferred from surface anomalies, such as soil staining from percolating water through ore-bearing sediments, increasing area density of geological fault traces, and discontinuity in vegetation patterns. Many times these anomalies are far too subtle to be recognized on conventional images, but indeed can be seen on image products generated by special enhancement of digitized reflectance levels. This enhancement, as well as other classification techniques, usually requires computer technology. Since the developing world is rich in mineral resources, their interest in computers for this application is understandable.

From AID's perspective, the problem is the application, not the technology for pursuing the application. We agree that computer processing of remotely sensed data is at times the only conceivable way that anomalies associated with mineralization can be identified. We're also only too painfully aware that in many LDCs mineral exploitation stands the only chance that these countries probably have in ever pulling themselves away from total economic dependence on the industrialized world. However, AID's congressional mandate is to reach the rural poor in the extension of benefits resulting from science and technology (S&T). There is no industrial technology which has exploited the poor more blatantly, has crippled and killed more laborers, and has resulted in more economic inequity, than mining in the Third World. The tens of thousands of economically deprived Andean Indians who have perished in tin mines over the centuries are vivid reminders of an industry which does not represent a direct link between S&T and the poor majority. The gap between the very rich and the desperate poor still today grows wider in many LDCs because of this one industry alone.

Although we indirectly assist a handful of LDCs to master the fundamentals of digital image processing so that they can carry out mineral exploration on their own, we do have an implicit policy not to carry out extensive projects in mineral exploration. Thus many LDCs' requirements for entering the computer image processing arena to explore for minerals are not compatible with AID's mandate to assist the rural poor. The need for computer technology to improve inventories of agricultural crops has not been articulated to us in our projects in over 35 LDCs. If and when this requirement is identified, we can policy-wise enter the computer environment in a more meaningful and comprehensive manner.

F. CAPITAL-INTENSIVE TECHNOLOGY

Compared to light tables, hand lens, density slicers, color additive viewers, and other analog equipment, computers represent capital-intensive technology. Our investments to equip a visual analysis laboratory range from $200,000 to $800,000. For the few computer multispectral facilities, the investments have ranged from $1,000,000 to over $5,000,000. The computer facilities employ from 5-10 professionals of a special nature; the visual analysis labs generally support 15 to 50 multidisciplinary resource technicians, many of whom possess lower level skills than the specialties associated with computer facilities. Each visual analysis center thus employ more people with a greater variety of skills than the computer facility does. Since employment is a serious economic, as well as a social, concern in LDCs, the more intermediate technology associated with visual analysis is more acceptable to our Agency's strategy than is computer technology.

II. CASE EXAMPLES

A. INTRODUCTION

There is no intention in the following four case examples to cast disparaging remarks about resource departments and managers in any developing countries. If any blame is to be placed, then we in AID must assume our share, as the development of the computer facilities described was carried out for the most part under our remote sensing assistance program. However, the four countries were carefully selected because, after experiencing the problems described below, all four are struggling with different degrees of success to carry out remote sensing projects with the assistance of, or in spite of, their computer capabilities. All four today have solid reputations in using remote sensing to survey their natural resources. The discussion of their (and our) problems is intended to provide guidance, and suggest awareness and caution, to other LDCs which, in spite of this paper, decide to embark on the rocky road of computer image processing.

In LDCs where computer image processing systems are supplied by private manufacturers, the company name will not be stated. The reason for this name avoidance is to preempt any possible public slander of a private corporation, although the misuse or poor management of a computer system of course in no way casts any reflection on the quality of the system. Anyone working with remote sensing in the developing world will know the system anyway, without my having to mention it. In the case of software programs developed by universities, I will take the liberty of identifying them, as well as the type of computers on which they were installed, for the purpose of illustrating the degree of complexity in the technology transfer process.

B. EGYPT

The Egyptian Remote Sensing Center is located in the Academy of Scientific Research and Technology, Cairo. The Center is noteworthy in its potential for data analysis and processing using the advanced interactive computer facilities which include advanced digital processing, display and recording techniques. The year 1971 saw the tripartite cooperation among the Academy, Oklahoma State University, and the U.S. National Science Foundation in remote sensing. This handful of scientists with limited skills in resource management got remote sensing off to a bad start. The fact that Egypt is disproportionately rich with U.S. foreign assistance dollars (half of AID's budget goes for special economic assistance to Egypt and Israel) triggered the Egyptian request for some of the best remote sensing processing machinery which the U.S. had to offer.

To give one an idea of the size of the Center, 65 highly qualified scientists and resource specialists are employed there. The attraction of this Center has enticed geologists, mining engineers, hydrogeologists, agronomists, soils scientists, geophysicists, photogrammetrists, civil engineers, and physicists to go to work at this Center, thus leaving operational line agencies where they were previously employed. Since the Center does not have the charter nor manpower necessary to effectively carry out resource surveys, the country's overall mapping programs have suffered. They now seek funds for mapping, indicating the Center is having difficulty in coordinating activities with the line agencies.

This stalemate to carrying out an effective resource survey program is unfortunate, as the Center is truly one of the most advanced in the developing world. Possessing a multispectral analysis capability, the Center also has a photographic development, printing, and enlargement laboratory with both black and white, as well as color, capabilities. The Center also boasts two twin-engine aircraft equipped with an 11-channel multispectral digital scanner, a single channel scanner, infrared thermovision cameras, gamma spectral radiometric scanners, and aeromagnetic systems. The Center itself possesses densitometers, light tables, stereoscopes, a 4-channel color additive viewer, a zoom transfer scope, and automatic spectrophotometers. Because of the lack of training in electronic troubleshooting, the computer multispectral analysis equipment was recently down for over one year.

C. THAILAND

Thailand has been actively applying remote sensing to natural resource problems since the early 1960's. It was Thailand which first applied Landsat data to study the rate of deforestation, a phenomenon adversely affecting almost every country of the developing world. In 1961, the Thais mapped their entire forests using aerial photography, and concluded that 58% of their country was forested. In 1973, using Landsat images, they remapped their forests at scales of 1:500,000 and 1:1,000,000, and were shocked to learn that their forests had decreased from 58% of the country to 37%. Many of the forests were being illegally poached, in addition to being cleared for firewood by individual farmers. The Thais presently have strict laws to control clearcutting, and, despite all the rhetoric from the remote sensing community about the need for deforestation surveys, the Thais have one of the only national forest monitoring programs in the world. The need for rapid identification and measurement of forested lands prompted the Thais to adapt computer routines in 1974.

The National Research Council (NRC) of Thailand has successfully implemented two computer programs for Landsat image analysis, the LIGMALS and the RECOGX.

NRC has LIGMALS (a simplified system developed by the University of Michigan) set up for running on the Burroughs 1710 at the Burroughs Corporation, a U.S. firm with a branch office in Bangkok. Although most of NRC's effort with LIGMALS has been devoted to getting the program running on the 1720, NRC plans, for cost reasons, to set the program up on an IBM 370/135 at Chulalongkorn University. NRC will fund this adaptation themselves.

NRC was able to successfully adapt the Colorado State University RECOG image analysis program, which runs on the CDC 6400 computer, to the Asian Institute of Technology (AIT) IBM 370/145 computer. The three basic interpretation features of this new RECOGX package are density level slicing, Euclidean Distance Rule, and the Maximum Likelihood Classifier. The Thais went one step further, by adding a cubic convolution subroutine for averaging brightness levels, necessary when enlarging a Landsat sub-image.

The NRC applied the RECOGX software to classify mangrove around the Bang Pakong estuary, land uses around Bang Pra reservoir, and the delta of lower Bang Pakong estuary and Wang Noi District.

No agency, including NRC and AIT, are using the RECOGX frequently at the present time. Operational use is discouraged due to the requirement of having an AIT systems programmer load the program in computer memory core and set up the job control cards to get the program running. As AIT to date has not had the operational charter nor the academic commitment to computer image processing, a dedicated systems programmer is not available to set RECOGX up whenever a user wishes to process Landsat imagery. This situation has discouraged NRC from making ample use of the software system they were instrumental in developing. It is envisioned that the development of a regional remote sensing center at AIT will see a firm commitment to image processing and dedicated programmers who will be charged with maintaining many image analysis programs.

D. SRI LANKA

In 1974, a serious shortfall of cereal grains required Sri Lanka to import 950,000 metric tons of these grains. Since Sri Lanka traditionally imports up to 50% of its food supply (mostly rice), paying for it by export crops such as tea, rubber, and coconut products, it was realized by Sri Lanka's Ministry of Agriculture and Lands that digital processing of Landsat data over the small island was necessary to identify and measure these small fields.[1]

Since the phased approach (described under PROBLEMS, D.) was recognized as necessary, manual techniques preceeded the digital systems, with a Zoom Transfer Scope and a small digital programmable calculator purchased for the country. Secondly, the simple computer software package LIGMALS (adopted also by Thailand) was modified and adapted for operation on the existing computer facility (an IBM 360/25) at the Sri Lanka Department of Census and Statistics. The modifications consisted of dividing the LIGMALS package into five stand-alone programs for batch-mode operation. Outputs from these modifications in Sri Lanka are graymaps of single Landsat bands or ratios of bands, histogram plots, and computations of classified data.

Sri Lanka has put this technology to good use, monitoring very narrow strips of rice grown in relatively inaccesible floodplain areas. They are presently improving their system, striving to add color capability, for identification of irrigated and rain-fed rice, rubber, coconut, sugar cane, and tea. Their progress is presently threatened by high-sales pitches from another U.S. university to Sri Lanka government officials. These discussions, ignoring the orderly development of digital technology described here, have forced the Deputy Surveyor General to take a defensive position, describing to these officials the limitations of satellite remote sensing. The officials are presently viewing the Landsat as a panacea for all of their informational needs, and seem prepared to commit the small island nation to a greater reliance on this technology than results to date warrant.

E. BOLIVIA

Since the launch of Landsat-1 in 1972, Bolivia has developed one of the Third World's finest remote sensing centers. Termed GEOBOL, the Center employs almost thirty full-time professionals, who continually generate geology, soils, and land use maps of their vast and poorly mapped country. The techniques they use are manual, relying on simple analog instruments and excellently-trained photo interpreters for turning out these operational maps. The reputation of GEOBOL is known to anyone who professes to be a remote sensing professional in any country of the world.

In early 1975, in a cooperative project with the U.S. Geological Survey, GEOBOL successfully classified over ten different concentrations of salt brines in the vast Salar de Uyuni. Subsequent field surveys in the areas of highest brine concentrations identified the highest Lithium concentrations yet discovered in the world and netted the Government of Bolivia $137,000,000 in exchange for exploration rights by a mining firm. As the salt brine densities could only have been mapped by computer classification, Bolivia began an intensive effort in the winter of 1975-76 to acquire digital classification software. Under AID and other foreign assistance funding, GEOBOL settled on the LARSYS package of Purdue University and, with the technical assistance from LARS/Purdue experts, began setting up the programs on computers in La Paz. To date, the programs are operating, and have been used to a limited extent to map land uses in Bolivia's eastern rain forests. The Bolivian's intent on using the LARSYS for mineral exploration depends upon their success in obtaining funding assistance to pay for computer time and personnel to analyze Landsat images. AID has had to turn down this request due to our charter to reach the rural poor, but the Inter-American Development Bank is now considering the request. In addition, because the Brazilians format their Landsat Computer Compatible Tapes (CCT) differently than NASA's, and because LARSYS was originally written to read NASA formatted CCT's, AID had to write a second contract to LARS to develop a computer program which converts Brazilian tapes to NASA-formatted tapes.

III. SUMMARY

We in AID do not advocate the general use of computer image processing in the developing world, and, in many cases, have actively discouraged governments from adopting this technology in their national programs. In certain, rare circumstances, where a country has already developed a strong capability to manually analyze remotely sensed data, we have, and will, provide extraordinary assistance in developing computer technology, where that country can show, and we concur, that the additional capability is technically and economically justified.

In addition to the six problems previously mentioned in transferring this technology, we in AID feel obligated to advise LDCs not to adopt computer systems for other, more fundamental reasons. Most systems have been developed in the U.S., and some specifically to handle Landsat data. Presently, the U.S. does not have a national remote sensing policy; indeed, there is no mission planned after Landsat-D to monitor earth resources. Since the best developed plans for the 1980 era are those of the French, Japanese, and other industrialized countries, we are advising LDCs to carefully consider these programs when shopping for digital processing systems. In addition, since LDCs are generally forced to grab data when they can (since they are outside the coverage circles of foreign Landsat stations), they must continue to take advantage of any space system flown in the future. In particular, the NASA Large Format Camera, proposed for flight on the Shuttle, may offer an excellent, hard-film source of high resolution information. Computer processing systems would be almost worthless for analyzing this imagery; a better job could be done by manual techniques, and LDCs would save themselves a large investment and many headaches by ignoring the potentially obsolete computer systems. Likewise, some military/intelligence high resolution photos may become declassified in the next few years and, if so, could represent data complementary to Landsat for LDCs to map their resources, again without sophisticated computer systems. And, to encourage LDCs further into looking to hard film in the future, the Soviets are now releasing MKF-6 imagery (20 meter resolution, multispectral) to selected LDCs in an attempt to initiate a remote sensing technical assistance program. This imagery, far superior to Landsat and of great value to more and more LDCs as the Russians make this imagery more available, requires at the present a special MSP-4 multispectral projector for analysis.

Finally, instead of simply purchasing computer systems from industrialized countries, we encourage LDCs, working with or without U.S. technical experts, to develop their own systems, following the examples of Mexico and India. In this way, the LDCs have a complete understanding of both their hardware and software and, more importantly, develop the technical pride in knowing that their hybrid system has been designed in light of the resource monitoring requirements of their own country.

REFERENCE

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