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ATMOSPHERIC EFFECTS IN ERTS-1 DATA, AND ADVANCED INFORMATION EXTRACTION TECHNIQUES

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ABSTRACT

Atmospheric effects in satellite multispectral scanner data can influence results obtained with manual image interpretation techniques and with computer information extraction techniques. The atmosphere attentuates radiation arriving from the surface and, more importantly, adds an extraneous path radiance component to the received signals. Initial results of an investigation of atmospheric effects in ERTS-1 data are presented. Empirical analyses of ERTS MSS data and simultaneous airborne MSS underflight data for one frame (1033-15580), along with theoretical calculations of atmospheric effects, are discussed.

Another important factor in the analysis of ERTS data is the effect of the spatial resolution element size on the accuracy of recognition processing operations. Problems occur when a resolution element contains a mixture of materials. Results from the initial application of ERIM techniques for estimating proportions of materials within individual elements are presented and discussed.

E 73-10180

Paper I 2

DETERMINATION OF AEROSOL CONTENT IN THE ATMOSPHERE

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ABSTRACT

The objective of this investigation is to demonstrate the feasibility of determining the aerosol content in the atmosphere from contrast measurements of ground features, and from radiance measurements. Theoretical relationships between aerosol content and contrast reduction and radiance have been derived for ideal model atmospheres. Satellite monitoring of the atmospheric aerosol content will provide information important in predicting the effect of man's activities on climate, and in correcting observations of surface features for the effects of the atmosphere.

The preliminary data analysis of the MSS transparencies has shown promising results for the contrast-aerosol content relationship in the Salton Sea/desert region. Results of ground-truth measurements of target inherent contrast with the NASA aircraft, and of the aerosol content made with a Volz photometer, will be presented. It is planned to present some results of the radiance-aerosol content relationship based on analysis of the digital tapes of the MSS data.

E 73-10181

Paper I 3

A TECHNIQUE FOR CORRECTING ERTS DATA FOR SOLAR AND ATMOSPHERIC EFFECTS

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ABSTRACT

This paper reports results achieved by ERTS-Atmospheric Experiment PR303 whose objective is to establish a radiometric calibration technique. This technique, which determines and removes solar and atmospheric parameters that degrade the radiometric fidelity of ERTS data, transforms the ERTS sensor radiance measurements to absolute target reflectance signatures. The need for target reflectance signatures evolves from the needs of individual PIs, from NASA's requirements to correlate results of a large number of investigators, and the pre-conditions of wide-area extrapolations of ground truth data for automatic data processing technqiues. Target reflectance data are needed by all – man and machine in order to obtain the unambiguous interpretation of ERTS data. The paper includes:

- Details of the Radiant Power Measuring Instrument (RPMI) which provides the measurements of the solar and atmospheric parameters (global irradiance, sky irradiance, radiance from narrow solid angles of sky, and direct beam solar irradiance) needed to transform ERTS data to reflectance.

- Results of field measurements of these parameters,

- Techniques for deriving additional atmospheric parameters (beam transmittance, path radiance) from RPMI measurements.

- Procedures for using measured and derived atmospheric parameters in the transformation of ERTS computer-compatible tapes into imagery and tapes corrected for atmospheric effects.

- Estimates of benefits expected from atmospheric corrections for various ERTS data applications.

E 73-10182

Paper I 4

MASKING BULK RBV IMAGES TO REDUCE STATIONARY RESIDUAL ERRORS IN RADIOMETRIC CORRECTION

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ABSTRACT

RBV vidicon tube calibration data are used to correct spatially non-uniform radiance response in individual vidicons, during post-acquisition signal processing. However, examination of different ERTS-1 RBV-1, -2, and -3 image scenes showed stationary, repetitive residual inaccuracies in shading correction, large enough to affect qualitative and quantitative image analyses.

Photographic masks designed to reduce residual shading were prepared from RBV-1, -2, and -3 images of a relatively cloud-free ocean scene of uniform reflectance. When applied to other RBV scenes, the masks enabled more closely corrected RBV images to be printed. Illustrations ar. given of RBV images before and after correction, compared with equivalent MSS spectral images of the same scene.

E73-10183

GEOMETRIC QUALITY OF ERTS-1 IMAGES

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ABSTRACT

Geometric fidelity of an image is fundamental for referencing earth resource data to map positions. Image coordinates should register between spectral bands and between sequential images of the same scene. In addition the image coordinates should have a defined relation to map projections of the area. Selected RBV and MSS images have been precisely measured and compared with calibrated reseau and ground coordinates. The magnitude and pattern of several types of geometric distortion have been determined.

E 73-10184

Paper I 6

DIGITAL RECTIFICATION OF ERTS MULTISPECTRAL IMAGERY

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ABSTRACT

Rectified ERTS multispectral imagery have been produced utilizing all digital techniques, as the first step toward producing precision corrected imagery. Errors arising from attitude and ephemeris sources have been corrected, and the resultant image is represented in a meter/meter mapping utilizing an intensity "resampling" technique. Early results from available data indicate negligible degradation of the photometric and resolution properties of the source data as a consequence of the geometric correction process. Work utilizing ground control points to produce precision rectified imagery, and including photometric corrections resulting from available sensor calibration data, is currently in progress.

E 73-10185

Paper I 7

RESULTS OF PRECISION PROCESSING (SCENE CORRECTION) OF ERTS-1 IMAGES USING DIGITAL IMAGE PROCESSING TECHNIQUES

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ABSTRACT

Digital image processing techniques for the correction of ERTS image data are believed to be a feasible and effective technology. ERTS-1 MSS and RBV data recorded on Computer Compatible Tapes have been analyzed and processed, and preliminary results have been obtained. It is shown that the RMS positional error of the processed images, as measured at the ground control points, is approximately 110 meters and the maximum error is approximately 200 meters. No degradation of intensity (radiance) information occurred in implementing the geometric correction. It is further shown that computer detection and location of reseau marks and ground control points, used for determining internal and external sensor geometry, is practical. All reseaus searched for to date (486) have been detected and located, and no false detections have occurred. Ground Control Point detection has been achieved with about 88% probability of detection to date, and location accuracy is about ± 1/2 picture element.

The quality and resolution of the digitally processed images is very good, due primarily to the fact that the number of film generations and conversions is reduced to the minimum possible.

Processing times of digitally processed images are about equivalent to the NDPF electro-optical processor.

E73-10186

Paper I 8

SIGNIFICANT TECHNIQUES FOR THE PROCESSING AND INTERPRETATION OF ERTS-1 DATA

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ABSTRACT

In the course of conducting discipline oriented investigations using ERTS-1 data, many significant techniques have been developed at MSC. The techniques encompass the areas of Preprocessing, Classification, Correlation of the data with ground features, and Analysis of the spectral clustered results. The specific techniques are presented in the context of how they may be utilized by investigators analyzing ERTS-1 data. The specific techniques covered are:

Preprocessing: (a) Atmospheric Corrections - A program (PREPS-ROTAR) has been developed which corrects MSS data for scattering and absorption in the atmosphere. It derives target reflectances from the ERTS instrument response data. In test cases these reflectances are accurate to about 1%. (b) Striping Removal - The ERTS-1 calibration procedures do not completely remove effects due to the six different detector responses in each channel. In order to remove the striping and make correlation of the data with ground target features easier, a procedure has been devised to move each detector response to the average response for its channel.

Classification: The wide range of data values presented in ERTS scenes has necessitated a refinement of the clustering algorithm (ISODATA) in use at MSC so that meaningful clustering results could be achieved throughout the range with little apriori knowledge of its extent. The anaogy between ERTS data and Poisson processes suggest that the allowable standard deviation within a cluster be proportional to the square root of the mean in that cluster.

Correlation: The techniques for correlating specific cluster or classification maps with ground control points or aerial photography are being developed at MSC. Aspects of these techniques are discussed along with their utility in training field selection for supervised classification as well as resolving anomalies in processed results.

Analysis of Spectral Clusters: Objective techniques have been developed in the context of urban and water coastal studies for estimating the proportional composition of resolution elements. This has been applied to the estimation of the surface area of water bodies by counting ERTS-1 picture elements. The technique includes a solution to the mixture problem at the water/non-water interfaces and is amenable to computer processing.

E 73-10187

Paper I 9

COMPUTER TECHNIQUES USED FOR SOME ENHANCEMENTS OF ERTS IMAGES

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ABSTRACT

The JPL VICAR image processing system has been used for the enhancement of images received from the ERTS for the Arizona Geology Mapping Experiment.* The system contains flexible capabilities for reading and repairing MSS digital tape images, for geometric corrections and inter-picture registration, for various enchancements and analyses of the data, and for display of the images in black and white and color.

The images as received on MSS tapes contain numerous band lines which are detected and eliminated by computer. Initial enhancement for subsequent visual inspection is by computer contrast stretching of each of the color components followed by photographic recombination to produce an enhanced pseudo color picture. In this display appreciably more detail is visible than in the original color images. A second type of color display is used in which the input components to the color reconstruction are ratio pictures, formed by taking the ratio pixel by pixel of green/red, IR1/red, and IR2/red. The ratioing process largely eliminates the brightness components of the original pictures and produces a color display whose color variations are more indicative of material variations than the simple pseudo color displays.

Structural details have been enhanced by using high pass filters which eliminate the low spatial frequency (broad brush) variations in the brightness without attenuating the high frequency detail. High frequency detail is then subsequently contrast stretched isotropically or antisotropically. Antisotropic filters oriented in various directions enhance geologic structures which were previously inconspicuous.

Classification using the 4 MSS bands has been accomplished by using manually chosen training samples to represent the various materials visible. After defining their clusters in four dimensional space, a simple and rapid table lookout is used for identifying material in the remainder of the untrained area of the picture.

Computer mosaicking and superposition of images is accomplished by first locating precisely pass point areas in the overlap regions by computer cross-correlation, followed by computer translation, rotation and/or rubber sheet stretching to produce precise pixel by pixel match. Picture differencing of the overlapped area has primarily been used at this point for the detection of temporal changes.

The images have been rectified by correcting the aspect ratio and by digitally producing the required skew. This allows direct registration with topographic maps, which in turn has allowed the field geologist to directly correlate the ERTS imagery with geologic features observed on the ground.

*Goetz, Preliminary geologic investigation in the Colorado Plateau using enhanced ERTS images.

E 73-10188

Paper I 10

DIGITAL ENHANCEMENT OF MULTISPECTRAL MSS DATA FOR MAXIMUM IMAGE VISIBILITY

V. Ralph Algazi, *Department of Electrical Engineering, University of California, Davis*

ABSTRACT

A systematic approach to the enhancement of images has been developed. This approach exploits two principal features involved in the observation of images: the properties of human vision and the statistics of the images being observed. The rationale of the enhancement procedure is as follows: in the observation of some features of interest in an image, the range of objective luminance-chrominance values being displayed is generally limited and does not use the whole perceptual range of vision of the observer. The purpose of the enhancement technique is to expand and distort in a systematic way the grey scale values of each of the multispectral bands making up a color composite, to enhance the average visibility of the features being observed.

Some properties of the enhancement procedure are of particular importance in remote sensing applications:

1. Enhancement of multispectral images is extremely fast. One iteration does not require more than a few minutes for a 256 x 256 image.

2. The procedure does not presume a certain number of classes (crops, vegetation types, etc.) to be distinguished. It will provide enhanced visibility of whatever is present in the subarea on which the enhancement algorithm is designed. Thus, it is a very powerful experimental tool for discovering new patterns and relations not anticipated by the investigator.

E73-10189

Paper I 11

ERTS-1 IMAGE ENHANCEMENT BY OPTICALLY COMBINING DENSITY SLICES

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ABSTRACT

The technique of density slicing using a photographic film and its application to enhancement of ERTS-1 imagery has proved to be u~eful for mapping varigated areal phenomena and provides a useful supplement to the I^{2}S Mini-Addcol viewing system. Early difficulties experienced with obtaining high resolution enhanced imagery from ERTS-1 through Diazochrome enhancing methods and initial use of the 70 mm MSS chips in the I^{2}S Mini-Addcol Viewer led to experimentation with an equidensity film. This black and white emulsion, Agfacontour Professional, was used to pre-enhance selected ERTS-1 MSS bands. The initial experiments conducted with this film were encouraging.

Initial results indicated that this technique of density slicing using readily accessible darkroom facilities and simple darkroom procedures allows rapid, accurate, and facile interpretation of certain areal phenomena to be made from the imagery. The distribution of the tree yucca Yucca brevifolia in the Eastern Mojave Desert of Southern California was used as an example to test the accuracy of the technique for mapping purposes. This distribution was mapped at a relatively high level of accuracy. The density slicing technique was also used to enhance certain geomorphic surrogates found in the region. Additionally, specific urban environments have been successfully isolated.

Density slicing of ERTS-1 imagery as realized from this technique has the potential for increasing the interpretability and use of the imagery and can provide the geographer with environmental data not as easily obtained with other technology. The technique can contribute to studying various physical and cultural environments and their areal signatures as recorded on the imagery can be mapped at a high level of confidence.

E73-10190

Paper I 12

PSEUDOCOLOR TRANSFORMATION OF ERTS IMAGERY

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ABSTRACT

For several years, a group at Rand has been studying human vision and the effectiveness for improving detection and recognition. In the course of this work, a number of image enhacement techniques have been developed.

One of the photographic techniques which shows great promise as an aid in interpreting ERTS imagery is pseudocolor transformation. It is a process where each shade of gray in an original black-and-white image is seen as a different color in the transformation. The well known ERTS-1 MSS image of the Monterey Bay-San Francisco area was transformed using a technique which requires only two intermediate separations. Possible faults were delineated on an overlay of the transformation before referring to geologic maps. The results were quite remarkable in that all large active or recently active faults shown on the latest geologic map of California were interpreted from the image for all, or much, of their length. Perhaps the most interesting result was the Reliz fault. The fault is shown as covered; however, a lineation corresponding to the position of the fault is visible on the image.

The usefulness of ERTS images in identifying recently active faults is demonstrable. Although the faults are also visible in the unenhanced image, they are clearly accentuated and more easily mapped on the pseudocolor transformation.

E 73-10191

DIGITAL INTERACTIVE IMAGE ANALYSIS BY ARRAY PROCESSING

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ABSTRACT

The relationship between seismic processing and ERTS data analysis is natural because both data sets result from remotely sensed reflected, attenuated, shifted and degraded energy. Seismic processing is, however, already routine, cost effective and application oriented.

Methods, software and equipment used in processing all types of seismic and other geophysical records are being adapted to ERTS digital CCT's. Displayed results are 2-dimensional images or contours, not unlike ERTS imagery, except for the dynamic range which is uneroded, and for the total information content which is selected and reduced to specifics.

The Array Processor represents a shortcut in processing, in that the most frequently used mathematical steps in data correlation are hard wired and need not be programmed, thereby decreasing man and machine time.

Examples are densitometry for true color determination of waters, vegetation, crops, soils and rock formations, which are customarily done either by use of color composites or black and white singular spectral frames. The array process uses direct magnetic digital data, thus eliminating the errors and data decay of measuring devices. The investigator may not be eliminated, but his role changes to that of a selector and interpreter. Another example is contouring and display of algorithmic relationships in different spectral windows, and different temporal stages. This information may pertain to crop state and identity, soil or rock identity or land use. The product results automatically from as many as 48 individual frames of the same scene (ERTS/MSS or RBV data), which were taken over the same scene in a number of repeat overflights.

The Array Process frees the investigator to interpret and utilize displayed data products. Therefore, this service increases the potential application and utilization of ERTS data, by providing higher quality (S/N) displays, by making available more processed data than so far available, and by increasing the time and number of present and potential users and investigators. The same was true in the seismic field at one time.

E73-10192

Paper I 14

COMBINING HUMAN AND COMPUTER INTERPRETATION CAPABILITIES TO ANALYZE ERTS IMAGERY

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ABSTRACT

The human photo interpreter and the computer have complementary capabilities that are exploited in a computer-based data analysis system developed at the Forestry Remote Sensing Laboratory, University of California, designed to optimize the process of extracting resource information from ERTS images.

The human has the ability to quickly delineate gross differences in land classes, such as wildland, urban, and agriculture on appropriate ERTS images, and to further break these gross classes into meaningful subclasses. In agricultural areas, the subclasses can be delineated on the basis of general tone and texture differences that relate to crop type and field size. In the wildland areas, delineations can also be made, based on tone and texture, which represent general vegetation systems, such as grasslands, brush, trees, and barren areas. The computer however, can more efficiently analyze point-by-point spectral information and localized textural information which can result in a much more detailed agricultural or wildland classification based on species composition and/or plant association.

These human and computer capabilities have been integrated through the use of an inexpensive small scale computer dedicated to the interactive preprocessing of the human inputs and display of raw ERTS images and computer classified images. The small computer is linked to a large scale computer system wherein the bulk of the statistical work and the automatic point-by-point classification is done.

E73-10193

Paper I 15

ANALYSIS OF ERTS IMAGERY USING SPECIAL ELECTRONIC VIEWING/MEASURING EQUIPMENT

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ABSTRACT

Electronic techniques are being used to derive measurements from ERTS data needed by several investigators in the USGS program on Dynamic Hydrology.

These measurements are obtained using the SRI Electronic Satellite Image Analysis Console (ESIAC) which permits the application of television editing and animation techniques to the ERTS data. This sytem provides time lapse sequences and scaled measurements from such sequences. Quantitative measurements are made of areas, distance and brightness profiles. Additional capabilities include densitometry, additive color viewing, feature enhancement, display and photography in color.

Color sides and movies are used to illustrate examples of snowfield extent, sediment plumes from estuary discharges, playa inventory, phreatophyte and other vegetative changes.

E73-10194

Paper I 16

COMBINED SPECTRAL AND SPATIAL PROCESSING OF ERTS IMAGERY DATA

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ABSTRACT

Spectral, textural and context features are three fundamendal pattern elements used in human interpretation of imagery data. Spectral features describe the average band to band tonal variations in a multiband image set where as textural features contain information about the spatial distribution of tonal values within a band. Context features contain information derived from areas surrounding the sub-image region being analyzed. When small image areas are independently processed by a machine, only the textural and spectral features are available to the machine.

In much of the automated procedures for processing image data from small areas, such as in crop classification studies, only the spectral features are used for developing a classification algorithm. Other than simple averaging of spectral values within an image area to eliminate irregularities, texturel features are generally ignored. Because the areal characteristics of texture carry so much information it is important to use the textural features in automated image processing schemes, except in applications where the poor resolution of the imagery does not provide meaningful textural information.

Other than some work with Fourier, Hadamard transforms and autocorrelation function, there exists little or no theory to aid in establishing what the textural features should consist of. We have developed a set of quickly computable textural features for automatic analysis of MSS and other imagery. We used these features to perform a land use classification of a 5100 square mile area covered by part of an ERTS-A, MSS band 5 image consisting of over 600 blocks of size 64 X 64 resolution cells. The land use categories identified consisted of coastal forest, wood lands, annual grass lands, water bodies, urban areas, small and large irrigated fields. Up to 70% of the image blocks were identified correctly based on the textural features, compared to an accuracy of 74 to 77% for a scheme based on the spectral characteristics of the 4 band MSS image set. When the combined textural and spectral features were used as inputs to the classifier, up to 83.5% of the images were identified correctly. While the 83.5% accuracy of the machine is still lower than the accuracy of image interpreters, it must be pointed out that human interpreters rely heavily on contextual information which was not available to the machine. If the context information is taken into account by the automatic classifier, we expect that the accuracy of the classifier will approach the accuracy of human interpreters.

E73-10195

Paper I 17

TERRAIN TYPE RECOGNITION USING ERTS-1 MSS IMAGES

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ABSTRACT

For the automatic recognition of earth resources from ERTS-1 digital tapes, both multispectral and spatial pattern recognition techniques are important. Recognition of terrain types is based on spatial signatures that become evident by processing small portions of an image through selected algorithms.

This paper describes an investigation of spatial signatures that are applicable to ERTS-1 MSS images. Artifacts in the spatial signatures seem to be related to the multispectral scanner. A method for suppressing such artifacts is presented. Finally, results of terrain type recognition for one ERTS-1 image are presented.

E 73-10176

Paper I 18

CLASSIFICATION OF ERTS-1 MSS DATA BY CANONICAL ANALYSIS

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ABSTRACT

The objective of canonical analysis as applied to the classification of MSS data is to obtain the maximum separability among a number of categories. For each category the spectral signature (i.e., the mean vector) and the covariance matrix are computer based on a number of observations which belong to the category. Based on this, an orthogonal transformation is derived which maximizes category separability in as few axes as possible. Each unknown observation can be classified into one of the categories on the basis of the euclidean distance between the transformed unknown vector and each of the transformed category mean vectors with certain constraints. Alternatively, the classification can be done by a table look-up technique for increased computational speed.

The application of canonical analysis was investigated using the merged MSS ERTS-1 data from two scenes viewed on different dates. Experiments with merged data indicated that blocks of considerable size may be brought sufficiently into registration by translation to enable further analysis. Considerable changes in signatures for various targets were observed for the two scenes, and these will be discussed in detail. Because of temporal effects, the separability among some targets was increased thus improving classification success. Also, the contribution of each of the four channels in each set toward the separability of the major targets will be discussed.

E73-10197

Paper I 19

IN SITU SPECTRORADIOMETRIC QUANTIFICATION OF ERTS DATA

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ABSTRACT

Three test sites were selected for a spectroradiometric analysis of the terrain. These data were to be related to the image density as seen on ERTS-1 multispectral bands. The test sites consisted of Willcox playa, Phoenix and Prescott, Arizona. A truck mounted telespectroradiometer was used to obtain the data which were reduced on site using a minicomputer. Required changes in multispectral camera exposure were determined by measuring the downwelling illumination in the spectra bands employed and were relayed to the aircraft overflying the test site.

Weather conditions have only permitted spectra to be taken at Copper Basin to date. Low altitude photography was obtained simultaneously with the spectra of mineralized and non-mineralized vegetation. Results of this multispectral photography are presented and collated with the spectra and ground truth. A multispectral photographic analysis of the Willcox playa was also made using ERTS-1 imagery on three consecutive overpasses. The results of conventional multispectral synthesis of the four bands are shown as well as a time sequential multispectral color presentation. This latter photograph relates color to environmental changes as a function of time rather than spectral changes for any single date. Since the primary mission of ERTS is to detect changes in the environment, it is believed that this mode of data reduction should be employed by principal investigators in conjunction with conventional techniques.