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Digital Registration of Topographic Data and Satellite MSS Data for Augmented Spectral Analysis

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16. Abstract

The problem of utilization of topographic and other ancillary data exists in digital analysis of remote sensing data. The report describes techniques and an example of digital registration of topographic data to SKYLAB and LANDSAT MSS data for use in forest and land use classification of areas in the Rocky Mountain region.

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DIGITAL REGISTRATION OF TOPOGRAPHIC DATA AND SATELLITE MSS DATA FOR AUGMENTED SPECTRAL ANALYSIS

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BIOGRAPHICAL SKETCH

Paul E. Anuta is an Associate Program Leader for Data Handling Research at the Laboratory for Applications of Remote Sensing at Purdue University, West Lafayette, Indiana. He received a B.S., Electrical Engineering, Purdue University in 1957; M.S.E.E., University of Connecticut in 1967; and an M.S. in Computer Science in 1969, Purdue University. As an employee of the IBM Federal Systems Division he investigated hybrid computer applications and conducted guidance and control systems analysis and software design activities for missile and spacecraft computers. Mr. Anuta joined the LARS staff in 1967, and has designed data handling systems for a multispectral aircraft scanner system, interferometer spectrometer and other sensors. Mr. Anuta is responsible for research and evaluation of remote sensor data preprocessing techniques. Current key data handling research areas are image registration, geometric correction and resolution enhancement of satellite multispectral imagery. Mr. Anuta is a member of Tau Beta Pi, Eta Kappa Nu, the Institute of Electrical and Electronic Engineers and the American Society of Photogrammetry.

ABSTRACT

The techniques of computer based analysis of multispectral scanner data from satellite borne remote sensors has been applied to agriculture, geology, forestry, land use and many other disciplines requiring surface feature mapping. These efforts have had varying degrees of success. In many cases the effect of topography on spectral response has significantly influenced the classification performance. Slope and shadow effects are major factors that cause complications in the analysis of spectral signatures from surfaces in areas of significant topographic relief. The availability of elevation, slope, and aspect values for each pixel of multispectral scanner data would enable topographic effects to be included in the analysis. The digital registration study described in the paper used Defense Mapping Agency digital topographic data which was obtained from 1:250,000 scale maps. Reformatting, data preprocessing, and control point definition procedures are discussed. The digital registration process in which topographic data was combined with SKYLAB and LANDSAT MSS is then described and error analysis is included for the data set used, which was the one degree square Durango West quadrangle in Colorado. This data set involved over 2,700,000 pixels of SKYLAB and LANDSAT MSS data. The topographic data becomes an additional channel on the MSS data set after registration. Slope and aspect angle are computed by discrete differentiation of the topographic channel. This produces a gradient vector, the magnitude of which is the

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slope and the direction is the aspect angle. Many potential uses exist for the topographic channels. Use as a feature in a single level and layered pattern recognition system (LARSYS), delineation of shadowed areas, delineation of watersheds, and other applications are current applications activities.

INTRODUCTION

The objective of the work reported here was to develop a prototype system for relating topographic information to the SKYLAB S-192 multispectral scanner data. In particular an elevation, slope and aspect angle channel is required for each pixel of the MSS data. The purpose of this objective is to enable machine analysis of spectral/topographic data to enable a better understanding of the impact of topographic effects on spectral response and it should allow more accurate forest cover type mapping than has been possible with only MSS data.

A project has been completed in which digitized topographic data has been digitally overlayed onto SKYLAB S-192 as well as LANDSAT data for the San Juan Mountains area in Colorado. Software was developed and applied to the topographic elevation data to produce additional slope and aspect data channels. Thus, the work has produced large dimension digital overlays in which thirteen SKYLAB channels are registered for two times with topographic data. These large coincident data sets are believed to be unique in the remote sensing data machine processing field and have the potential of enabling more accurate and productive analysis of the remote sensing data. This paper describes the details of the registration and topographic data processing which was carried out.

DATA SET DESCRIPTION

Due to the large area coverage and early availability of LANDSAT-1 data for the Colorado test area this data type was chosen as the reference data set for all the other data used in the project. LANDSAT Frame 1317-17204 obtained June 5, 1973 formed the reference four channels and the topographic data was registered to this data. The S-192 SL-2 data set from June 5, 1973 was then overlayed on the LANDSAT data. This brought the three data types into registration. The S-192 SL-3 data from August 8, 1973 was later overlayed on the LANDSAT reference bringing it into registration with all the previous data. Finally LANDSAT data from frame 1407-17193 obtained on September 3, 1973 was overlayed on the reference to enable comparison with the August S-192 data.

The major problem in handling the various data sets was the great disparity in angular orientation of the frames and the lack of coincident data over large areas. Only a small part of the test site near Durango contains data for all SKYLAB and LANDSAT and topographic channels.

The topographic data is north oriented and covers the west half of the Durango 1:250,000 scale U.S.G.S. map quadrangle.

The June 5, 1973 LANDSAT data covers a 100N. Mi block encompassing the west Durango quad. The June 5 S-192 SL-2 data set is rotated approximately 45° west with respect to north and is approximately 45 N. mi miles square centered almost on Durango. The September LANDSAT data coincides closely with the June 5 LANDSAT frame. The original LANDSAT data is rotated approximately 12° east with respect to north. The SKYLAB SL-3 S-192 data from August 8, 1973 covers an 80 by 45 mile area centered on the San Juan Mountains.

TOPOGRAPHIC DATA

Digital topographic data was obtained from the U.S. Defense Mapping Agency (DMA) - Topographic Center, Washington, D.C. This data is obtained from the contours from 1:250,000 scale U.S.G.S. maps. The contour interval for the sheet used in this study (NJ13-7W Durango, Colorado) is 61 meters and the range of elevations is 1805 meters to 4344 meters. The contours are digitized by hand on a table digitizer by the DMA and the resulting data points are interpolated [1] using a "planar" algorithm which fits a plane to a triangle of three data points to define new points within the triangle. In this manner a uniform grid of elevation values is obtained from the unequally spaced contour samples. The digitizing increment is .254 mm in the x and y directions and on a 1:250,000 map this corresponds to 64 meters. The output grid cell is thus made 64 meters square to coincide with this sampling resolution.

The topographic data is written in 16 bit words (15 bit plus sign) on tape and delivered to users. At our laboratory the data was reformatted and placed in a format which utilizes 8 bit words. The quantization level of the original data is:

$$\frac{(4344-1805)\text{ meters}}{32{,}767} = .08\text{ meters}$$

In order to fit this range into 8 bits (0-255) the data had to be scaled resulting in a quantization of:

$$\frac{(4344-1805)}{256} = 9.9\text{ meters}$$

thus a significant quantization is introduced with respect to the contour interval of 61 meters but percentage wise with reference to the range of 2539 meters it is only .4% which is assumed to be reasonable. The accuracy of the original elevation points is not known but since they were interpolated from contours having an interval of 61 meters it can be assumed that the error is no worse than that obtained in interpretation of elevations from the original map.

Another problem was encountered in that the rows of the topographic data were oriented north-south on the DMA tapes and row direction in the LARSYS and most remote sensing systems is east-west or across track of flight lines thus a tranposition of the topographic data array on tape was required. The final topographic tape contained 1 channel of eight bit values in a 64 meter grid for the entire Durango west quadrangle which covers a one degree rectangle of latitude and longitude. In order to retrieve the true elevation values from the eight bit words the lower and upper limits of elevation (1805 m and 4344 m in this case) are stored in full precision format on the tape identification record and used to rescale the eight bit data to the original range. Thus true elevations can be printed out by LARSYS but subject to the .4% quantization error. This topographic data tape formed one of the several inputs to the registration process.

REGISTRATION PROCESSING

All the remote sensor data sets were first rotated to an approximate north orientation before registration operations. For LANDSAT data this is approximately 12 degrees counter clockwise and for SKYLAB S-192 data this was about a 45° clockwise rotation. Also, the topographic data had to be transposed as mentioned. The normal procedure for image to image registration at LARS [2] is to use a numerical correlation procedure to find control points in the images to be registered. For the registrations required here manual techniques were required due to the dissimilar nature of the data involved. The topographic data in general will not correlate with the LANDSAT data and although the SKYLAB data is similar in type it was difficult to find low noise channels corresponding to LANDSAT channels which would correlate. Thus nominally twelve matching points in the data to be registered were found visually using the digital image display and computer line printer generated images. The coordinates of these points were punched on cards and processed by a least squares bi-quadratic polynomial approximation program [3] to define coefficients for use by the registration program.

The registration algorithm used a nearest neighbor rule to define output points which are required between existing input data points. Since the topographic grid spacing is 64 meters square and the LANDSAT reference grid is 79 meters square the registered topographic data will have position errors which range from zero to 32 meters which is an error characteristic of the nearest neighbor method. Similarly the S-192 data has a sample spacing of about 66 meters. Thus a comparable nearest neighbor error will result for overlay of this data.

The June and August S-192 data were registered onto the June LANDSAT reference as was the topographic data and September LANDSAT data. The number of control points used and the curve fit errors for the various registrations are listed in Table 1. Numerical correlation was used for the September LANDSAT overlay since the data types matched; hence, a large number of control points was obtained with a lower resulting error. All other points were obtained manually and since very few points could be seen and obtained the fit error is larger. Several data sets were generated with different combinations of channels on them; however, since all the data was registered to a common reference the coordinate system is the same for each channel and no problem

Table 1. Summary of Overlay Errors

Data Registered to June LANDSAT	No. Control Points	(Root Mean Square) Error In Columns (E-W)	RMS Error In Lines (N-S)
Topographic	6	.54	1.2
June S-192	12	.97	.85
August S-192	8	.74	.81
Sept. LANDSAT	51	.48	.39

results from combining any channel of any data type. All variables were assembled on one master data tape having the channels indicated in Table 2.

TOPOGRAPHIC SLOPE AND ASPECT DERIVATION

The data analysis process could make good use of slope and direction of slope information if it could be made available on a pixel basis as additional registered channels on the data tape. This requirement was met by numerically differentiating the topographic data to produce an estimate of the gradient vector at each pixel location. The magnitude of the vector is then used to derive slope angle and the direction is used as the aspect angle. The approximate gradient at line i and column j is computed as:

$$\nabla\vec{z} = \vec{i}(z_{i-1,j} - z_{i+1,j}) + \vec{j}(z_{i,j-1} - z_{i,j+1})$$

where $\nabla\vec{z}$ is the gradient vector

z_{ij} is the topographic elevation at i,j

i,j are line and column coordinates

$\vec{i}$ and $\vec{j}$ are line and column unit vectors

The slope angle is computed from the magnitude of gradient. The $|\nabla\vec{z}|$ value is the vertical change in elevation over one unit of pixel distance thus the slope is

$$s_{ij} = \tan^{-1} \frac{\sqrt{(z_{i-1,j} - z_{i+1,j})^2 + (z_{i,j-1} - z_{i,j+1})^2}}{\Delta d}$$

where: s_{ij} is the slope angle at point i,j with $0 \leq s \leq 90$ degree.
Δd is the pixel spacing

The aspect angle is derived from the vector direction of the gradient:

$$\alpha = \tan^{-1} \left[\frac{(z_{i-1,j} - z_{i+1,j})}{(z_{i,j-1} - z_{i,j+1})} \right]$$

where α is the direction of slope measured clockwise from north.

Table 2. Tape Format for Overlayed SKYLAB, LANDSAT, and Topographic Data for SL-2 or SL-3 Data Sets

Channel	Wavelength Band	Source
1	0.50- 0.60	LANDSAT
2	0.60- 0.70	LANDSAT
3	0.70- 0.80	LANDSAT
4	0.80- 1.10	LANDSAT
5	0.41- 0.46	SKYLAB
6	0.46- 0.51	SKYLAB
7	0.52- 0.56	SKYLAB
8	0.56- 0.61	SKYLAB
9	0.62- 0.67	SKYLAB
10	0.68- 0.76	SKYLAB
11	0.78- 0.88	SKYLAB
12	0.98- 1.03	SKYLAB
13	1.09- 1.19	SKYLAB
14	1.20- 1.30	SKYLAB
15	1.55- 1.75	SKYLAB
16	2.10- 2.35	SKYLAB
17	10.20-12.50	SKYLAB
18	Elevation, Feet or Meters	DMA
19	Slope, Degrees	DMA
20	Aspect, 0-180°	DMA
21	Aspect, 0-1	DMA

Since only positive values from 0-255 can be represented on the eight bit format tapes the aspect angle is recorded on a range of zero to 180 in one channel and an additional channel is added which has only the values zero or one. If the slope is uphill to the east semicircle the zero-one channel will have a value of zero and if uphill to the west semicircle it will be one. Thus a pixel having a slope upward toward the east will have an angle value of 90° and a flag value of zero. The resolution of the slope and aspect angles is one degree.

The slope and aspect angle derivation was implemented in a program which adds the three angle channels to a data tape as three additional channels assuming the last channel on the input tape was the topographic elevation channel. Example gray scale images were generated for an area centered near the Vallecito Reservoir to illustrate the topographic channels. Figure 1 contains an image from the LANDSAT MSS data and from the three topographic channels. The upper left image is LANDSAT data from band 5 (.6 - .7 micrometers), the upper right image is a gray scale representation of the elevation channel with low values having darker gray levels and high values brighter levels. The gray resolution of the image is very limited at only about 10 levels and the image does not relate the information available well. There are actually 256 descrete elevation levels available and these are compressed to the 10 gray levels seen in the image. The lower left image contains a gray scale reproduction of the slope angle channel. Bright areas represent steep slopes and dark areas shallow with black being flat areas. The lower right image is a gray scale representation of the aspect angle for the same area. Darker areas represent

DIGITAL REGISTRATION OF LANDSAT AND TOPOGRAPHIC DATA

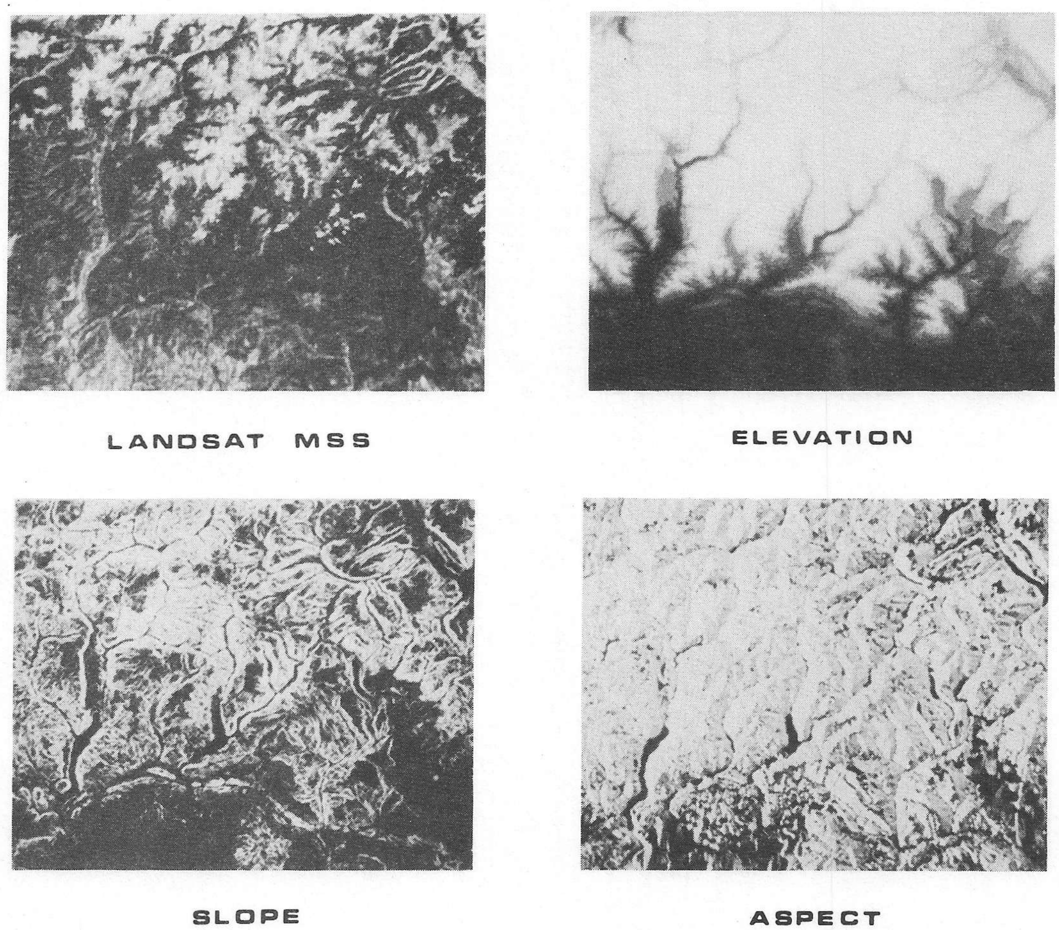

Figure 1. Gray scale image reproductions of MSS and topographic channels San Juan Mountain test site in south central Colorado.

southerly facing slopes and lighter areas represent northerly facing slopes. Black areas are level areas.

UTILIZATION OF TOPOGRAPHIC DATA

The work described here was limited to developing the technology for providing the topographic data in digital registered format on tape. Applications methodologies have yet to be worked out; however, certain output products can be produced with current methods. The basic product with our current image generation capabilities is a gray scale or symbol coded image generated from the topographic channels. These images can then be physically overlayed on multispectral scanner imagery, classification results maps, or cluster maps to relate spectral properties to topographic characteristics. Further work will develop software for mathematically performing these comparisons. Ultimately a layered classifier method will be developed which will use topographic data directly in the classification process. A great deal can be done, however, with the physical overlay procedure and the current project has benefited from the development of this capability.

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