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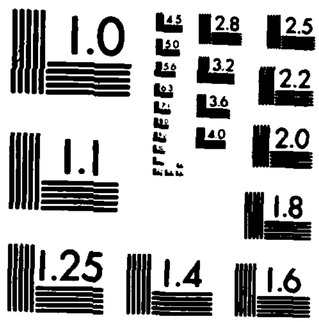

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A number of feature extraction techniques have been developed and tested on the Digital Image Analysis Laboratory (DIAL) at ETL. These techniques inlude stereo matching, edge detection, texture extraction, and statistical pattern recognition on digitized aerial imagery, as well as interactive binary image cleansing (raster processing) on the derived results. Experiments have shown that each of these techniques has some limited success at performing its task, but as isolated entities, they fail to perform at a level needed in a cartographic feature extraction system. This paper discusses some of the capabilities of DIAL and

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) concludes that a method of coordinating simple feature extraction techniques under the management of a heuristic rule-based system should be investigated.

CARTOGRAPHIC FEATURE EXTRACTION ON ETL'S DIAL SYSTEM

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ABSTRACT

A number of feature extraction techniques have been developed and tested on the Digital Image Analysis Laboratory (DIAL) at ETL. These techniques include stereo matching, edge detection, texture extraction, and statistical pattern recognition on digitized aerial imagery, as well as interactive binary image cleansing (raster processing) on the derived results. Experiments have shown that each of these techniques has some limited success at performing its task, but as isolated entities, they fail to perform at a level needed in a cartographic feature extraction system. This paper discusses some of the capabilities of DIAL and concludes that a method of coordinating simple feature extraction techniques under the management of a heuristic rule-based system should be investigated.

INTRODUCTION

The subject of semi-automated feature extraction has been studied at the US Army Engineer Topographic Laboratories (ETL), Fort Belvoir, encompassing such areas as texture extraction, statistical classification, edge detection, binary image cleansing, and the extraction of elevation data. This work supports a goal to extract cartographic features from digital and digitized aerial images. Thus far, the problem has been simplified to consider only the easiest of cartographic features such as buildings, roads forests, fields, and lakes.

Those feature extraction techniques that proved to be of interest have been implemented on the Digital Image Analysis Laboratory (DIAL), an interactive facility that will serve as a common testbed for the techniques in future research activities. Techniques include statistical classification using either a supervised Bayes algorithm or an unsupervised clustering algorithm, edge detection via the Sobel or Marr method, and binary image cleansing using a raster processing algorithm. The feature vector having the greatest impact as input to the classification process was implemented: a simple two-component vector consisting of the average gray shade over an N x N window of gray shades, and the standard deviation over that same window. Other image descriptors that were implemented consist of measures that are variations of the Laws texture algorithm.

A program for compiling match-point data from stereo imagery has also been implemented on DIAL. This program is discussed under the heading of feature extraction capabilities because it provides the essential data needed to compute elevations. Elevations and elevation-related information can be considered feature primatives that provide relevant knowledge about cartographic features.

THE DIGITAL IMAGE ANALYSIS LABORATORY FACILITY

The Digital Image Analysis Laboratory (DIAL) is an interactive system that has been used at ETL to research a variety of mapping and photo-interpretation techniques. Some of DIAL's capabilities include gray-level mapping, magnification, filtering operations, mosaics, warping, scrolling, targeting, image fusion, and perspective viewing. Other capabilities include the feature extraction methodologies discussed in this paper.

DIAL consists of two work stations connected to a mainframe computer system via a PDP 11/50 mini-computer. Each work station has a keyboard and display, two trackballs, an x-y tablet, and two color monitors. The display in each work station is linked to a copying unit, and one of the color monitors is linked to a color-camera system. The two stations utilize a CYBER 170 sequential computer and have access to an associative-array processor. Peripheral units include eight disk drives and four magnetic-tape units.

The system software on DIAL is made to support a modular program structure. Typically, a programmer wishing to perform a particular task codes his algorithm as a DIAL Program Module (PM). Users of DIAL can then call the module from one of the work stations. PMs are called individually. The output from a PM is stored on a DIAL file (or a set of DIAL files). Subsequent calls to this PM or other PMs can utilize the file and produce other files. Thus, a sequence of PMs can be used to perform a number of small tasks which build on each other, resulting in the completion of some larger task.

FEATURE EXTRACTION CAPABILITIES ON DIAL

Texture Extraction

Various texture measures have been investigated for their feasibility as input to statistical classification runs. Experiments tested the following measures: Max-Min texture (Crombie, Rand, and Friend; January 82, July 82), Edge texture measures and a two-component Ad-Hoc measure (Crombie, Friend, and Rand; October 82), and the Laws texture measure (Rand, Shine).

These experiments were run in a batch-mode environment. They invoked the use of the "Divergence Measure" as a test for class separability, a measure of distance between two class samples that is computed from the information content in each sample, and was developed from the concepts defined in Information Theory. The experiments performed a number of auto-classification runs using a Bayes classifier (the term "auto-classification" refers to the fact that the processing was done only on the training areas of an image, not the entire image). Some complete images were also processed. A common set of imagery was used throughout the experiments -- digitized aerial imagery consisting of 1024 x 1024 8-bit pixels having a resolution of about one meter.

Results of the experiments showed that the simple two-component Ad-Hoc measure, consisting of the average gray shade over an N x N window of gray shades, and the standard deviation over that same window, had the greatest impact for statistical classification. The performance of the Laws texture and Max-Min texture was about the same; however, considering the expense in extracting the Max-Min texture, Laws texture was rated the preferred of these two measures. See Table 1, extracted from ref. Rand and Shine for a comparison of the Laws, Max-Min, and Ad-Hoc measures (The Edge Texture was nct included here because it was eliminated in an earlier study). Based on the results of these experiments, the two-component Ad-Hoc measure and a variation of the Laws texture measure was implemented on the interactive DIAL facility.

Table 1 Comparison of Laws Texture Max Min-Texture and the Ad-Hoc measure

Scene	Texture Measure	Class (percentage of correct hits)					
		1	2	3	4	5	6
A	Laws	84	71	59	74	79	74
	Max-Min	68	89	61	95	82	60
	Ad-Hoc	63	81	90	99	78	90

Statistical Classification

The capability to perform statistical classification on a variety of input data is incorporated onto the DIAL facility. In addition to the texture data mentioned above, a variety of data types can be processed; including, but not limited to, panchromatic, infrared, and LANDSAT images. The essential characteristic of the input is that the data set be a collection of registered DIAL image planes For example, if an experiment is intended to test the feasibility of combining a panchromatic, infrared, and textured image, the system requirement is that (1) each image be placed in a DIAL format and (2) each image be registered to the other two images.

Two algorithms are available to perform the statistical classification: a supervised Bayes algorithm called MAXLIK, and an unsupervised clustering algorithm called CLUSTER. In either case, the processing is highly interactive. MAXLIK requires that the training areas be defined -- a process where the operator delineates possible sample areas on a psuedocolored-superimposed display of the set of input images, and then selects the best set of samples based on an interactive statistical analysis of the data. CLUSTER requires the interactive adjustment of a number of clustering parameters.

An interactive experiment on DIAL, testing the feasibility of combining various texture measures, was recently performed (Rand). This experiment confirmed earlier results, concluding that the simple two-component Ad-Hoc measure, by itself, is the best candidate for use in a statistical classification process. The addition of other components onto this measure did not significantly improve a classifier's performance.

Edge Detection

Currently, two types of edge detection exist on DIAL: Marr and Sobel. Each method is a windowing technique that attempts to delineate edges that exist on an image by detecting noticeable changes in image gray-shade values. The Marr method attempts to detect peaks in the rate of intensity change along the direction of local intensity gradients by counting signed zero-crossings in the second derivative. Some filtering is used to attenuate the high spatial frequency signals above the scale of resolution desired. The Sobel method convolves a 3 x 3 nonlinear enhancement operator over a gray-shade image, producing an edge image of the same resolution as the original. Experiments using these edge detection methods to detect roads and drainage patterns have been performed (Brown). These methods of edge detection are effective, but only when used in conjunction with the binary cleaning operation (discussed below), since significant cleansing of an edge image is required.

Binary Image Cleansing

An output image generated by an edge detection or statistical classification run can be smoothed (cleansed) by a DIAL program called RASTER. This program operates on binary imagery, processing data in a raster format, as opposed to a vector format. The raster processing approach is ideally suited to array processing; therefore, the algorithm was implemented on the associative array processor, a subsystem that is interfaced with DIAL.

Raster is controlled entirely by the commands of an operator. The user of RASTER defines the areas he wishes to process and selects the operations to be applied to that area. Operations that can be invoked allow the following: undesirable clutter to be eliminated from user-specified areas, lines to be thickened and thinned, and small line segments to be either merged or erased.

As mentioned, RASTER requires binary imagery. The output images generated by the edge detection routines are binary and can be used directly in RASTER. However, the images generated by the classification routines are not. Therefore, if a classified image needs to be smoothed, the procedure to follow is to establish binary planes of data, one for each class. A complete description of the RASTER processing method has been published in an ETL report (Friend).

Extraction of Elevation Features

Studies on techniques to complete match points and extract elevation data from stereo imagery over the past 10 years have in the development of an interactive program on DIAL called the Digital Interactive Mapping Program (DIMP). This program provides a mechanism to interactively complete and edit stereo match points that can then be converted to elevation data by a supporting DIAL routine.

DIMP relies heavily on the stereoscopic display of the image pair being matched, and the overlay of match-point results onto that image pair. Anaglyphic techniques are used to display an image pair on a single monitor, providing a 3-D visual model. Match-point results are also display in 3-D using graphic overlays. Typically, a user initializes the program by placing a "floating-dot" mechanism on the ground at a number of user-specified points. The selected points define the area to be processed and an initial 3-D model. The program will then automatically compute match points until it gets lost, at which time, the user intervenes and places the floating-dot on the ground.

DIMP allows the user to specify the functions and parameters that run its algorithm. One of three correlation functions can be selected: the linear correlation coefficient (RXY), the covariance correlation coefficient (SXY), or the absolute difference coefficent (DXY). Among the adjustable parameters are point spacing, the sizes of the left and right matching windows, error limits that flag match points needing user intervention, and a window-shaping parameter.

The performance of DIMP depends on the properties of the image area being matched. An area containing a moderate amount of detail will match almost automatically, whereas areas containing too-little or too-much detail will require frequent operator intervention (e.g., if an area does not contain much detail then there may not be enough information on which to correlate). In any case, the quality of the final results can be controlled through the skilled intervention of an operator.

DISCUSSION

Currently, the following feature extraction capabilities exist as separate entities:

- the extraction of elevation data
- edge detection
- statistical classification

The capability to extract elevation data has an immediate application of generating a digital terrain matrix. Edge detection is effective for simple features when used in conjunction with binary image cleansing; however, this technique (Marr or Sobel), a low-level operator, must now be applied to higher-level functions. Statistical classification has not proved feasible for identifying even the simplest cartographic features. This capability may find its best application in a supportive role, identifying surface-material categories, vegetative land-cover, and land-formations (Rice, Shipman).

Methods to combine DIAL's feature extraction capabilities are being investigated. A synergistic combination of these capabilities is being sought, possibly invoking the use of symbolic processing and methods of knowledge representation. Note that image-interpreters use a vast amount of knowledge in the process of extracting features, either explicity (e.g., supplying information on a map sheet) or implicitly (e.g., replying on past experience to detect and identify features). This same symbolic-type information is also what ultimately defines a cartographic feature, not the numeric-type (low-level) information being extracted by the computer. Currently, the feature extraction processes on DIAL supply a limited amount of such knowledge, but only through the interactive intervention of a human operator -- the algorithms merely consider the mathematical properties of an image.

In support of this investigation, a rule-based strategy for coordinating isolated feature extraction techniques and invoking constraints on solutions is being studied. Part of the plan is to develop rules that enforce consistency among derived cartographic primitives. For example, a terrain model can be used to develop paths of creeks, drainage, and railroads (and vice versa). Methods to supplement match-point compilation with edge-detection techniques are being considered; for example, a preliminary terrain model might be developed using the match-point data derived only from image points corresponding to lineal features of high-curvature (e.g. road intersections, corners of buildings).

Expectations for this recent approach are being kept reasonable. Computer processing techniques, regardless of whether they deal with number processing or Artificial Intelligence, are effective only on well-defined problems having limited domains. Cartographic feature extraction is not a well-defined problem and its domain is essentially unlimited.

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