LANDSAT DATA AND INTERACTIVE COMPUTER MAPPING

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ABSTRACT

A large amount of earth resource data currently resides on maps. Efforts are underway in diverse environments to convert this data to digital form. The basic techniques used include manual digitizing and automatic scanning. In both cases, the data capture process is typically more than one generation away from the original source, and that inevitably entails some degradation of the data. However, original source data can be acquired without the degradation associated with conversion from existing maps. LANDSAT data is such a source.

LANDSAT data is a valuable source of original earth resource observations. Its abundant supply has stimulated its use in many diverse applications. Increasing numbers of resource professionals are compiling and analyzing data derived from satellite imagery; included are agronomists, archaeologists, cartographers, engineers, foresters, geographers, geologists, geophysicists, meteorologists, oceanographers, planners and others. The demand for interpreted image data is growing. Such data has great potential as input to Geographic Information Systems (GIS).

The tools for processing LANDSAT data are becoming more responsive. The opportunity to quickly view the results of processing is important so as not to interrupt the workflow and thought process of the resource professional. Also important is the linkage of processed imagery to descriptive data. Interactive computer mapping can provide these capabilities and more.

BACKGROUND

The application of computers to mapping has evolved over a period of more than thirty years. The evolution can be divided into three parts: 1) 1950-65; 2) 1965-75; and 3) 1975-present.

During the first period, 1950-65, computers were seldom dedicated to any one particular application such as mapping. They were generally used for data processing. Emphasis was on solving numerical problems in batch mode. Computer mapping was slow and the graphic quality of output was poor. The delay between input, processing, and output interrupted the workflow; and editing delayed the process further. Significantly, observations from space began during this period.

During the second period, 1965-75, computer mapping began to slowly move out of the passive phase of batch mode processing. Electronic devices for displaying graphics improved, and minicomputers made mapping-specific systems more economical. The graphics-using community refined its taste and level of expectation toward computers. Some of the first functional computer mapping systems were configured for interactive mapping during this period. Also, remote sensing from space became established, and image processing emerged.

During the most recent period, 1975-present, interactive computer mapping gained acceptance. Computer equipment became less expensive and more powerful. Price declined as performance improved. Systems became easier to operate, and programming specific to mapping improved in functionality and availability. Research and development continued in image processing.

This paper will continue by expanding on three subjects: 1) Remote Sensing and Image Processing; 2) Interactive Map Compilation; and 3) Integrated Geographic Information Systems.

REMOTE SENSING AND IMAGE PROCESSING

For the purpose of this paper, the discussion of satellite image analysis will be restricted to techniques applied to Multi-Spectral Scanned (MSS) data collected by LANDSAT.

There are a number of things that the analyst is concerned with when processing satellite imagery; included are the spectral (color), spatial (size and shape), and temporal (rate of change) characteristics of a LANDSAT scene. Tone, texture, and context are also of interest. A basic premise is that different features of the earth's surface have distinguishable spectral signatures. It is also known that different features of the earth's surface come in different shapes and sizes. And, since LANDSAT scans the entire surface of the earth every 18 days, we can monitor conditions that change with time.

LANDSAT data is readily available to the private as well as public sector. Applications include wood supply studies, crop yield forecasts, soil moisture and erosion studies, water quality assessment, drainage studies, land use and route planning, energy and mineral exploration, and evaluation of damage from insects, fires, disease, and storms.

Except for the Thematic Mapper (TM), which is no longer sending back signals, LANDSAT scanners record energy reflected from the earth's surface in four spectral bands. Each LANDSAT scene covers about 185 square kilometers, and each scene can be broken down into pixels that are roughly 80 square meters each. The pixel resolution of the TM scanner was about 30 square meters, and seven spectral bands were recorded for each pixel instead of the usual four.

Locational data extractable from LANDSAT images meet U.S. Geological Survey mapping standards at 1:250,000. One of the main requirements for effective use of satellite imagery is the ability to locate the area of interest in terms of accurate geographic coordinates.

To accurately represent the earth's surface, LANDSAT imagery requires several types of correction. Geometric correction is needed to register the image to geographic coordinates. Also, since six scan lines are obtained in each scanning sweep, and each scan line is recorded by a different detector for each band, radiometric corrections are necessary to adjust output from the detectors to some standard. In addition, haze correction is needed to reduce atmospheric scattering, and solar illumination correction to adjust for the average brightness across an entire scene.

The bandwidths on LANDSAT imagery were selected for their specific information content. Reflected energy in the green band (500-600 nanometers) gives data on the density and vigor of vegetational cover, sediment loads in water, soil contrasts, snow cover, and sea-ice. The red band (600-700 nanometers) is suitable for distinguishing landforms, geologic structures, cultural features, drainage patterns, and land use. The reflective infrared bands (700-800 and 800-1100 nanometers) are useful for vegetation classification, wetland and flood delineation, urban area delineation, water pollution detection, and plant disease determination.

Traditionally, a number of analog and digital techniques have been employed to make effective use of the spectral data from LANDSAT's repetitive coverage. The techniques are to enhance and/or classify subtle variations in the imagery that otherwise would go unnoticed.

Analog techniques include image projection through filters and color enhancement (film density slicing). Film densities control the proportion of light transmitted through colored filters or are converted to equivalent voltages and used as input to the color guns of a video display system. Quantitative digital values are not necessarily employed with these techniques. The main drawbacks are that the film is one generation away from the source and a priori knowledge of which filter combinations will work best on which spectral regions is not always available; much time can be spent registering images and creating composites.

Digital techniques are most relevant to interactive computer mapping systems. They are either supervised or unsupervised. The technique used depends on whether the analyst chooses to input known information (a priori knowledge) or let the statistical relationship of the data determine the classification.

Supervised classification requires a priori knowledge. Training sets comprised of known features for a given area are identified by the analyst. The computer is trained to recognize each known feature (such as pine forest) based on the associated spectral value which can be identified. The computer can then search the entire image area for features having the same spectral values and classify them into groups which can be assigned a distinguishing color for display purposes. Interactive response is highly desirable for supervised classification. The quicker the response, the more subtle features the analyst can seek. A minimum of computer knowledge should not detract from the analyst's pursuit of distinguishable data.

Unsupervised classification assumes no a priori knowledge of the items to be classified. The analyst must specify several statistical parameters, usually on a trial and error basis. The total population of data is inspected by the computer for relationships based on the statistical parameters and classified into similar groupings. Clusters can be formed either by progressive division of the total data set, or by building groups through progressive addition. The analyst must then examine the groupings for some known information in the area of coverage and identify each class. This also represents an interactive requirement.

In addition to the image classification techniques already discussed, there is a requirement for image enhancement routines. Such routines are mainly used to boost an image so that the human analyst may be able to discern a greater amount of information from the image data than otherwise possible. Spectral techniques, for example, can be used to bring out the appropriate contrast in a LANDSAT image, preferably in real-time.

Sometimes, the size, shape, and orientation of objects in an image are as important as the spectral characteristics. In geology, for example, spatial criteria is critical for enhancing linear features such as faults, and circular features such as salt domes. Locating such features on enhanced images takes a skilled analyst. With enhancement techniques, the analyst combines visual inspection and computer-aided processing to extract the data inherent in an image.

Clearly the commercial processing of LANDSAT data has taken root. All of the major oil companies, along with most large forest resource companies, have capabilities of processing LANDSAT data. The growth of commercial applications will be stimulated by the integration of image processing capabilities with interactive computer mapping systems.

INTERACTIVE MAP COMPILATION

Map compilation is performed by surveyors, photogrammetrists, remote sensing specialists, and cartographers who gather, convert, and integrate data with a variety of tools and techniques. Interactivity is the quick response of the computer to operator demands.

The collection, or gathering, of data relies on either existing base materials or original surveys, and sometimes both. Existing maps and documents can serve as the foundation upon which other information is built; or, information can be derived from existing materials to build a new base. Original surveys provide source data suitable for building new base maps and compiling overlay information. Included are land surveys, aerial surveys, seismic surveys, satellite surveys, demographic surveys, and others.

Once data has been collected in some form, the next step is conversion, or data capture. If the source data is already in some type of digital or analog format, it must be translated into the system being used. For land survey data, standard coordinate geometry can be used to build a digital file. Coordinates can be keyed-in from survey notes or legal descriptions, or entered from an electronic measuring device, such as an electronic theodolite. A stereodigiting interface can be used to compile planimetric and topographic details from aerial photographs. Existing maps can be digitized automatically using laser scanning technology, or digitized manually using an electronic cursor device on a digitizing table. Satellite imagery can be classified to recognize different earth characteristics. An important conversion requirement is the feature coding of map and related data as it is entered into a data base.

After conversion, and sometimes during, map data must be integrated into a common, consistent format for easy retrieval and maintenance. Different scales and projections may need to be brought to a common ground for merging with other map coverage. A continuous base map with a wide area of coverage and large-scale accuracy can be created and maintained. Maps on materials with unstable physical properties can be distorted by changing humidity conditions. Mathematical fitting routines need to be used to correlate data from such distorted sources with known coordinates on dimensionally stable media. Also, aerial photographs and satellite images need to be adjusted for distortions inherent in flat representations of the earth's curved, irregular surface.

One missing component of most interactive computer mapping systems is the ability to process satellite image data. However, with raster display technologies being perfected for vector graphics, the opportunity currently exists to integrate vector data with raster imagery. In fact, a capability has been demonstrated between Intergraph and some of the leading image processing firms for converting Intergraph compiled vectors to grid data and overlaying on raster imagery to perform interactive edits. The next step is to perfect some automatic image enhancement and classification routines on the integrated systems.

It is now appropriate to begin a discussion of integrated Geographic Information Systems (GIS).

INTEGRATED GEOGRAPHIC INFORMATION SYSTEMS

Geographic Information Systems (GIS) emerged during the late 1960s and became firmly established during the 1970s. GIS represents a multidiscipline approach to describing the spatial characteristics of data innate to a geographic area for resource planning and management purposes. Point, linear, area, and attribute data are all integrated into GIS.

A need exists to improve the input to Geographic Information Systems. GIS data bases are fairly expensive to establish and maintain. Remotely sensed images offer a way to help establish and maintain these data bases. In turn, GIS vector data acquired from other sources can be used to help classify imagery. The integration of earthbound studies and surveys with space observations is highly desirable.

Until recently, the processing of LANDSAT data has gone on largely independent of GIS endeavors which typically took place on interactive computer mapping systems. GIS requirements usually include interactive map compilation capabilities, polygon and grid data processing, digital terrain modeling, and dynamic linkages between map graphics and descriptive nongraphic information. The dual data base concept is very important for a number of reasons. For one thing, maintaining a nongraphic file independently keeps the graphic file lean; and yet, the linkages can be maintained to allow dynamic cycling back and forth between the map and the descriptive information. For example, a set of soil polygons can be defined for an area; all the relevant characteristics of the various soil types can be loaded into a nongraphic file for quick retrieval based on the selection of the relevant polygon. The descriptive data also should allow automatic resymbolization of the graphics at different scales. This integrated dual data base approach is fundamental to Geographic Information Systems.

Some of the key areas for the application of an integrated GIS approach include agriculture, forestry, and energy exploration on a global scale. Also, the planning phase of large civil engineering projects will benefit from the application of integrated GIS capabilities.

SUMMARY

The integration of image processing capabilities with interactive computer mapping systems is feasible. The accomplishment of this integration will result in powerful new Geographic Information Systems. These systems will enhance the applications of LANDSAT and other types of remotely sensed data in solving problems in the resource planning and management domain, both public and private.