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REMOTE SENSING ANALYSIS INSTRUMENTATION FOR GEOTHERMAL EXPLORATION

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ABSTRACT

Detailed analysis of remotely sensed imagery is an important first step in determining the viability of an area for geothermal interest. Advances in quality and quantity of imagery require that the analysis process be improved. Where gross information is required, computer programs scan imagery, measure gray scale levels, and correlate density information to previously defined subjects. In area of geothermal interest, detailed analysis of small information elements is required. Instrumentation consists of imagery support, transport and illumination, stereoscopic viewer, and graphic information transfer device. Instrumentation must support the human operator from one of the geothermal disciplines. New and fully capable analysis exploitation and equipment is available and should be used if the total economies of remote sensing are to be realized in geothermal studies.

INTRODUCTION

A block diagram of a remote sensing analysis system, Figure 1, will include a collection system providing the input, an interpretation-analysis block supported by a selection of equipment, and a report to the user as the system output. It should be noted that the system activity is not considered complete until the remotely sensed imagery has been analyzed and the resultant information presented in a logical format to a decision making level of personnel.

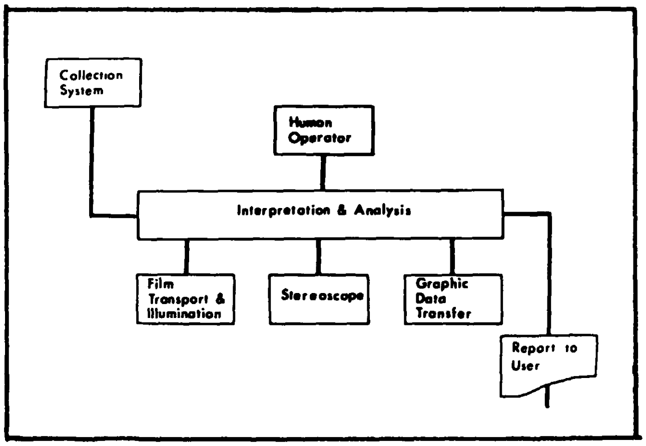

Figure 1.

During the past several years, many different imagery collection systems have been developed and put into active use. These collection systems have the capability to collect and deliver imagery at a rate that far exceeds the total analysis capability.

A review of the film libraries at the EROS Data Center in Sioux Falls and the ASCS in Salt Lake City will graphically demonstrate that there are millions of frames of imagery available that are not being and cannot be analyzed. This overabundance of imagery has made many people call for help in completing the analysis task.

For many years, whenever a data volume problem becomes too large to handle conveniently, one solution has been to write a new program and let a computer manage it. This has been done to some extent with the imagery analysis data problem. Sophisticated programs backed by reasonable sized computers can divide images into shades of gray and, by assigning certain gray levels to specific land use, the computer can evaluate large land areas and present the information as a land use print-out.

The digital data base for cartographic purposes contains some 10^{15} bits of data and will cost about 500 million dollars to generate. Storage will require development of the plastic bubble memory and will occupy space about like a home garage. This data base contains only the geodetic and planimetric information. It does not contain contour or land use information

Many users of remote sensing imagery are not yet prepared to go at full speed toward the digital concept because of the cost and because they are interested in a level of detail much finer than the relatively gross areas currently within the analysis capabilities of the computer programs. Also, the total area involved may be less than the multiple quadrangles which makes the computer analysis so efficient. It is to these users of detail information over smaller areas that this paper is directed.

In developing the computer analysis approaches, every effort has been made to remove the human operator or to reduce the system dependence on him because of his limited ability to handle gross quantities of data in a timely fashion. This concept is fully valid in some major programs, but it tends to ignore the analysis activities in which a human operator is far more capable than the computer. These activities cover the observation of minute imagery detail and the analysis of this detail to determine the activity which has been imaged by the collection system. The classical concept of interpretation consists of the four basic steps of Detection, Recognition, Identification, and Evaluation. This is true "Imagery Interpretation" rather than gray level detection and recording. There are many imagery analysis problems in which the human "Eye-Brain-Fingertip" combination still performs in the most effective manner. These problem areas include activities wherein the detail may be small, the activities within the area of interest are varied, and the "Imagery Noise Factor" of extraneous information is high.

SYSTEM DESCRIPTION

The system under discussion here consists of four basic elements:

(1) A light table for imagery support, transport and illumination;

(2) A stereoscope for detailed stereoscopic imagery study;

(3) A graphic data transfer instrument for preparing the information in a usable format;

(4) The human operator.

The Light Table

The requirements for the light table are based on the specific activities of the interpreter and the imagery with which he is working at the time. The interpreter may be working with either opaque prints or transparencies. The imagery support, transport and illumination requirements are, of course, different in each case. Most users of transparencies maintain them in roll form for ease of storage. Therefore, there must be a roll film handling capability on the light table. This may be either hand driven or motorized. If it is motorized, speed and torque controls must be carefully designed to prevent film damage during transport. The illumination system must have an even intensity throughout the entire observation area. This intensity must be variable since the density of the observed material may vary. A further consideration is the color temperature of the illumination system since much of the imagery used today is either true color or color infrared. The illumination source color will naturally influence the color observed by the interpreter and could improperly influence the analysis. These, then, are some of the general requirements for the light table in this system.

A brief review of historical equipment will sometimes make the current operator realize the efforts which have been expended on his behalf. A very simple light table was used extensively during and after World War II and through the Korean conflict. The light source was two fluorescent tubes, and the intensity control was an on/off switch or the plug in or out of the socket. The film drive system was hand-operated and required two pins (which were usually lost) to lock the rear spindle in place.

A small but modern film viewer is produced by N. Yingling Associates in Amherst, Ohio. It is portable with detachable film spool cranks so that it becomes essentially a suitcase for carrying. For use in the field, a convertor is available for operation from a 12V source such as the cigarette lighter in a car. The illumination source is five fluorescent tubes with a low-medium-high intensity selection switch.

One of the extensive line of light tables produced by the Richards Corporation of McLean, Virginia, is the Master Interpretation Module (MIM-3). This unit has an illuminated surface of 11 x 36 inches. It can be equipped with hand or motor operated film transport, and it has a film accumulator for special collection systems wherein conjugate stereo images are separated by more than the nominal distance.

The light source of the MIM-3 is a cold cathode grid with a surface intensity of 2500 foot lamberts and a color temperature of either 5500°K or 3500°K. This illumination is variable throughout its range by rheostat. The light table is mounted on an elevating stand to accommodate various height operators. The MIM-3 has a mount which will accept either of the Bausch & Lomb zoom stereoscopes. This mount is on an x-y scanning bridge which permits the operator to scan the entire stereo model without moving the film.

Bausch & Lomb has designed a high intensity light table specifically for use with the Zoom 240 stereoscope. The light source is a quartz-halogen lamp with parabolic reflectors. Since the only area under observation is the ring described by the moving rhomboids, only this ring is illuminated. This permits a more evenly concentrated light over the useable area. An x-y scanning carriage permits moving the film under the stationary optical head.

The Stereoscope

The purpose of the stereoscope in any imagery analysis system is to direct the analyst's eyes to the proper image of the stereo pair, provide some magnification for imagery study, and to accomplish these with a minimum of eye strain on the operator.

One stereoscope has been used to produce more "PI" reports than all others in the free world combined. It is the two power, wire legged, folding pocket stereoscope; and it is still used by many interpreters today, especially those who must carry them into the field for on-the-spot interpretations.

The mirror stereoscope provides the analyst with the capability of viewing the entire stereo model without overlapping the prints and without scanning. However, the magnification is slightly less than 1X, so for detailed imagery study, 5X fixed power binoculars were added. Of course, as in any optical system the increased magnification resulted in a decrease in the field-of-view and, therefore, moving the stereoscope is required for scanning the entire stereo model at the higher magnification.

The Olde Delft scanning stereoscope provides two different fixed magnifications and a means of scanning the stereo model in x and y by moving mirrors within the optical system without physically moving the instrument.

The Zoom 70 stereoscope was the forerunner of the modern stereoscope available today. It was designed to accommodate 70mm wide film in roll form and had a variable zoom magnification from 7X to 60X. The optical trains could be zoomed independently to accommodate imagery of different scales, and the basic pod could be used as a StereoZoom microscope for detailed study of single images.

Today, the Remote Sensing Analyst has available three stereoscopes which use the highest quality optics with a variable magnification capability.

The Zoom 95 stereoscope has a variable magnification between 2.5X and 40X. The objective rhomboids have a variable separation between 3 and 7-3/4 inches. The interpupillary distance is adjustable between 55mm and 72mm, and the high eye relief eyepieces permit the use of the instrument by operators with or without corrective eyeglasses. In addition, an image rotation capability may be added to the optical systems for crab correction when using uncut roll film. The Zoom 95 is normally supplied with a light table and an x-y scanning stage, making it a complete stereo interpretation system, the SIS-95.

The Zoom 240 stereoscope is mechanically similar to the Zoom 95. The magnification is variable from 3X to 90X, and the variable rhomboid separation is 1.3 inches to 15 inches on the X-axis and up to 10 inches on the Y-axis. This capability will accommodate conjugate image separation of 70mm to 9" x 18" frames in almost any orientation on uncut rolls of film. The optical image rotation featured is standard on all Zoom 240's. In addition, the rhomboids of the Zoom 240 may be easily removed from the optical path, and the pod may be used as a direct StereoZoom microscope for analysis of single images.

The Zoom 500 stereoscope is the latest unit in the Bausch & Lomb line of imagery analysis instruments. This instrument is a major advance in that the optical system has been designed to provide maximum information with images of low contrast. The total magnification range is from 3.0X to 135X with three sets of objectives and two sets of eyepieces. An optical switch permits the analyst to view either the right photo or the left photo monoscopically with both eyes, or to view the two images superimposed as well as viewing them stereoscopically. The system resolution at all magnifications is well beyond the threshold of the human eye. The Zoom controls are motorized, and each optical train may be zoomed independently for stereoscope scale matching purposes.

The Graphic Data Transfer Instrument

Once the imagery analysis is completed, the information must be prepared in the form of a report usually containing graphic information. The task of transferring graphic data from a new input to an existing base at a different scale was formerly accomplished using a reflecting projector. This unit was operated in a darkened room, and because of the light limitations, used a large aperture lens which produced a less than sharp image.

Today the Bausch & Lomb Zoom Transfer Scope, or Z.T.S., graphical data transfer instrument is available which operates in normal office illumination and uses high quality microscope optics which provide a sharp image.

In use, the Z.T.S. operator observes the base graphic at a fixed magnification and, simultaneously, the new input with a variable magnification system. The operator optically matches the scales of the two images, superimposes them and draws the new information onto the old data base.

The data base information may be observed using any Z.T.S. model at fixed magnifications of 0.7X, 1X, 2X or 4X. The new input material may be opaque or transparent and is essentially limited to the 10 x 10 inch area of a standard aerial photograph using the vertical stage model. This new imagery may be observed at any magnification ratio of from 1:1 to 14:1.

The transilluminator is a color-corrected cold cathode grid for proper viewing of color transparencies. The opaque print illuminator and the data base illuminator are incandescent lamps. The intensity of each illumination source is individually controllable by the operator.

In addition to the zoom capability, the image of the new input may be stretched by a 2:1 ratio in any direction to compensate for tilted imagery, errors in V/H ratios in scan imagery, and for some of the image displacements of panoramic imagery.

The horizontal version Zoom Transfer Scope instrument operates in the same manner as the vertical unit. The changes are the input data stage; instead of being limited to a 10 x 10 inch area, the stage has been made a horizontal platen 20 x 42 inches to permit the use of map sheets or other large graphics without cutting or folding;

the new data zoom system, variable between 0.75X and 14X; and the transilluminator, a standard incandescent lamp. All other functions are identical between the two units.

The latest development in the Z.T.S. line is the stereo model. The stereo model operates in the same manner as the other models except the optical train has been duplicated so the operator may view the aerial photos in stereo while also looking at the map. The zoom range has been extended to 0.6X to 16.1X.

The stereo Z.T.S. instrument is equipped with an optical switch so the operator may use the instrument in either the stereoscopic or monoscopic mode. In addition, there is a camera adapter port so the operator may photograph the overlayed images with either a 35mm camera for slides or a 4" x 5" Polaroid camera for prints.

The Operator

The preceding paragraphs have described some of the equipment available for use by the imagery analyst. The most difficult element of the system to describe and define is the human operator. Since the analysts are human, they are available in different shapes, sizes, and sexes with varying technical backgrounds and capabilities. The most efficient analyst is one who is technically proficient in a given discipline such as transportation, land use analysis, geothermal energy, or others. If an analyst knows the many elements that make up a technical field, he or she can be taught to use photographs as basic data input in a relatively short period of time. For example, an engineer who has worked for five years in the geothermal energy field can be taught to use a stereoscope, to understand vertical exaggeration and even to make simple measurements within a few weeks. If the opposite approach is used and geothermal engineering is taught to a trained image interpreter, it would take several years.

SUMMARY

The system discussed in this paper is not new, complex, or a revolutionary concept. However, once in a while, it is advisable to stop and take a look at simple and available alternatives to the extensive and expensive computer-supported systems which have been developed to support the mass of imagery available from all of the collection systems in operation today.

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