JAMES D. TURINETTI*
OLIN W. MINTZER†
USAF Rome Air Development Center
Griffiss AFB, New York 13441

Computer Analysis of Imagery

Combinations of day and night thermal imagery can be useful in land-use identification.

ABSTRACT: *An investigation was conducted to determine computer analysis procedures applied to gray-tone data from day and night thermal-infrared imagery to classify land uses. A computer program was devised to identify three choices of land use: water, vegetation and construction materials (soil, asphalt, steel, etc.). As the quality of the model improved, the accuracy of the identification also improved; the image interpreter's tasks were reduced, allowing him to concentrate on the identifications of the more complex landuses. Over 40 percent of the targets were uniquely and correctly identified based on only thermal-infrared density information.*

INTRODUCTION

AS THE VOLUME of data collected from remotely sensed images using photo interpretation techniques increases, an updating of the interpretation techniques is essential. For the past 25 or 30 years the techniques have largely been manual in character. Today, a great need exists to automate this process in order to keep up with masses of acquired data inputs. This is particularly true as data are derived from the ERTS-A system which is now producing images (data) at a rate far surpassing any other process; (consider 40,000 to 50,000 9×9-inch images per week for one year). To date no complete system has been devised to process the rapidly-accumulated data into intelligible information. Even in the past 10 or 12 years scientists and engineers have feverishly attempted to automate the derivation of quantitative intelligence from large amounts of image data. Let us take a look at a sampling of some of the attempts.

Fischer and Ray (1960) showed that technique development was under way to quantify the photo image using densitometer measurements of photographic gray tones. Simple perception experiments by Murray (1961) demonstrated that alphabetic letters and simple geometric figures could be perceived and recognized automatically on images. Rosenfeld (1962) experimented with visual textures of terrain image samples which could be distinguished by automated measurements, and then he later made an approach to automate photo interrpetation by extracting the textural nature, shapes and sizes of objects' images. Hawkins and Munsey (1963) combined an optical technique of examining the photo film in a multistage, nonlinear decision process to perform routine photo reading tasks.

In 1965, Doverspike, *et al.*, applied the microdensitometer to the examination of color film in determining land-use classification, without much success, but pointed out that the blue portion of the spectrum offered more potential than red or green. In 1969 Rib and Miles stated that densitometer measurements of tone and texture of multichannel images and ther spectral response signatures for some targets offered a potential means of delineating terrain features.

Centner and Hietaner (1971) discussed the overall potential of automatic pattern recognition, and adopted a pattern recognition technique by training a decision logic network to classify objects viewed on the imagery. The network accumulated statistical information from known image classes, and then classified additional data samples accurately.

* Presented at the Fall Convention of the American Society of Photogrammetry, Columbus, Ohio, October 1972.

† Prof. Mintzer is with the Ohio State University, Columbus, Ohio.

The Centner/Hietaner pattern-recognition process seems to have potential in the automation of photo interpretation. One important step of this method is adapting the computer to do the routine analysis of the data classification. An oversimplified list of the steps involved in this process would include: (1) image production, (2) image density (tone) extraction, and (3) identification of the object represented by the densities. The object of this paper is to consider Step Three.

As seen earlier, scientists and photo interpreters have attempted to automate portions of, or all of, the above steps, yet have not been completely successful. Much more work is yet to be done. Our investigation shows how computer assistance reduced the interpreter's routine tasks, and how day and night thermal-infrared (TIR) imagery may be of some use in land-use identification. Using the density data and computer to analyze the density data, some element of success has been achieved in land-use classification over a limited area. The effort reported herein shows how density (tone) data from day and night thermal-infrared imagery are processed by computer into landuse identities or classes.

Procedure

The procedure involves two steps: (1) extracting densities representing three general land uses from both day and night TIR imagery; and (2) programming the computer to organize and analyze the density data to provide an output in the form of the land-use classes represented by the densities.

The day/night TIR densities had a relationship which enabled the computer to discriminate the targets' land uses based on sets of tone (density) data. In this instance, tones which represented each of the land uses were manually read and recorded.

A paper gray-tone step wedge of 10 gray tones (Figure 1) was used as a density standard, and a number ranging from zero to one corresponding to the step wedge tone that matched a given image was recorded for each target from both the day and night TIR images. The tones were then organized into two-dimensional density vectors for the targets observed. Each target was represented by a set of vectors constructed from the daytime imagery and the night-time imagery. These tone data were extracted from thermal imagery flown in June 1967 by Bendix Aerospace Corporation. The imagery covered an area near Huron, a few miles north of Ann Arbor, Michigan. Ten target types were grouped into three broad land-use categories. These listings are shown in Table 1.

Fig. 1. Paper gray-tine step wedge.

Computer Program Aspects

A computer was programmed to set up a model based on the two-dimensional gray-tone vectors and then subsequently used to identify objects based on this model. These values were also used as input data for the computer identification to evaluate the ambiguities in the analysis.

The model parameters were increased by the computer by a statistical process that assumed that the observed data were normally

TABLE 1. TARGET TYPES

Water	*Vegetation*	*Construction Materials*
1) Rivers	3) Field Crops	6) Asphalt Surfaces
2) Lakes	4) Grass	7) Gravel Surfaces
	5) Trees	8) Railroad Tracks
		9) Metal Bridges
		10) Metal Roofs

distributed. In this application we assumed that 95 percent of the time 95 percent of the observations were within the population of densities on the imagery, and we constructed a tolerance interval based on these assumptions. The limits from these tolerance intervals were then used to establish the upper and lower limits for the densities for each target.

In this investigation the land uses of all of the targets were known. For the analysis a portion of the targets were considered to be unknown and then identified. Image densities of the known land uses were used to establish a model which would be used to represent the other land uses throughout the study area. The unknown target densities were then compared with this model and identified accordingly. The densities used in the model for the unknown target points were all taken from the same imagery as was used for the model, and unknown target densities were taken from image points close to the model points to insure that the vegetation and atmospheric conditions would be the same for both. The objects for the model and unknown target points were taken from the same images so that the physical parameters of the scene, scale and chemical processing were all the same.

If the inputs to the model actually represented the larger family of image densities that was used to describe the various landuses, the model was a fairly accurate landuse discriminator. If the inputs to the model were ambiguous, the model had very general, broad parameters, and the results were also ambiguous.

THE FORTRAN PROGRAM

The computer program (Fortran) constructed a model based on image densities from the various landuses. The densities of the images of an unknown target were then compared with this model, and if the target and the model were compatible, the target was identified.

The program was divided in two main sections. The first section constructed the evaluation model, and the second section compared

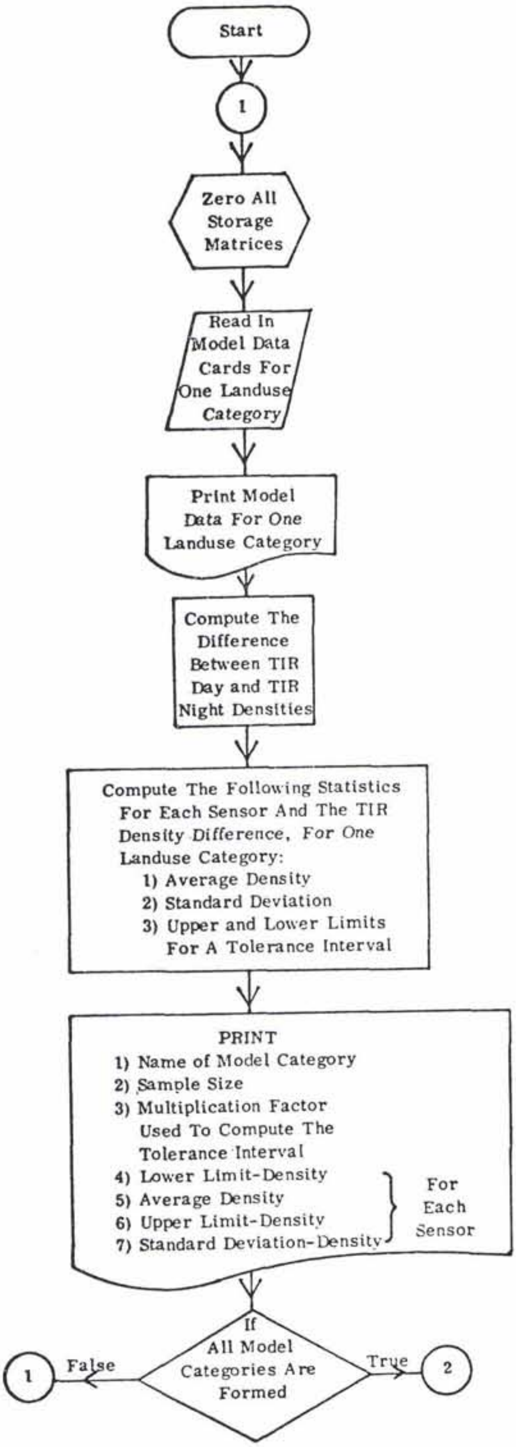

FIG. 2. Flow chart for model formation.

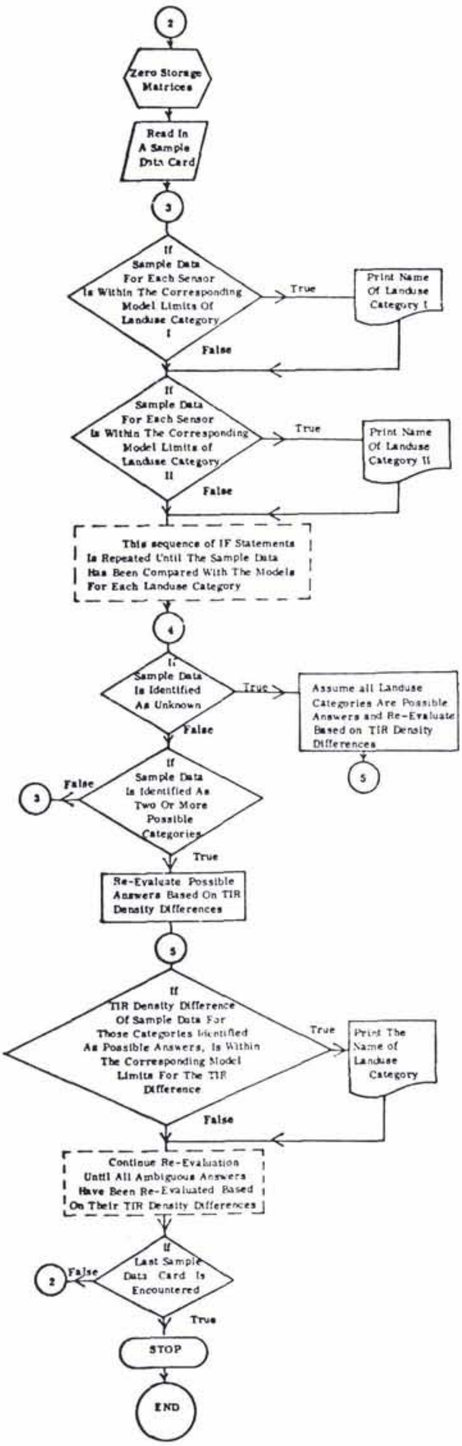

FIG. 3. Flow chart for target evaluation.

the densities of the targets with the evaluation model by using Boolean logic to perform the land-use identifications.

The evaluation model was a numerical approximation for a set of land uses. This model contained the projected high and low values for the image densities of known land uses for a given set of imagery. (This model may not be useful if applied to any other set of imagery.)

The flow chart in Figure 2 traces the general steps in the model formation. The densities are read in, the standard deviation is computed for each sensor's densities, and tolerance intervals are established with these standard deviations (one interval for each sensor input). The tolerance intervals are then used in the logic statement.

Figure 3 illustrates the steps taken in the target evaluation portion of the program.

A Fortran IF statement implemented the Boolean logic used for the land-use identifications.

An IF statement is defined as a logical expression which, when evaluated, gives the answer *true* or *false*. If the expression is true, it is executed.

> *Example: IF (A.LE.B)C = 1.0* indicates that if the value of *A* is less than or equal to the value of *B*, then C is set equal to *1.0*. If A is not less than or equal to *B*, then *C* is not set equal to *1.0* and the next sequence is executed.

Figure 4 is a flow chart which further illustrates how an IF statement functions. A series of *True/False* questions are posed by the computer. If the answer is *True*, the program continues along the *True*-valued branch of the flow chart. If the answer is *False*, the program follows the *False*-valued branch and continues to the next statement.

The upper and lower values of the densities for each specific land-use category for each type of imagery were stored in a matrix, and the target densities were evaluated

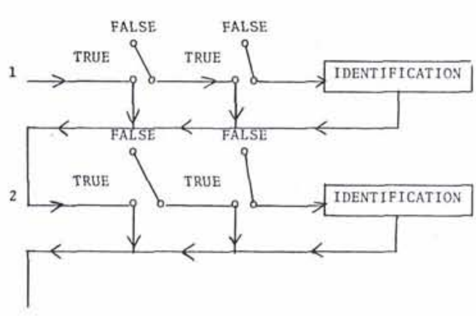

FIG. 4. Flow chart for *IF*-statement.

against these limits. If the target density for the first sensor's imagery was within the limits of the densities for that category on that sensor, the IF statement was true; therefore the program executed the next branch of the IF statement. If the sample density for the second sensor's imagery was within the density limtis for this sensor, that portion of the IF statement was also true, and the process continued until all branches of the IF statement had been evaluated and found to be true, or until the target density and the model density limits were not compatible; in the latter instance, the program exited the IF statement.

If the sample data were within the limits of the model for all the sensors used in the IF statement, the sample was identified as that land-use category. The evaluation was then repeated with the same target data for the next land-use category; this continued until the target data were all evaluated against all of the possible land uses, each being identified or rejected.

It was seen that multiple or ambiguous identifications were possible. To reduce the ambiguity, the differences between the day and night TIR densities were used to establish a separate tolerance interval, and the ambiguous identifications were re-evaluated based on the differences between their day and night TIR densities.

Analysis of Results

The models set up for the day and night imagery tones for this investigation were successful in differentiating water from its background, and in differentiating asphalt from its background. Grass was differentiated 75 percent of the time from the other objects, but confused with others 25 percent. The so-called gress fields were probably not completely covered with grass; that is, open soil patches occurred in the same area where the grass was observed.

Metal roofs were confused with other items 90 percent of the time, but on the night imagery the black tone of metal roofs is blacker than anything else, so this result can be attributed to the difficulty of tone-matching with the gray-tone wedge used. Table 2 contains a summary of these statistics.

Table 2. Summary of Results

Out of Three Possible Choices:	
Unique Identification (Landuse Correctly Identified)	42%
Choice of Two Identifications (One Landuse Listed was Correct)	56.5%
Unable to Identify Landuse	0.3%
Wrong Answer	1.2%

With the large volume of data to be collected by means of various types of imagery, the automatic detection and identification of objects or terrain features is an attractive possibility. It would relieve some of the routine work now executed by photo interpreters. The computer identification could include other more sophisticated forms of input data; for example, shape and size, or more complex forms of logic. It is concluded from the results of this investigation that the computer identification of a range of objects, using day and night tones from infrared imagery, has reasonable possibilities.

Conclusions

- Combinations of day and night thermal imagery can be useful in land-use identifications.
- Of the six pattern elements used in photo interpretation, we find that tone alone can be used to classify land uses.
- Computerizing the identification procedure reduces drudgery of the photo interpreter's work and liberates him to concentrate on more complex targets or tasks.

References

Ray, R. G. and Fischer, W. A., "Quantitative Photography—A Geologic Research Tool," *Photogrammetric Engineering*, 26:1, March 1960.

Murray, A. E., "Perception Applications in Photo Interpretation," *Photogrammetric Engineering*, 27:4, Sept. 1961.

Rosenfeld, A., "Automatic Recognition of Basic Terrain Types from Aerial Photographs," *Photogrammetric Engineering*, 28:1, March 1962.

Rosenfeld, A., "An Approach to Automatic Photographic Interpretation," *Photogrammetric Engineering*, 28:4, Sept. 1962.

Hawkins, J. K., and Munsey, C. J., "Automatic Photo Reading," *Photogrammetric Engineering*, 29:4, July 1963.

Doverspike, G. E., Flynn, F. M., and Heller, R. C., "Microdensitometer Applied to Land Use Classification," *Photogrammetric Engineering*, 31:2, March 1965.

Rosenfeld, A., "Automatic Imagery Interpretation," *Photogrammetric Engineering*, 31:2, March 1965.

Rib, H. T., and Miles, R. D., "Automatic Interpretation of Terrain Features," *Photogrammetric Engineering*, 35:2, Feb. 1969.

Crabtree, J. S., "The BAI Image Correlator," *Photogrammetric Engineering*, 36:1, Jan. 1970.

Centner, R. M. and Hietaner, E. D., "Automatic Pattern Recognition," *Photogrammetric Engineering*, 37:2, Feb. 1971.