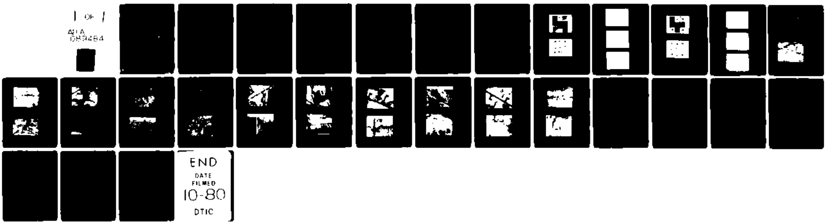
AD-A089 484 SOUTHEASTERN MASSACHUSETTS UNIV NORTH DARTMOUTH DEPT --ETC F/G 9/2
TWO EXPERIMENTS ON STATISTICAL IMAGE SEGMENTATION.(U)
SEP 80 C H CHEN, C YEN N00014-79-C-0494
UNCLASSIFIED SMU-EE-TR-80-9 NL



LEVEL II

AD A089484

Technical Report
Contract Number N00014-79-C-0494
SMU-EE-TR-80-9
September 15, 1980

# TWO EXPERIMENTS ON STATISTICAL IMAGE SEGMENTATION*



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* The support of the Statistics and Probability Program of the Office of Naval Research on this work is gratefully acknowledged.

TWO EXPERIMENTS ON STATISTICAL IMAGE SEGMENTATION

Recently there has been a considerable research interest in applying statistical pattern recognition theory to image segmentation. As the image is rich in statistical information, effective segmentation of images into meaningful parts can be performed by using statistical techniques. In this report, we present segmentation results on infrared and reconnaissance images using two different statistical pattern recognition methods.

The first experiment is on the Alabama data base infrared images using the Fisher's linear discriminant analysis [1]. To preserve the inter-pixel dependence as much as possible, measurements are taken in the form of a 3 x 3 matrix. That is we are dealing with matrix measurements instead of vector measurements as typically considered in statistical pattern recognition. Let $x$ be a matrix measurement and $X_i$, $i = 1,2$ be the collection of $n_i$ measurements belonging to the ith class. The two classes considered are the target area and the background area. Define the sample mean matrix and the scatter matrices as

$$M_i = \frac{1}{n_i} \sum_{x \varepsilon X_i} x , \qquad i = 1,2$$

$$S_i = \sum_{x \varepsilon X_i} (x - m_i)(x - m_i)'$$

$$M = \frac{1}{n} \sum x = \text{mean of all samples; } n = n_1 + n_2$$

$$S_w = S_1 + S_2 = \text{pooled scatter matrix}$$

Then the Fisher's linear discriminant computes

$$y = w'x + \omega_o$$

where $W$ = weight matrix

$$= \alpha\, n\, S_w^{-1} (m_1 - m_2); \quad \alpha \text{ is an arbitrary constant}$$

$$\omega_o = -m'w$$

with w, x and m converted into vector form before computing y which is a scalar quantity. Decision is to choose class 1 if $y \geq 0$ and class 2 otherwise. For each infrared picture a 62 x 62 subimage that contains target(s) is used for the segmentation study. Only one picture is needed for computing the statistical parameters. Table 1 lists the mean and scatter matrices of the first picture considered. These parameters are used in all 18 pictures as tabulated in two sets in Table 2a. Table 2b is a description of the nature of target(s) in each picture along with the aspects. Fig. 2a and Fig. 3a are the original pictures (in two-level display) of Set I and Set II respectively. Figs. 2b and 3b are segmentation results with the bright regions for targets (hot objects). It is seen that the targets are clearly segmented from the background in all pictures. The results are somehwat better than those reported by Ahuja et.al. [2]. The object boundaries can be completely extracted from segmented images by using the cross (Robert) gradient and Sobel operator as shown in Figs. 2c, d and 3c, d.

The second experiment is on the reconnaissance images using two statistical features. Figs. 4 shows all 22 pictures considered. Only a portion of each picture is digitized into a 1024 x 1024 image for computer study. Each image contains one or several objects made of metals. Each image is divided into 256 subimages of size 64 x 64 each. For each subimage, compute a texture feature using co-occurrence statistics as defined in [3] and a gradient feature which is a count of the number of large gradient picture elements as defined in [4]. The coordinates (x,y) of pixels with ten largest feature values are tabulated in order of decreasing value in Table 3 for all images. If we divide the image into 16 x 16 subimages, coordinate x is the subimage column number counted from left to right and coordinate y is the row number counted from top to bottom. A careful analysis of the tabulated results indicates that over 95% of targets are identified correctly by at least one of the two features. However a number of non-target subimages are also identified. Performance improvement may be available by using additional features and the probabilistic labelling of feature importance. Further results will be reported in the near future.

## REFERENCES


1. R. O. Duda and P. E. Hart, "Pattern Classification and Scene Analysis," Interscience Publication, pp. 151-154, 1973.

2. N. Ahuja, A. Rosenfeld and R. M. Haralick, "Neighbor gray levels as features in pixel classification," Pattern Recognition, vol. 12, no. 4, pp. 251-260, 1980.

3. C. H. Chen, "On statistical and structural feature extraction," in "Pattern Recognition and Artificial Intelligence," edited by C. H. Chen, pp. 135-144, Academic Press, 1976.

4. C. H. Chen, "On three mathematical problems in image science," in "Image Science Mathematics" Symposium Proceedings, pp. 163-167, 1976.

## Table 1 (Figure 1)

*** MEAN MATRIX OF TARGET ***

| | | |
|---|---|---|
| 0.17251E 03 | 0.17714E 03 | 0.17855E 03 |
| 0.17579E 03 | 0.18043E 03 | 0.18189E 03 |
| 0.17320E 03 | 0.17755E 03 | 0.1[illegible]85[illegible]E 03 |

*** SCATTER MATRIX I ***

| | | |
|---|---|---|
| 0.11441E 09 | 0.82116E 08 | 0.56400E 08 |
| 0.82116E 08 | 0.88494E 08 | 0.67940E 08 |
| 0.56400E 08 | 0.67940E 08 | 0.80021E 08 |

*** MEAN MATRIX OF BACKGROUND ***

| | | |
|---|---|---|
| 0.40578E 02 | 0.39674E 02 | 0.38519E 02 |
| 0.34385E 02 | 0.33481E 02 | 0.32476E 02 |
| 0.31898E 02 | 0.31102E 02 | 0.30235E 02 |

*** SCATTER MATRIX II ***

| | | |
|---|---|---|
| 0.21476E 09 | 0.15418E 09 | 0.12317E 09 |
| 0.15418E 09 | 0.16979E 09 | 0.14295E 09 |
| 0.12317E 09 | 0.14295E 09 | 0.18751E 09 |

*** SAMPLE SCATTER MATRIX ***

| | | |
|---|---|---|
| 0.32917E 09 | 0.23629E 09 | 0.17957E 09 |
| 0.23629E 09 | 0.25829E 09 | 0.21089E 09 |
| 0.17957E 09 | 0.21089E 09 | 0.26753E 09 |

*** WEIGHT MATRIX ***

| | | |
|---|---|---|
| 0.20839E-02 | 0.22701E-02 | 0.24653E-02 |
| 0.10052E-01 | 0.10465E-01 | 0.10678E-01 |
| 0.10431E-01 | 0.10[illegible]99E-01 | 0.10[illegible]E-01 |

SET I :

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 5 | 6 |
| 7 | 8 | 9 |

SET II :

| | | |
|---|---|---|
| 10 | 11 | 12 |
| 13 | 14 | 15 |
| 16 | 17 | 18 |

Table 2a

| File No. | Target(s) | Aspect(s) |
|---|---|---|
| 1 | T | S |
| 2 | T | 3F |
| 3 | T | 3F |
| 4 | T | S |
| 5 | T | F |
| 6 | T | 3F |
| 7 | T | 3R |
| 8 | T,J | 3R,3F |
| 9 | T,J | S,S |
| 10 | T | 3F |
| 11 | T | S |
| 12 | J | 3R |
| 13 | T,J | 3R,3F |
| 14 | T | F |
| 15 | T | S |
| 16 | T | 3R |
| 17 | T | F |
| 18 | T | S |

Legend:
J = jeep
T = tank
S = side
F = front
R = rear
3 = 3/4 view

Table 2b

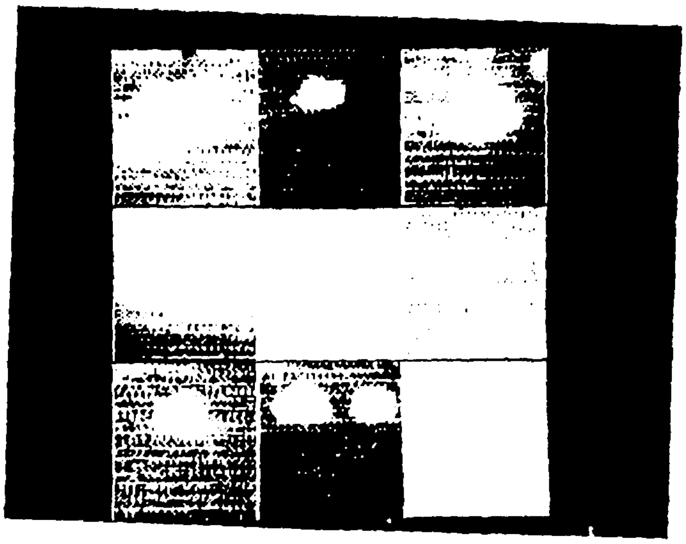


Fig. 2a

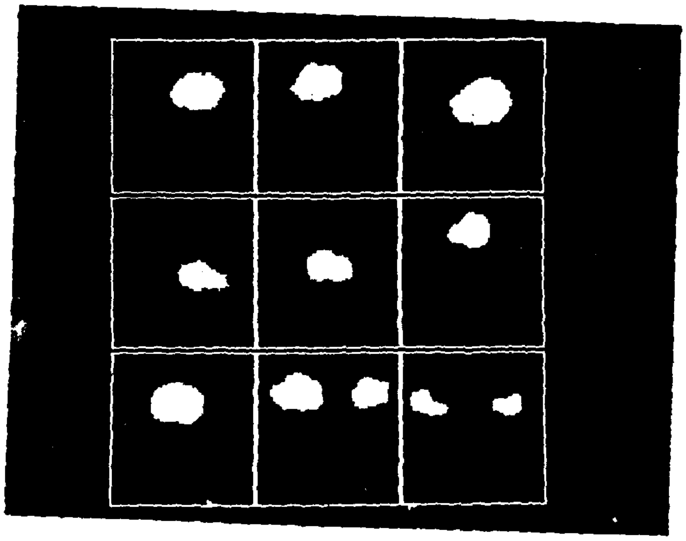


Fig. 2b

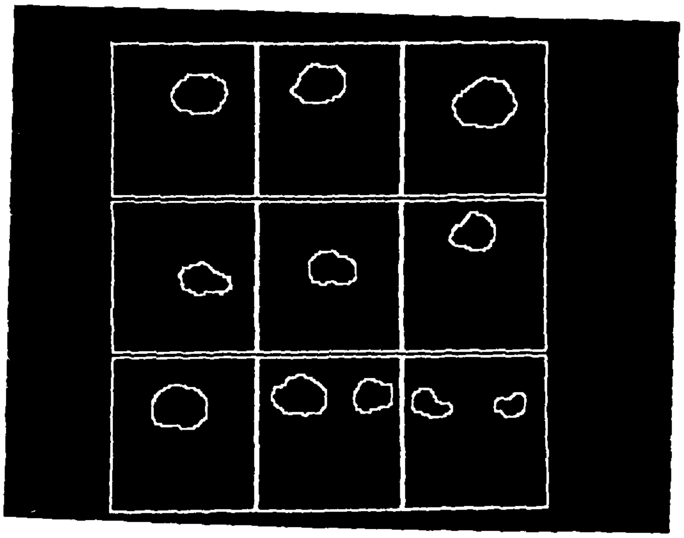
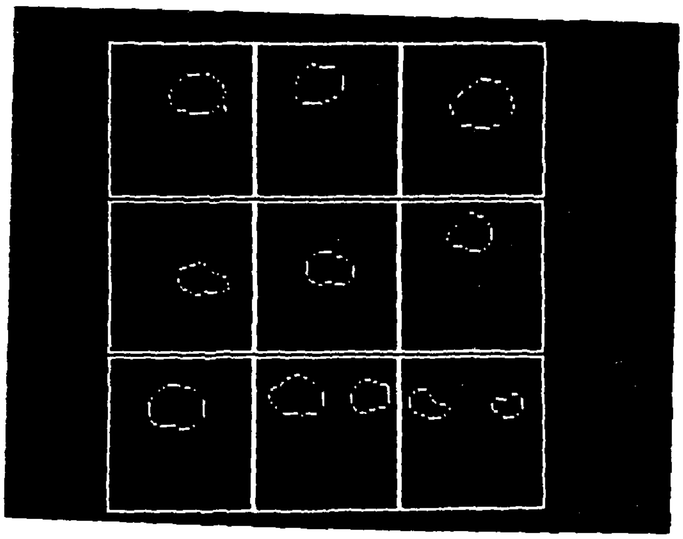


Fig. 2c



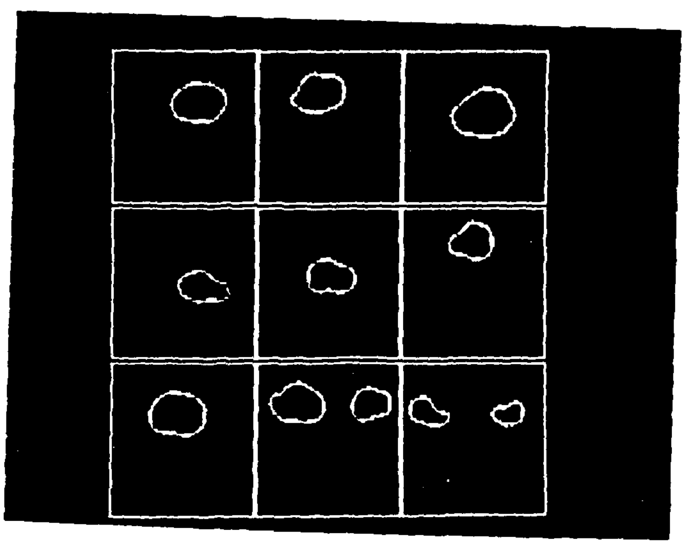


Fig. 2d

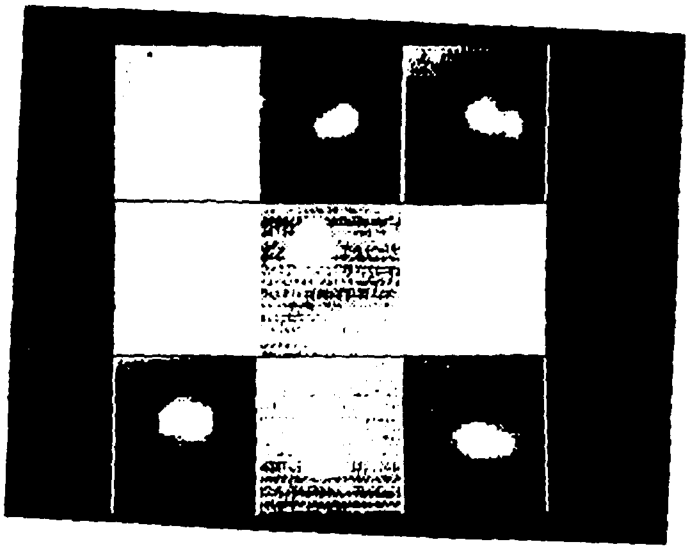


Fig. 3a

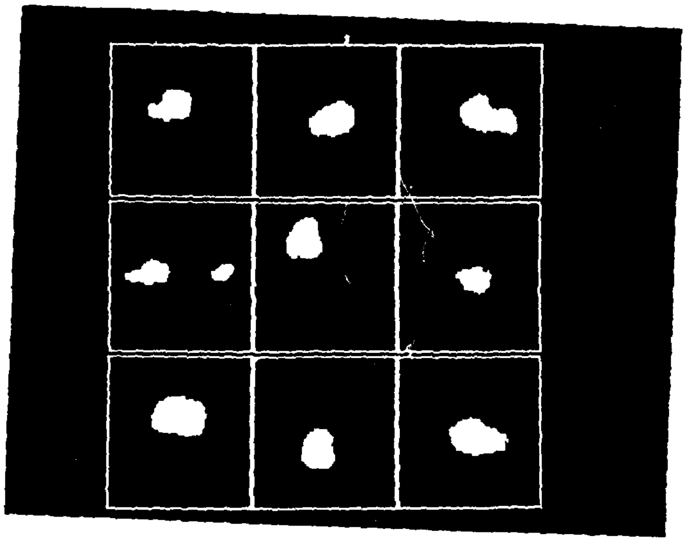


Fig. 3b

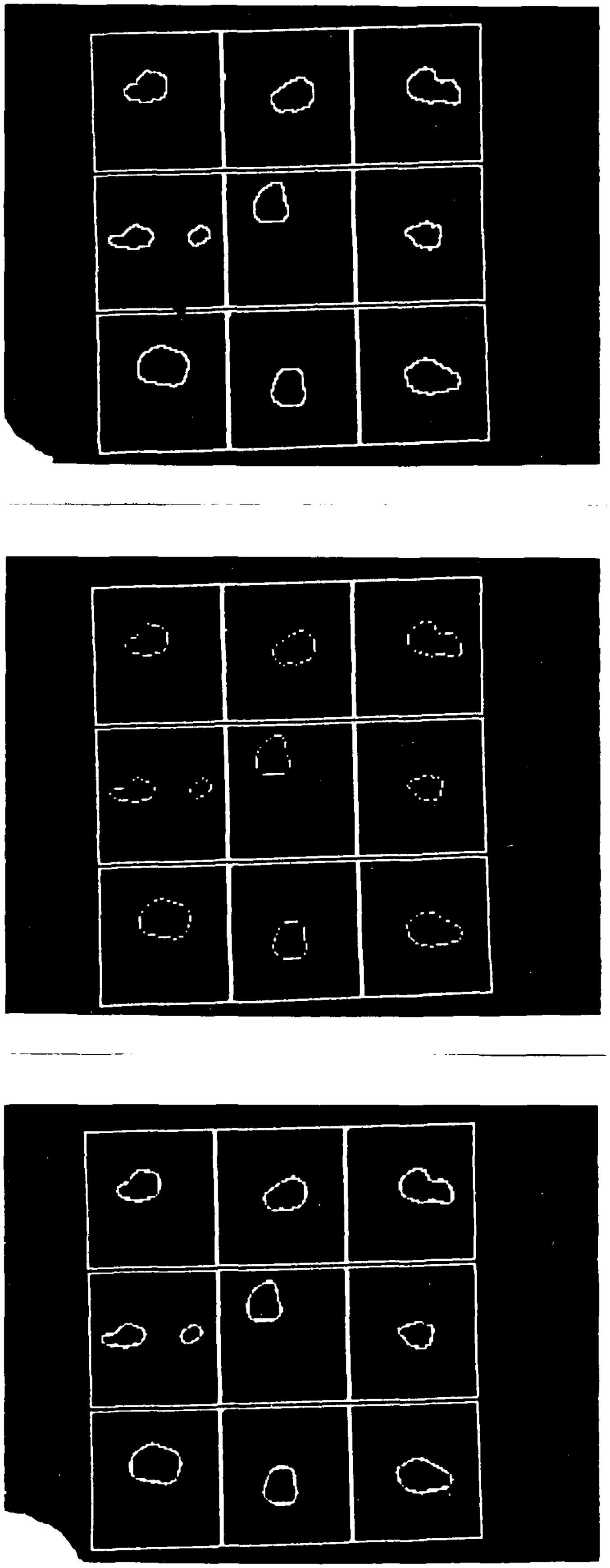


Fig. 3c

Fig. 4a
File 1

Fig. 4b
File 2

Fig. 4c
File 3

Fig. 4d
File 4

Fig. 4e
File 5

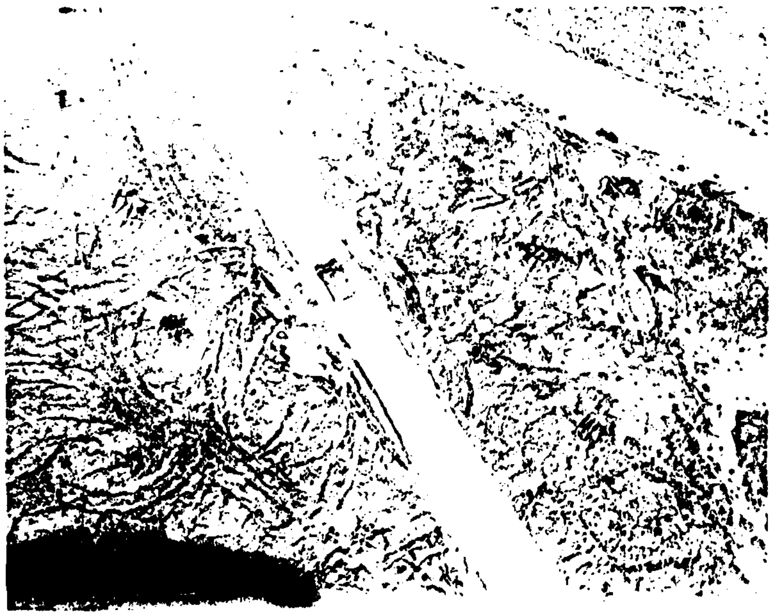


Fig. 4f
File 6

Fig. 4g
File 7

Fig. 4h
File 8

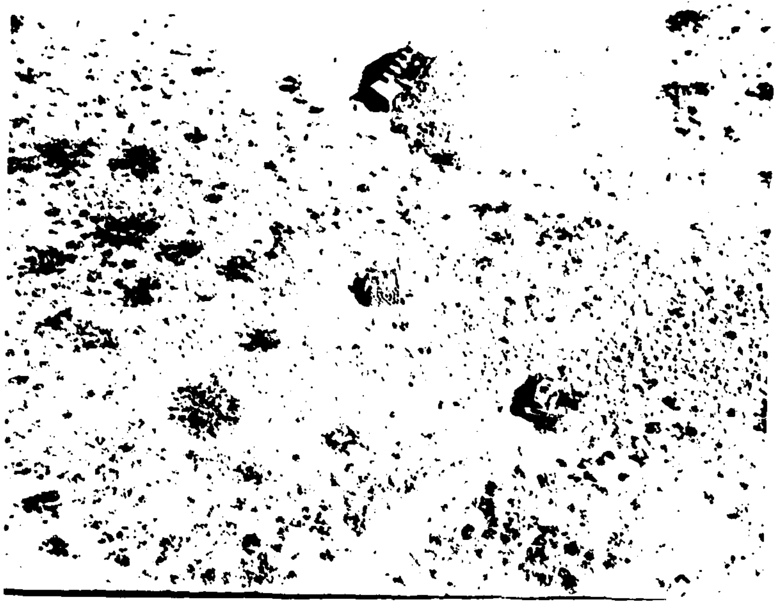


Fig. 4i
File 9

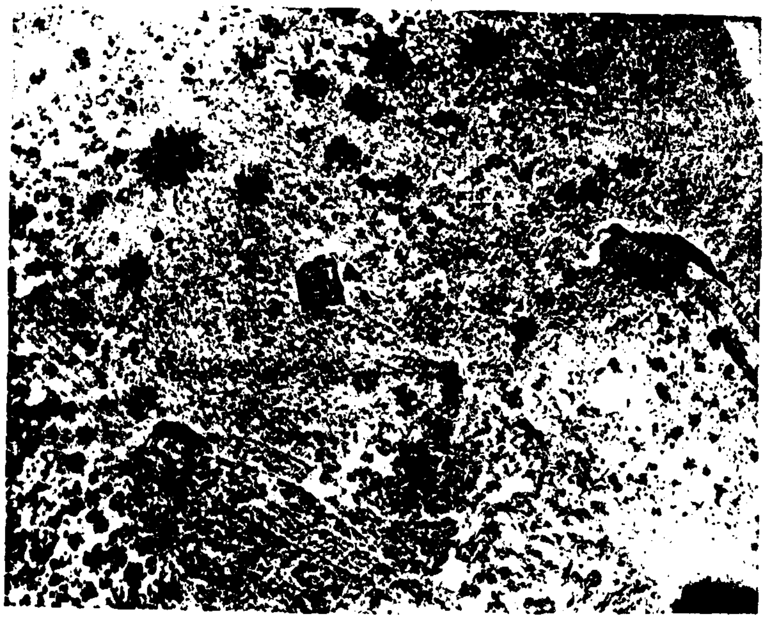


Fig. 4j
File 10

Fig. 4k
File 11

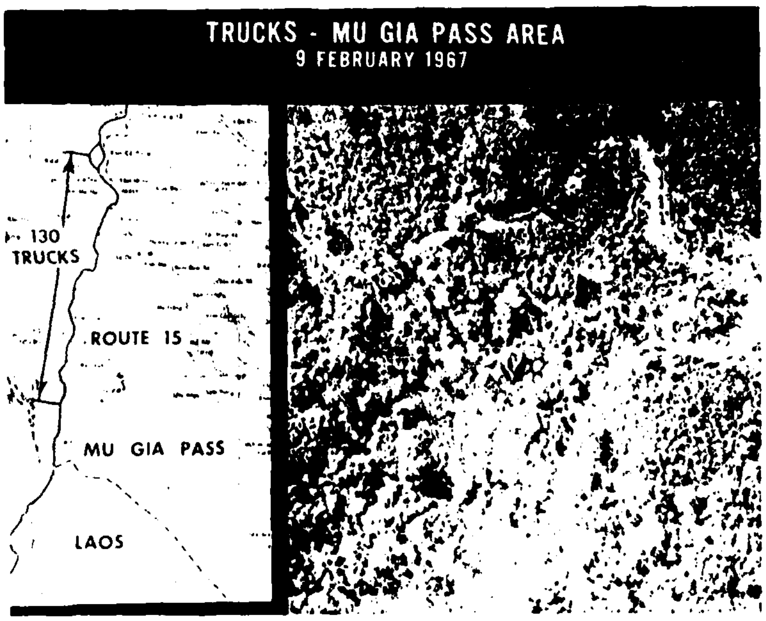



Fig. 4ℓ
File 12

Fig. 4m
File 13

Fig. 4n
File 14

Fig. 4o
File 15


Fig. 4p
File 16

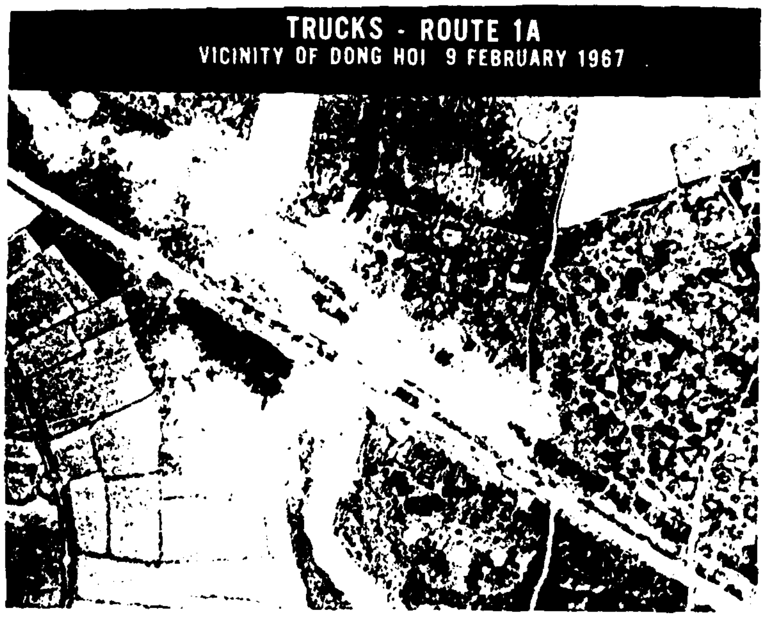



Fig. 4q
File 17

Fig. 4r
File 18

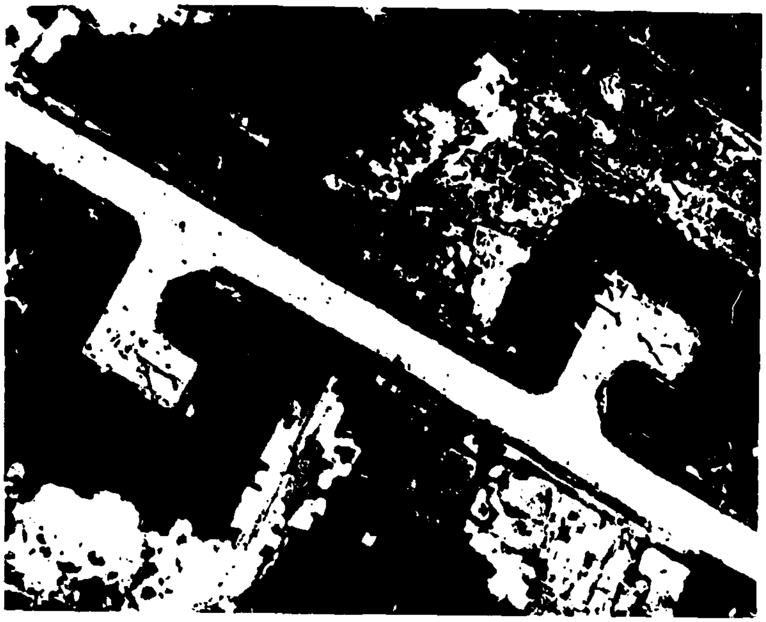


Fig. 4s
File 19

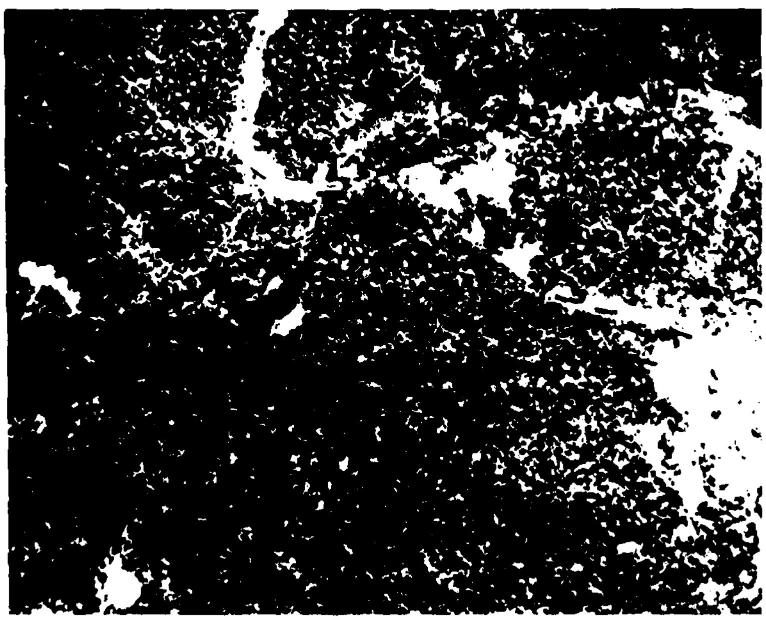


Fig. 4t
File 20

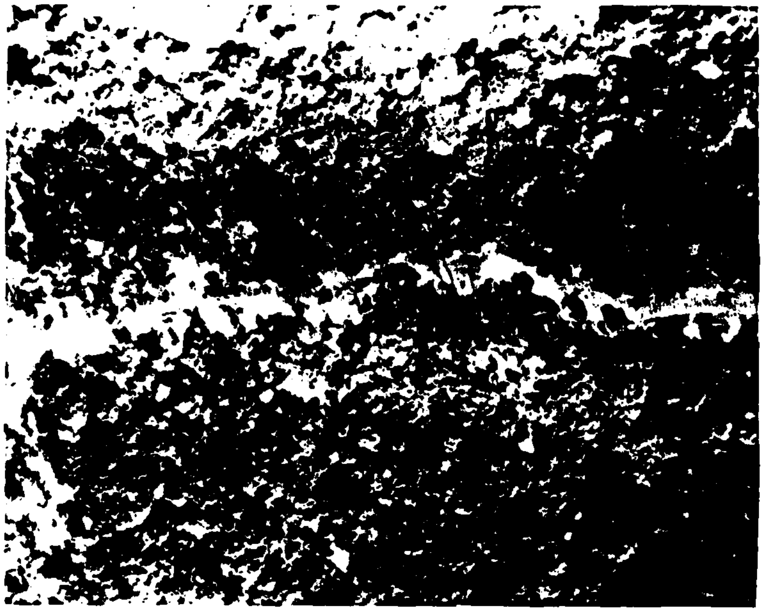


Fig. 4u
File 21

Fig. 4v
File 22

Table 3

IMAGE FILE 1

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

( 5, 4)
( 3, 4)
( 6, 4)
( 3, 3)
( 4, 4)
( 2, 5)
( 2, 3)
( 7, 4)
( 2, 4)
( 6, 3)

IMAGE FILE 1

POSSIBLE TARGET POSITIONS
DETERMINED BY THE GRADIENT FEATURE

( 5, 4)
( 6, 4)
( 3, 4)
( 2, 4)
( 4, 4)
( 6, 6)
( 2, 5)
( 2, 3)
( 2, 6)
( 3, 5)

IMAGE FILE 1

POSSIBLE TARGET POSITIONS
DETERMINED BY BOTH FEATURES

( 5, 4)
( 3, 4)
( 6, 4)
( 4, 4)
( 2, 5)
( 2, 3)
( 2, 4)

IMAGE FILE 2

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

(14, 15)
( 2, 6)
( 3, 6)
( 4, 10)
( 2, 8)
( 3, 5)
(15, 14)
( 5, 4)
(14, 7)
(14, 10)

IMAGE FILE 2

POSSIBLE TARGET POSITIONS
DETERMINED BY THE GRADIENT FEATURE

(14, 15)
( 3, 5)
( 3, 6)
(13, 15)
(14, 7)
( 2, 12)
( 4, 2)
(15, 10)
( 7, 4)
(15, 14)

IMAGE FILE 2

POSSIBLE TARGET POSITIONS
DETERMINED BY BOTH FEATURES

(14, 15)
( 3, 6)
( 3, 5)
(15, 14)
(14, 7)

IMAGE FILE 3

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

(15,13)
( 2, 6)
(11, 7)
(14, 8)
( 2, 5)
(13,10)
( 2, 8)
( 3, 7)
(10, 6)
(12, 9)

IMAGE FILE 3

POSSIBLE TARGET POSITIONS
DETERMINED BY THE GRADIENT FEATURE

( 2, 6)
( 3, 6)
( 2, 9)
( 6, 9)
(14, 9)
(13, 8)
( 2, 5)
(15, 8)
( 3, 8)
(13, 5)

IMAGE FILE 3

POSSIBLE TARGET POSITIONS
DETERMINED BY BOTH FEATURES

( 2, 6)
( 2, 5)
( 2, 8)

IMAGE FILE 4

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

( 8,15)
( 9,15)
( 3, 6)
( 8,14)
(11,12)
( 6,13)
(12, 3)
(15,14)
( 2, 6)
( 9,14)

IMAGE FILE 4

POSSIBLE TARGET POSITIONS
DETERMINED BY THE GRADIENT FEATURE

( 8,15)
(15,14)
(10,10)
(11,11)
(10,12)
(11,12)
( 8,14)
(12,12)
( 3, 6)
( 9,15)

IMAGE FILE 4

POSSIBLE TARGET POSITIONS
DETERMINED BY BOTH FEATURES

( 8,15)
( 9,15)
( 3, 6)
( 8,14)
(11,12)
(15,14)

Table 3 (continued)

IMAGE FILE 5

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

(10, 9)
( 9, 9)
( 8, 10)
( 4, 3)
( 3, 3)
(13, 7)
( 5, 7)
(15, 3)
(15, 9)
( 2, 4)

IMAGE FILE 5

POSSIBLE TARGET POSITIONS
DETERMINED BY THE GRADIENT FEATURE

( 5, 2)
( 7, 2)
( 2, 15)
( 9, 9)
( 6, 2)
( 3, 3)
(13, 2)
(15, 9)
(10, 9)
( 8, 2)

IMAGE FILE 5

POSSIBLE TARGET POSITIONS
DETERMINED BY BOTH FEATURES

(10, 9)
( 9, 9)
( 3, 3)
(15, 9)

IMAGE FILE 7

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

(14, 8)
( 3, 6)
( 5, 7)
(13, 7)
(15, 7)
(14, 7)
(12, 6)
(12, 9)
( 4, 6)
(15, 8)

IMAGE FILE 7

POSSIBLE TARGET POSITIONS
DETERMINED BY THE GRADIENT FEATURE

(13, 7)
( 2, 8)
( 3, 8)
( 2, 7)
(14, 9)
(14, 8)
(13, 8)
(12, 7)
(12, 8)
(15, 7)

IMAGE FILE 7

POSSIBLE TARGET POSITIONS
DETERMINED BY BOTH FEATURES

(14, 8)
(13, 7)
(15, 7)

IMAGE FILE 8

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

( 9,10)
( 8,10)
( 8,11)
( 3,11)
( 5, 7)
( 6, 8)
(15,10)
(12, 9)
(14, 9)
( 7,12)

IMAGE FILE 8

POSSIBLE TARGET POSITIONS
DETERMINED BY THE GRADIENT FEATURE

(14, 9)
(14,10)
(14,11)
(13, 9)
( 4, 8)
(11,11)
(12, 9)
( 2, 8)
( 3, 7)
(13,11)

IMAGE FILE 8

POSSIBLE TARGET POSITIONS
DETERMINED BY BOTH FEATURES

( 4, 8)
(12, 9)
(14, 9)

IMAGE FILE 9

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

( 9, 4)
(12,14)
( 6, 5)
( 7,10)
( 7, 5)
( 6,11)
( 7,11)
(13,12)
(10, 6)
( 6, 7)

IMAGE FILE 9

POSSIBLE TARGET POSITIONS
DETERMINED BY THE GRADIENT FEATURE

( 9, 4)
( 7,11)
(13,12)
(14,13)
(13, 5)
(15,12)
( 9,14)
(10, 3)
(14,12)
(11, 3)

IMAGE FILE 9

POSSIBLE TARGET POSITIONS
DETERMINED BY BOTH FEATURES

( 9, 4)
( 7,11)
(13,12)

Table 3 (continued)

IMAGE FILE 10

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

( 4, 9)
(13,10)
( 3, 9)
( 4, 7)
( 7, 3)
( 5,15)
( 3, 7)
( 5, 7)
(14,14)
(13, 8)

IMAGE FILE 10

POSSIBLE TARGET POSITIONS
DETERMINED BY THE GRADIENT FEATURE

( 3,15)
( 4,15)
( 4, 7)
( 5,15)
( 3, 6)
(10, 9)
( 5, 7)
( 4, 8)
(13, 4)
( 6, 9)

IMAGE FILE 10

POSSIBLE TARGET POSITIONS
DETERMINED BY BOTH FEATURES

( 4, 7)
( 5,15)
( 5, 7)

IMAGE FILE 15

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

(12, 5)
( 7, 4)
( 9, 4)
( 3, 4)
( 5, 5)
(13,13)
( 2, 4)
( 3,11)
( 2, 6)
(13, 5)
(15, 7)
( 3, 5)
( 5, 2)
( 7,13)
[illegible]

IMAGE FILE 15

POSSIBLE TARGET POSITIONS
DETERMINED BY THE GRADIENT FEATURE

(12, 5)
(15, 6)
( 5, 2)
( 4, 8)
( 3, 2)
(12,15)
(14,15)
( 7, 2)
( 7, 4)
( 3, 7)
(13, 5)
( 3, 9)
( 8, 3)
(13,15)
( 7,13)

IMAGE FILE 15

POSSIBLE TARGET POSITIONS
DETERMINED BY BOTH FEATURES

(12, 5)
( 7, 4)
(13, 5)
( 7,13)

Table 3 (continued)

POSSIBLE TARGET POSITIONS
DETERMINED BY THE TEXTURE FEATURE

| IMAGE FILE 11 | IMAGE FILE 12 | IMAGE FILE 13 | IMAGE FILE 14 |
|---|---|---|---|
| ( 6, 4) | (15, 5) | ( 9, 9) | ( 2, 4) |
| (13, 7) | (10,12) | ( 6,10) | ( 4, 4) |
| (13, 8) | (13, 3) | ( 7, 6) | ( 3, 4) |
| (13, 3) | (13, 2) | ( 2,15) | ( 3, 5) |
| (13,10) | (11,14) | ( 5, 4) | ( 4, 5) |
| (14,12) | (14, 5) | ( 5, 6) | ( 2, 3) |
| (11,13) | (10,13) | ( 6, 9) | ( 4, 6) |
| ( 4, 6) | (12, 9) | ( 5, 8) | ( 4,11) |
| (13, 6) | ( 9,13) | (15, 5) | (15, 8) |
| ( 8,15) | ( 9, 9) | ( 6, 6) | (14, 7) |

| IMAGE FILE 17 | IMAGE FILE 18 | IMAGE FILE 19 | IMAGE FILE 20 | IMAGE FILE 21 |
|---|---|---|---|---|
| ( 3, 2) | (15, 2) | (15, 4) | ( 8, 5) | ( 3, 2) |
| ( 2, 4) | ( 9, 3) | (12,15) | (13, 5) | ( 3,15) |
| ( 2,15) | (15,13) | (14, 3) | (11,13) | ( 6, 3) |
| (13, 5) | (12,13) | ( 8, 2) | (11,14) | ( 8, 4) |
| ( 2, 2) | ( 3, 3) | ( 5, 4) | ( 6, 7) | ( 7, 2) |
| ( 3,15) | ( 4,12) | ( 2, 3) | (15, 6) | (13, 9) |
| (15, 5) | (14,13) | (14, 4) | (12,13) | ( 7, 3) |
| ( 2, 8) | (15,14) | ( 6, 4) | (14, 7) | ( 2,12) |
| ( 3, 3) | ( 3,14) | ( 4,15) | (15, 7) | ( 8, 2) |
| (10, 6) | ( 3, 9) | ( 6,15) | (15, 8) | ( 7, 5) |

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| 4. TITLE (and Subtitle) Two Experiments on Statistical Image Segmentation | | 5. TYPE OF REPORT & PERIOD COVERED Technical Report |
| | | 6. PERFORMING ORG. REPORT NUMBER SMU-EE-TR-80-9 |
| 7. AUTHOR(s) C. H. Chen; Chihsung Yen | | 8. CONTRACT OR GRANT NUMBER(s) N00014-79-C-0494 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Electrical Engineering Department, Southeastern Massachusetts University, North Dartmouth, MA 02747 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS Statistics and Probability Program, Office of Naval Research, Code 436, Arlington, VA 22217 | | 12. REPORT DATE September 15, 1980 |
| | | 13. NUMBER OF PAGES 29 |
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fisher's linear discriminant
Statistical image segmentation
Infrared images; Reconnaissance images
Texture feature; Gradient feature

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)


Experiments on statistical image segmentation are performed on infrared image data base and reconnaissance image data sets by using respectively Fisher's linear discriminant and statistical features including texture and average gradient. The Fisher's linear discriminant is shown experimentally to be very effective in the segmentation of infrared images.


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S/N 0102-LF-014-6601

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