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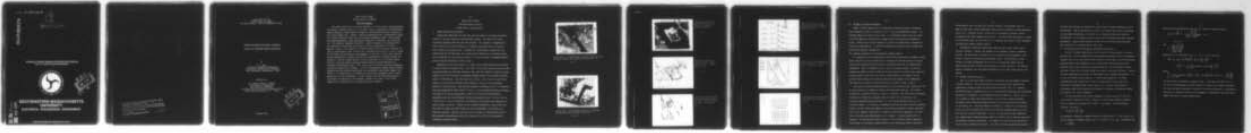   FEB 77   C CHEN   AF-AFOSR-2951-76

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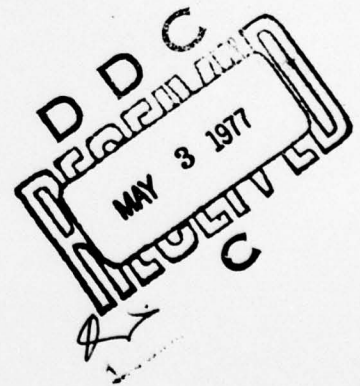
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TECHNICAL REPORT SERIES IN INFORMATION SCIENCES
(Dr. C. H. Chen, Principal Investigator)

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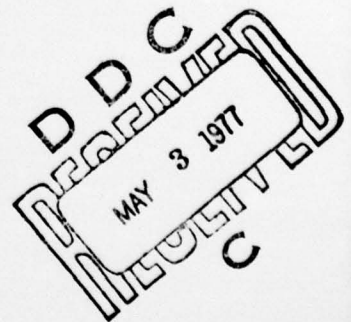**NORTH DARTMOUTH, MASS. 02747 U.S.A.**

FEATURE EXTRACTION AND SIGNAL PROCESSING

APPROACH TO REALTIME PATTERN RECOGNITION

by

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Interim Scientific Report

Technical Summary

This report describes the research progress in the five areas: image processing
and display, syntactic character recognition, feature formulation on reconnaissance
imagery analysis, seismic pattern recognition, and statistical pattern recognition
with finite sample size. Effort on image processing has been concentrated on simple
but efficient operations that meet the realtime recognition needs. This includes
histogram manipulation, image sharpening, compression, filtering, line detection,
etc. The syntactic character recognition compares favorably in performance with
the statistical recognition but requires much more computational complexity.
Emphasis is made on the extraction of both statistical and structural features. By
using a classification tree, features are formulated sequentially in order to arrive
at consistent interpretation on each segment of a picture. Factors that limit the
present capability in automatic analysis and classification of seismic events are
described. For the seismic records currently available, it is felt that further
effort on using the signal processing/feature extraction mixed approach can
increase the performance limit. This implies the use of phase spectrum information
and better seismic noise estimate. A class of nonparametric method using k-nearest-
neighbor rule has provided surprisingly good performance under finite sample size.
However it is cautioned that in general the performance degradation due to finite
sample size is very significant. And such effect should be taken into account in
all aspects of recognition system design. Finally some effect of the finite
sample size on information and distance measures is examined.

Grant AFOSR 76-2951

Interim Scientific Report

(March 1976 to February 1977)

I.   Image Processing and Display

During this period two new image data sets are added to our image recognition research. One set contains 21 reconnaissance images. The other is USC Image Processing Institute data base with 200 pictures. The purposes of examining new data sets are to test the feasibility of software algorithms already developed and to explore new problem areas. Although the reconnaissance imagery has less quality than the USC data base, it is particularly suitable for recognition study. It is interesting to note that the detection of airplane poses a somewhat different problem from the detection of tank or truck.

Regardless of the final objective in image study, image processing and display is almost always an essential step. Our effort in this area has been directed toward developing simple but efficient operations that meet the realtime recognition needs. Figures 1 and 2 show typical reconnaissance images studied (the original digitized image is 8 bits/pixel). For the target area in Fig. 1, Fig. 3a is an eight level display on the two-level Tektronix 4010 terminal. Figure 3b is the modified gradient of the same area. (The modified gradient as defined in Ref. 5 is different from those proposed by other authors.) Figure 3c is the modified gradient operation performed on the noise cleaned data. Spatial filtering and skeletonization algorithms have also been developed for the reconnaissance data. The two sides of a road in Fig. 1 can be detected by line fitting process using Hough transform as shown in Figs. 4a and 4b. Inspite of the equipment limitations, every effort has been made to provide the best display by using line-printer, X-Y plotter, and Tektronix terminal. Effort is also now made to acquire an electrostatic plotter which provides instantaneous multi-level display at our PDP 11-45 interactive recognition computer system.
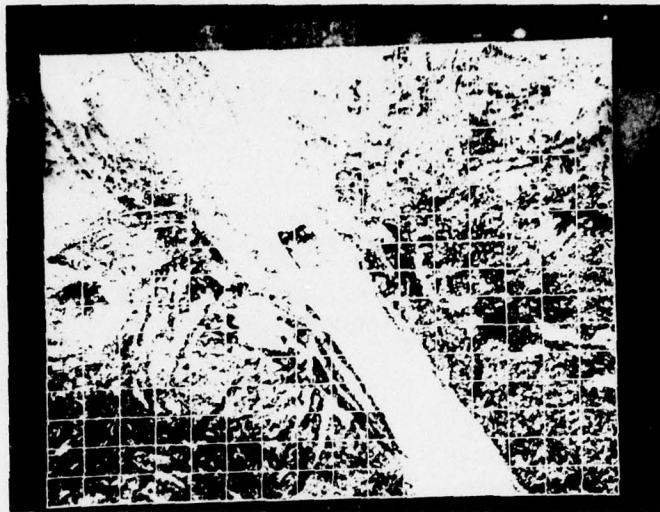
Aerial view of a tank moving on country road (file #6).
Two-level display with sliced levels 140 and 170.

Figure 1
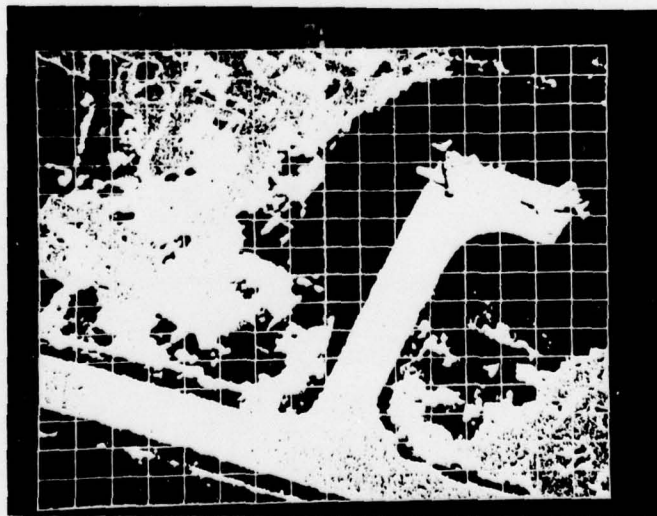
Aerial view of an airfield (file #15). Two-level
display with sliced levels 135 and 175.

Figure 2

Eight-level display of
target (tank) area in
Fig.1 on a two-level
display terminal.

Fig. 3a
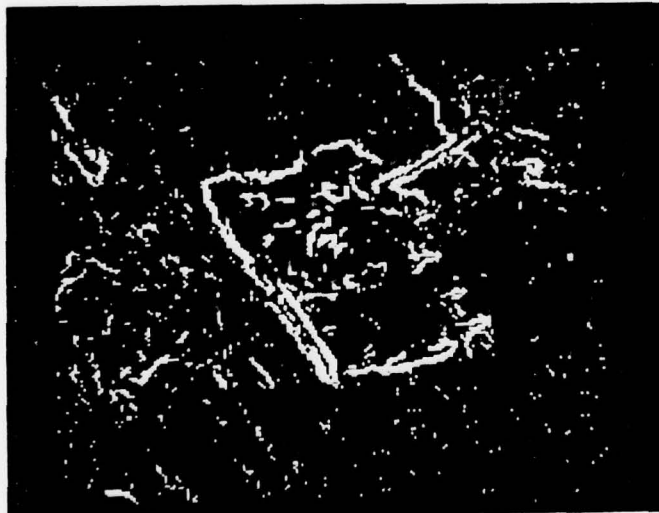
Modified gradient pic-
ture of target (tank)
area in Fig. 1. Thres-
hold is 38.

Fig. 3b

Modified gradient picture
of target (tank) region
in Fig. 1 on noise clean-
ed data. Threshold is
35.

Fig. 3c

Line fitting process for specified angles in Hough transform operation for the road in Fig. 1.

Fig. 4a

Results from Hough transform with two sides of the road in Fig. 1 fitted by lines.

Fig. 4b

Highleyman's character sets for syntactic recognition study.

Fig. 5

II. Syntatic Character Recognition

Figure 5 shows a typical set of handprinted characters studied. Stochastic syntax analysis is made on characters P and R using one-dimensional strings. Ten training samples are used for each class. The recognition result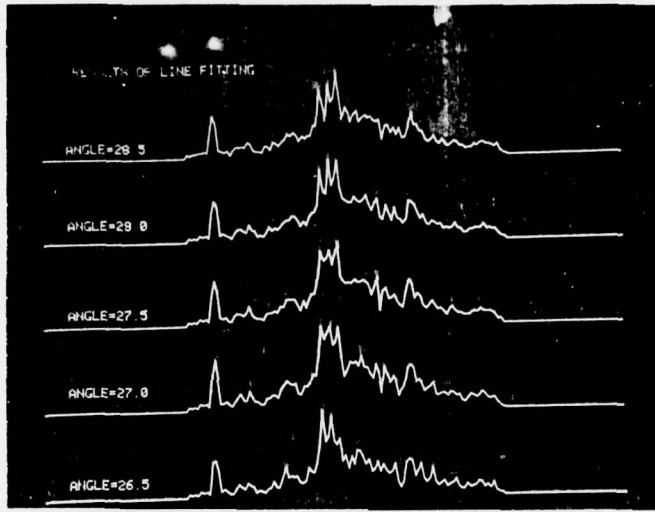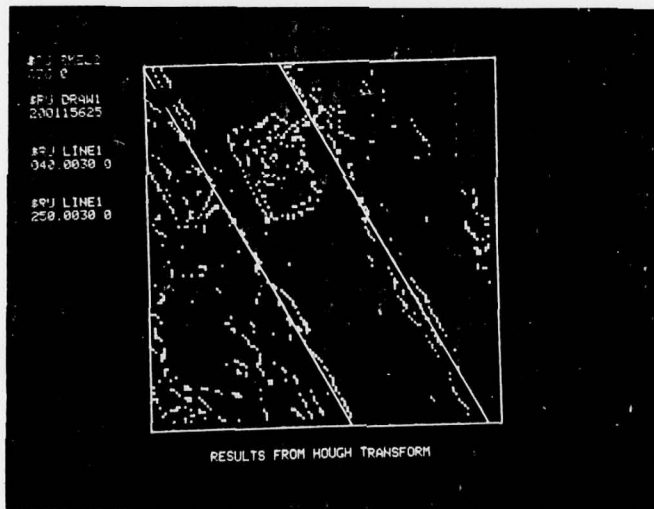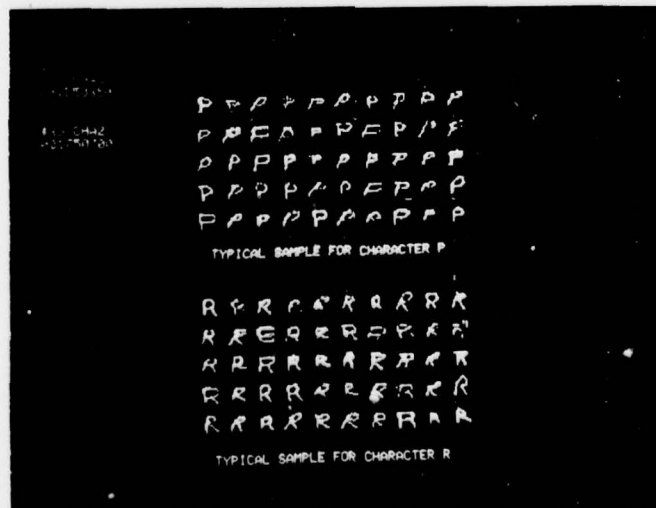 with two errors out of 100 samples is fairly good as comapred with the statistical recognition result. However there is more complexity involved in parsing than in finding the statistical distribution. We feel that statistical approach is more suitable for this kind of patterns (characters).

III. Feature Formulation on Reconnaissance Imagery Analysis

In conjunction with a preprocessing study of the reconnaissance imagery reported above, extensive effort has been made to formulate an efficient feature set which contains both statistical and structural information and meets the computational requirement. This is different from the feature selection process in classical recognition system in which a small set of good features is chosen from a large set. A major purpose of the study is a better understanding of the imagery through detection and locating of interesting object(s) and analysis of its background. Each image has at least one interesting object as shown in Figs. 1 and 2.

The class of features considered belongs to local features (pp. 61-85, Ref. 11) as they are much less complex to extract than the global features. The feature formulation is guided by a diverse source of knowledge. The statistical information includes the statistical parameters such as skewness of the histogram, the resolution-dependent entropy measures, and the textural measures based on a co-occurrence matrix. The structural information includes an average modified gradient measure, and the linear and symmetry characteristics detected by simple algorithms. Each of the features stated above is simple to extract but inadequate to be used alone to provide good understanding of the imagery. A classification tree is employed. By starting with simple features such as skewness, modified gradient, and entropy, the sequential classification process determines whether consistent

interpretation can be derived from existing features, what features are to be taken at next step, whether additional preprocessing is needed in certain ambiguous region, etc. Detailed computer results will be included in a master's thesis (expected in May 1977) supported by the Grant. Although human interaction is needed at the present study, we feel that this is a feasible step toward a fully automated reconnaissance imagery analysis system.

Preliminary recognition results show that all tanks, cars, trucks can be detected correctly. However, the shadows of the airplanes present a different problem. The graylevels of airplanes are very close to their background. The shadow is usually recognized as the airplane itself. The information on the direction of light illumination and the distance between the object and the shadow should be used to remove such ambiguity in object detection. The (phase) angular information from the modified gradient has also been considered for this purpose.

IV. Seismic Pattern Recognition

This is an area that signal processing techniques are much needed to extract effective features. The autocovariance features and the power cepstrum with alpha-minus-C energy estimate are both effective features (Ref. 3). However, the 89.32% correct recognition which is the best available indicates the performance saturation or limitation. Such limitation could be caused by: limited size in total seismic records, great variations among the seismic records available, inadequate noise statistics because the record is short and noise-only duration is very small, etc. Only the bodywave information is utilized in the study and there is no way to separate the surface wave from the bodywave again due to the fact that the record is very short. However, to work with the data available, more sophisticated signal processing techniques must be used to extract additional informations currently unavailable. For example the phase spectrum information can be used to generate new features. And the structural decomposition should be

performed with perhaps the synthesized seismic record to derive features from the surfacewaves. Thus by increasing the variety of features that contain statistical and structural informations, we believe the performance limit can be moved up considerably. It is doubtful that any single kind of feature can provide adequate performance. Again we must emphasize on the use of the statistical-structural mixed model for such complex pattern (Ref. 10).

V. Statistical Pattern Recognition with Finite Sample Size

In Ref. 6 we have shown that the lower bounds of the probability of correct decision for a class of sample-based classification procedures using the k-nearest-neighbor rule can be very close to that obtained with the Bayes linear discriminant analysis based on the assumption of two multivariate Gaussian densities with different mean vectors but equal covariance matrices. The nonparametric method obviously is good for the finite sample size under the assumed conditions. However once the conditions are changed, the performance can be changed considerably. It is also noted that a recent paper by S. Raudys which appears in the Third International Joint Conference on Pattern Recognition has given a much more pessimistic performance under finite sample size. Thus the classification performance under finite sample size constraint is largely an unresolved problem and remains to be further examined.

For the information and distance measures, continued study has been made on the finite sample size effect. Consider one-dimensional Gaussian densities with zero means and variances σ_1^2 and σ_2^2 which are equal. The Bhattacharyya distance is given by

$$B = \frac{1}{2} \log \left(\frac{\sigma_1}{\sigma_2} + \frac{\sigma_2}{\sigma_1} \right)$$

Let quantities obtained by sample estimate be indicated by "^". Also let N_1, N_2 be the numbers of training samples for both classes, $N = N_1 + N_2$. Furthermore let

$$\omega = \hat{\sigma}_1^2 / \hat{\sigma}_2^2$$

which has the F-distribution, with (N_1, N_2) degree of freedom, given by

$$p(\omega) = C \, \omega^{\frac{N_1}{2} - 1} \, \frac{\sigma_2^{N_1} \sigma_1^{N_2}}{(N_2\sigma_1^2 + N_1\sigma_2^2\omega)^{N/2}} \; ; \quad \omega \geq 0$$

$$0; \; \omega < 0$$

and

$$C = \frac{\Gamma(\frac{N}{2}) \, N_1^{\frac{N_1}{2}} N_2^{\frac{N_2}{2}}}{\Gamma(\frac{N_1}{2}) \, \Gamma(\frac{N_2}{2})}$$

Making use of the inequality $\log z \geq 1 - \frac{1}{z}$, $z \geq 0$, we can write

$$E(\hat{B} - B) = \frac{1}{4} E \log \frac{(1 + \omega)^2}{\omega} - \frac{1}{4} \log (\frac{\sigma_1}{\sigma_2} + \frac{\sigma_2}{\sigma_1})^2$$

$$\geq \frac{1}{4} \int_0^\infty [1 - \frac{\omega}{(1 + \omega)^2}] \, p(\omega)d\omega - \frac{1}{4} \log (\frac{\sigma_1}{\sigma_2} + \frac{\sigma_2}{\sigma_1})^2$$

where

$$\int_0^\infty \frac{\omega}{(1 + \omega)^2} \, p(\omega)d\omega = B(\frac{N_1}{2} + 1, \frac{N_2}{2} + 1)_2 F_1(\frac{N}{2}, \frac{N_1}{2} + 1; \frac{N}{2} + 2; 1 - \frac{N_1}{N_2} \frac{\sigma_2^2}{\sigma_1^2})$$

The lower bound is generally a negative number. This means that $E(\hat{B} - B) < 0$, and that the Bhattacharyya distance evaluated by using finite number of samples can lead to somewhat pessimistic estimate of the error probability. Although this conclusion is different from that of divergence, it demonstrates that the finite sample size effect is quite unpredictable.

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11. C.H. Chen, "Pattern Recognition and Artificial Intelligence", Academic Press, Inc., December 1976.

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This report describes the research progress in the five areas: image processing and display, syntactic character recognition, feature formulation on reconnaissance imagery analysis, seismic pattern recognition, and statistical pattern recognition with finite sample size. Effort on image processing has been concentrated on simple but efficient operations that meet the realtime recognition needs. This includes histogram manipulation, image sharpening, compression, filtering, line detection, etc.

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