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A MODIFIED GRADIENT TECHNIQUE FOR IMAGE ANALYSIS.(U)
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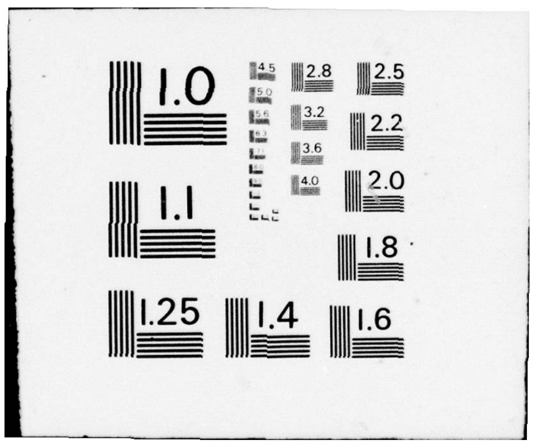
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(Dr. C. H. Chen, Principal Investigator)

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A MODIFIED GRADIENT TECHNIQUE FOR IMAGE ANALYSIS

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Abstract

The modified gradient operation considered in this report takes the product of four conventional gradient operations in four different directions. Such modified procedure is shown by extensive computer results to provide great improvement in noise reduction and boundary extraction over the conventional gradient operation. Furthermore, the procedure is computationally simple and insensitive to rotation of images. Computer results of modified gradient operation followed by image compression are also presented.

A Modified Gradient Technique for Image Analysis

C. H. Chen

The gradient operation may be considered as an approximation to the spatial differentiation of grayscale pictures. The resulting gradient picture, however, has a number of isolated or bursty noise elements, as well as disconnected object boundaries. The modified gradient proposed in this report places a greater emphasis on boundary points, which usually have larger gradient values, and greatly suppresses the noises resulting from differentiation. To compress the image spatially, it is more suitable to use the modified binary gradient picture because more boundary information is available. Compression provides further noise suppression in addition to size reduction.

A variety of digital gradient operators can be used for spatial differentiation. For the 4-point array

A B

C D

the gradient may be defined as one of the following expressions,

$$\frac{1}{2}(|A - D| + |B - C|) \tag{1a}$$

$$\frac{1}{2}(|A - B| + |A - C|) \tag{1b}$$

$$\frac{1}{2}(\sqrt{(A - B)^2 + (A - C)^2} \tag{1c}$$

$$\max(|C - D|, |C - A|) \tag{1d}$$

$$\max(|A - D|, |B - C|) \tag{1e}$$

Equation (1a) is the most commonly used conventional gradient operation. For the 9-point array given by:

A B C

D E F

G H I

some gradient operators are defined as

$$\max(|E - A|, |E - B|, |E - C|, |E - D|, |E - F|, |E - G|, |E - H|, |E - I|) \tag{2a}$$

$$\max\{|(A + B + C) - (G + H + I)|, |(A + D + G) - (C + F + I)|\}/3 \tag{2b}$$

$$\sqrt{(D - F)^2 + (B - H)^2 + \frac{1}{2}(A - I)^2 + \frac{1}{2}(C - G)^2} \tag{2c}$$

The actual performances of the operations given by Eqs. (1) and (2) are very similar. Theoretically speaking, an infinite array would be needed to achieve perfect differentiation. This is obviously impossible. Consider now a 16-point array,

```
A B C D
E F G H
I J K L
M N O P
```

The proposed modified gradient is defined as

$$\sqrt[4]{abcd} \tag{3}$$

where

$$a = |F - K| + |J - G|$$

$$b = |A - P| + |M - D|$$

$$c = |B - O| + |I - H|$$

$$d = |C - N| + |E - L|$$

Each point of the array is used once and only once. Equation (3) consists of the product of four conventional gradient operation (Eq. 1a) in four different directions. (Unless the arrays are uniformly speced horizontally and vertically, a and b do not coincide in directions). Thus the modified gradient is not sensitive to the rotation of images. Points along the object boundary of the original picture will be greatly emphasized because the product of large gradient values is large. Isolated noise points will be reduced because at least one of the four quantities a, b, c, d may become very small and the product would be small also.

In the computer study, the display is provided by XY-plotter which has only two levels: pen-down for a black point, and pen up for blank. A threshold is set such taht the pen is down when the threshold is exceeded. Thus only binary picture is available. In Figs. 1-17, the gradient picture refers to a binary picture computed from the conventional gradient operation given by Eq. 1a; and the modified gradient picture refers to a binary picture computed from Eq. (3). Figures 1-9 show a comparison between the gradient pictures and the modified gradient pictures. For a detailed discussion of the images studied, the readers should refer to the report by this author entitled, "Theory and Applications of Image Pattern Recognition", TR EE-75-3, April 1975, prepared for Grant AFOSR 71-2119.

The modified gradient obviously provides significant improvement over the conventional gradient in terms of noise suppression and object extraction. The thickened object boundaries may be thinned by thinning algorithms. The smaller number of gaps remaining may be filled in by boundary tracking or following algorithms. The required amount of computation which is slightly more than four times of the conventional gradient is quite small as compared with most image analysis algorithms.

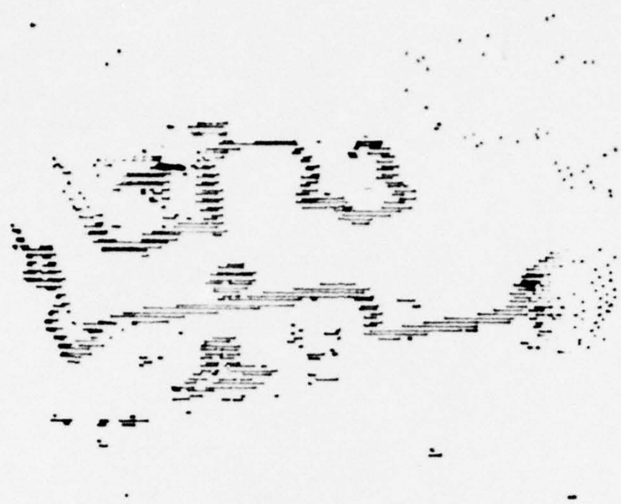
As a further step in image analysis, spatial compression from the modified binary gradient picture may be obtained by reducing every 9 points (a 3 by 3 array) into one point. A threshold of 3 is chosen such that when the number of 1's exceeds or equals to 3 in the 9 points, the 9 points are replaced by a single point of 1 (black); otherwise the new point is 0 (blank). Figures 10-17 show the full pictures of images obtained by modified gradient operation followed by 9 to 1 image compression. The complete operation very much preserves the original boundary information provided by modified gradient while the additional noise suppression is evident. It is noted that the XY plotter plots one line in every 12 lines. Thus there are actually 340 horizontal lines each in Figs. 10-17. If all lines are displayed the objects in pictures would appear to be more continuous.

From the compressed pictures we notice that further improvement should be made so that the object in each picture can be more clearly distinguished from the background. One other problem is the threshold selection to generate binary gradient or binary modified gradient picture. Figure 18 is a typical plot of the histograms of gradient and modified gradient pictures. The modified gradient histogram has a sharper peak but longer tail. The tail portion corresponds to the object boundary. Thus for the same threshold value, the area above threshold is larger in the modified gradient histogram than in the gradient histogram. If we lower the threshold in gradient picture to get the same number of points, there would be considerable increase of noise. This explains why the modified gradient performs better. The threshold may be determined by specifying a percentile (say 15%) of points above threshold or simply by trial and error on the scope of the keyboard or the XY plotter itself.

Fig. 1a The gradient picture of target area in File 1 with threshold 30

Fig .1b The modified gradient picture corresponding to Fig. 1a also with threshold 30.

(a)



(b)

Fig. 2 (a) The modified gradient picture of target area in File 2
(b) The gradient picture of the same area.
Threshold is 30 in each case. Target is a car.

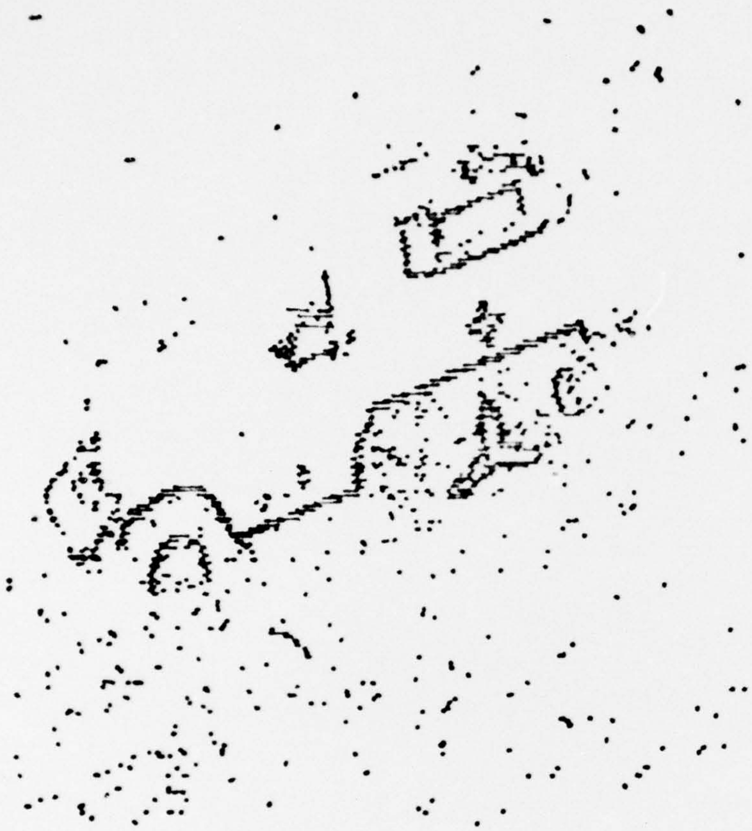


Fig. 3a The gradient picture of target area in File 5 with threshold 30.

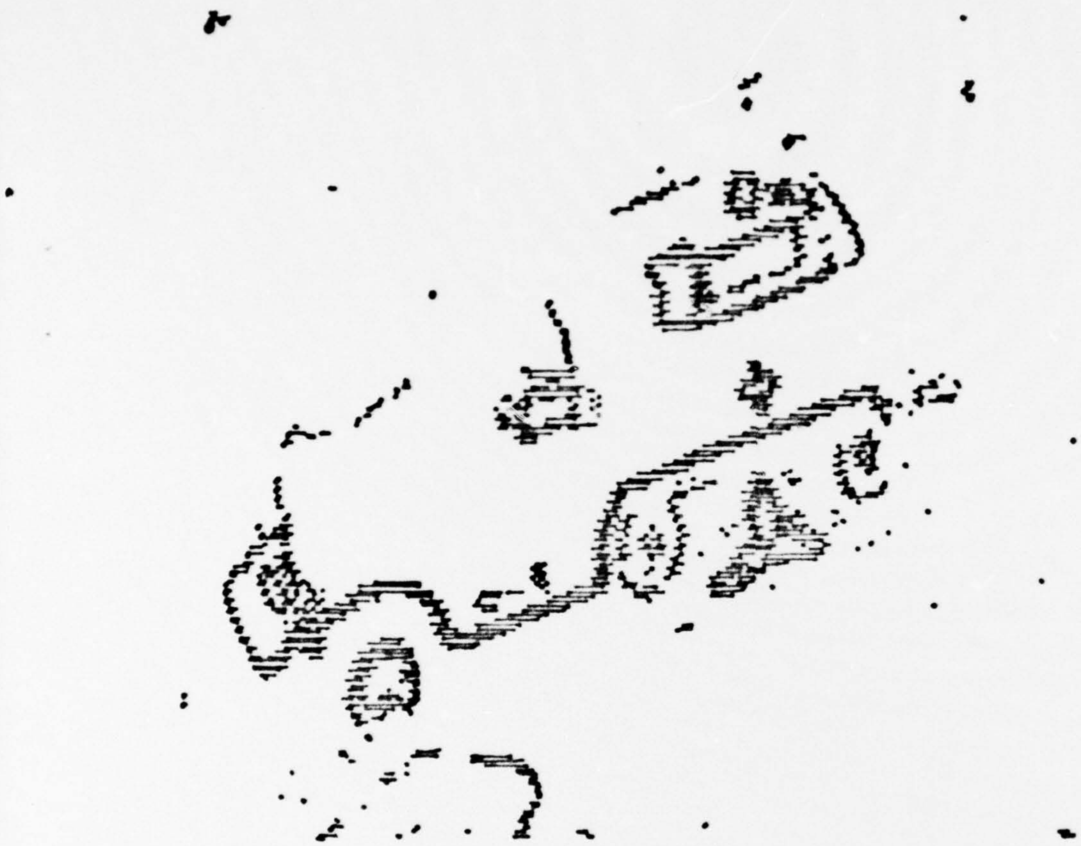


Fig. 3b The modified gradient picture corresponding to Fig .3a also with threshold 30 .

Fig. 4a The gradient picture of the target area in File 7 with threshold 30.

Fig. 4b The modified gradient picture corresponding to Fig .4a also with threshold 30 .

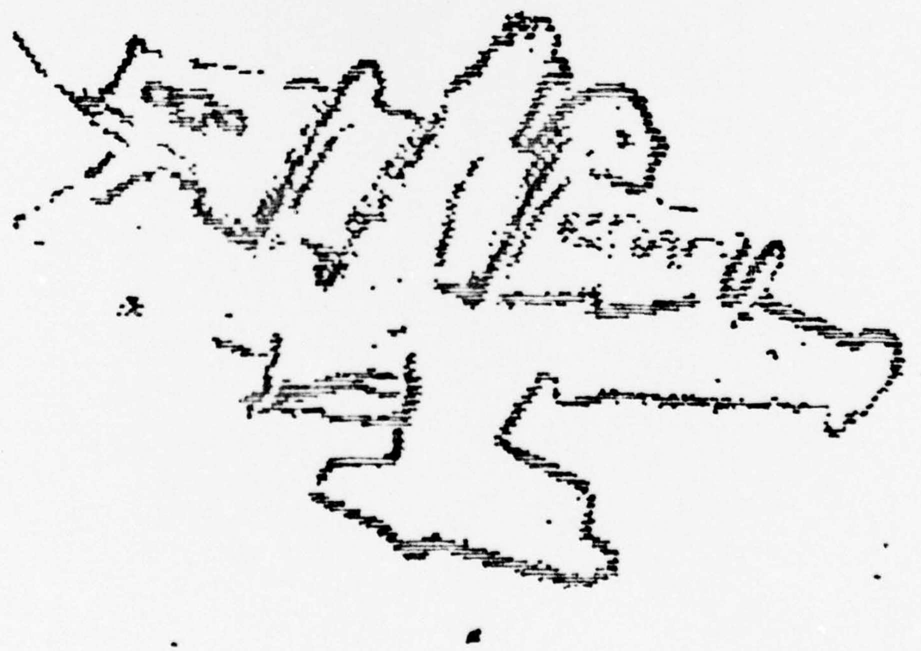


Fig. 5a The gradient picture of the target area in File 7 with threshold 50 .

Fig. 5b The modified gradient picture corresponding to Fig .5a also with threshold 50.

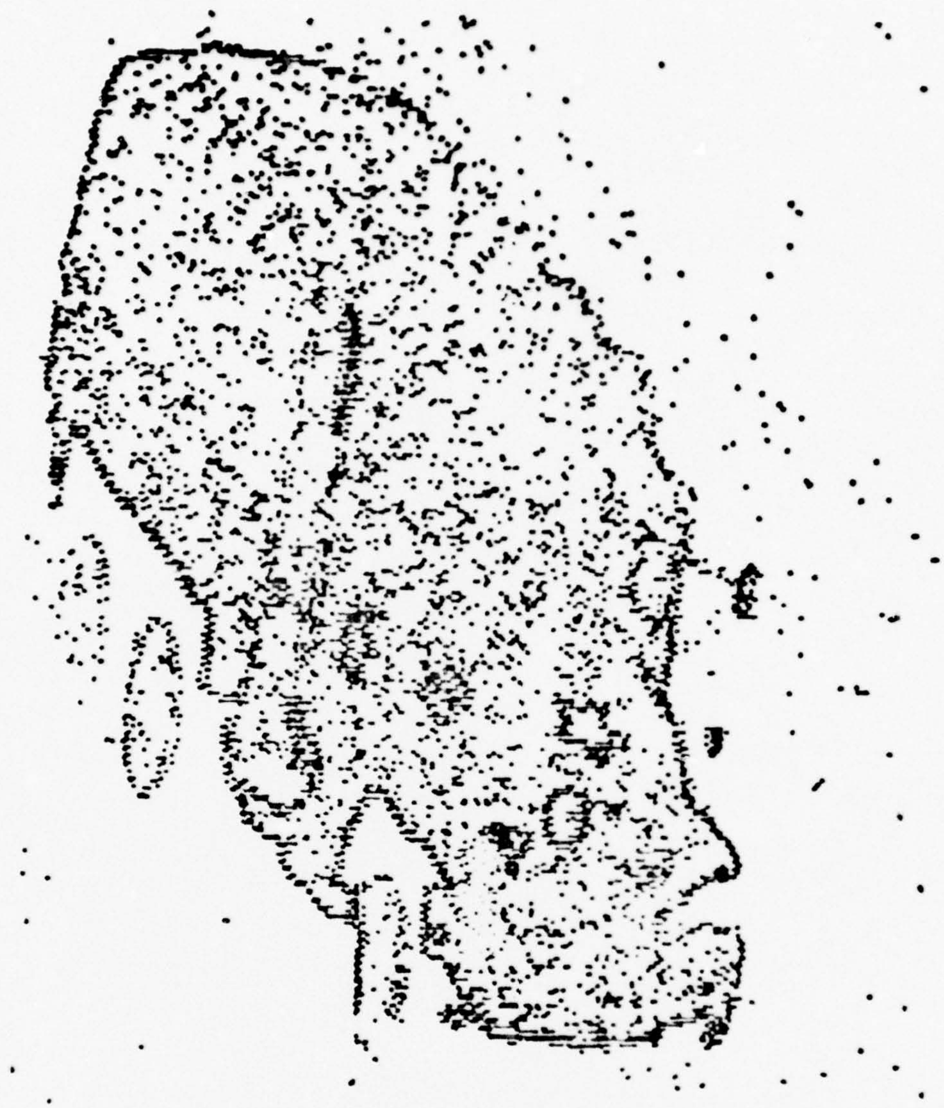


Fig. 6a The gradient picture of the target area in File 11 with threshold 30.

Fig. 6b The modified gradient picture corresponding to
Fig. 6a also with threshold 30.

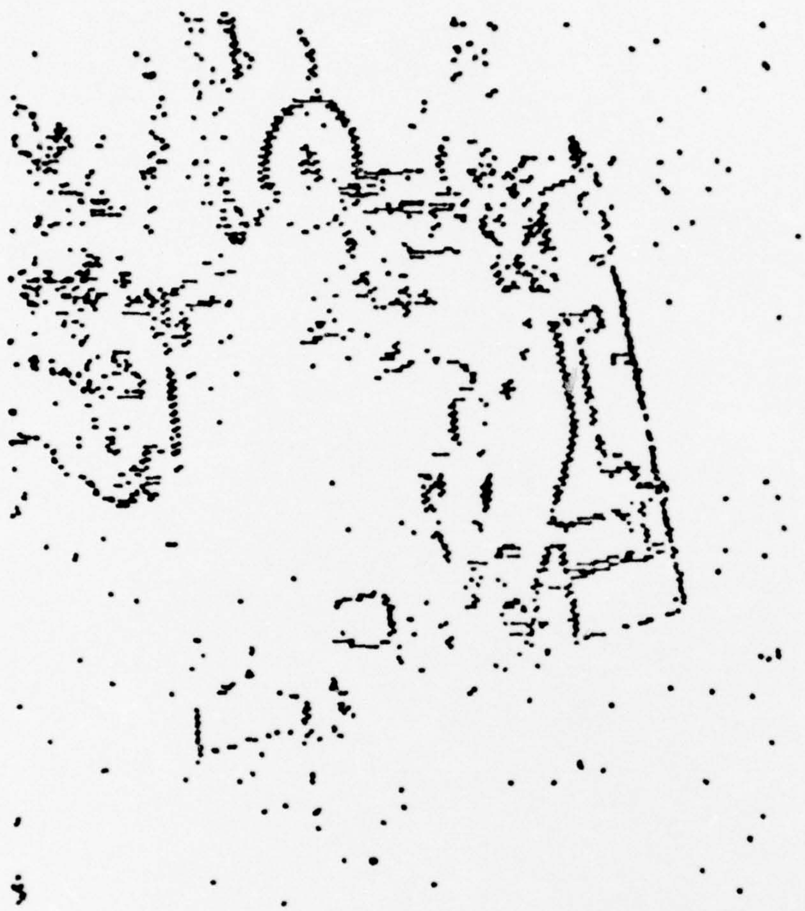


Fig. 7a The gradient picture of the target area in File 13
with threshold 50.

Fig. 7b The modified gradient picture corresponding to Fig. 7a also with threshold 50.

Fig. 8 The modified gradient picture of a portion of File 1 in new image tapes. Threshold is 38.
(OSCR 122)

(a)

(b)

Fig. 9 (a) The gradient picture and (b) the modified gradient picture of the target area in File 10 with threshold 35 in each case.

Fig. 10 File 1 full picture: modified gradient with threshold 30 followed by 9 to 1 compression of threshold 3.

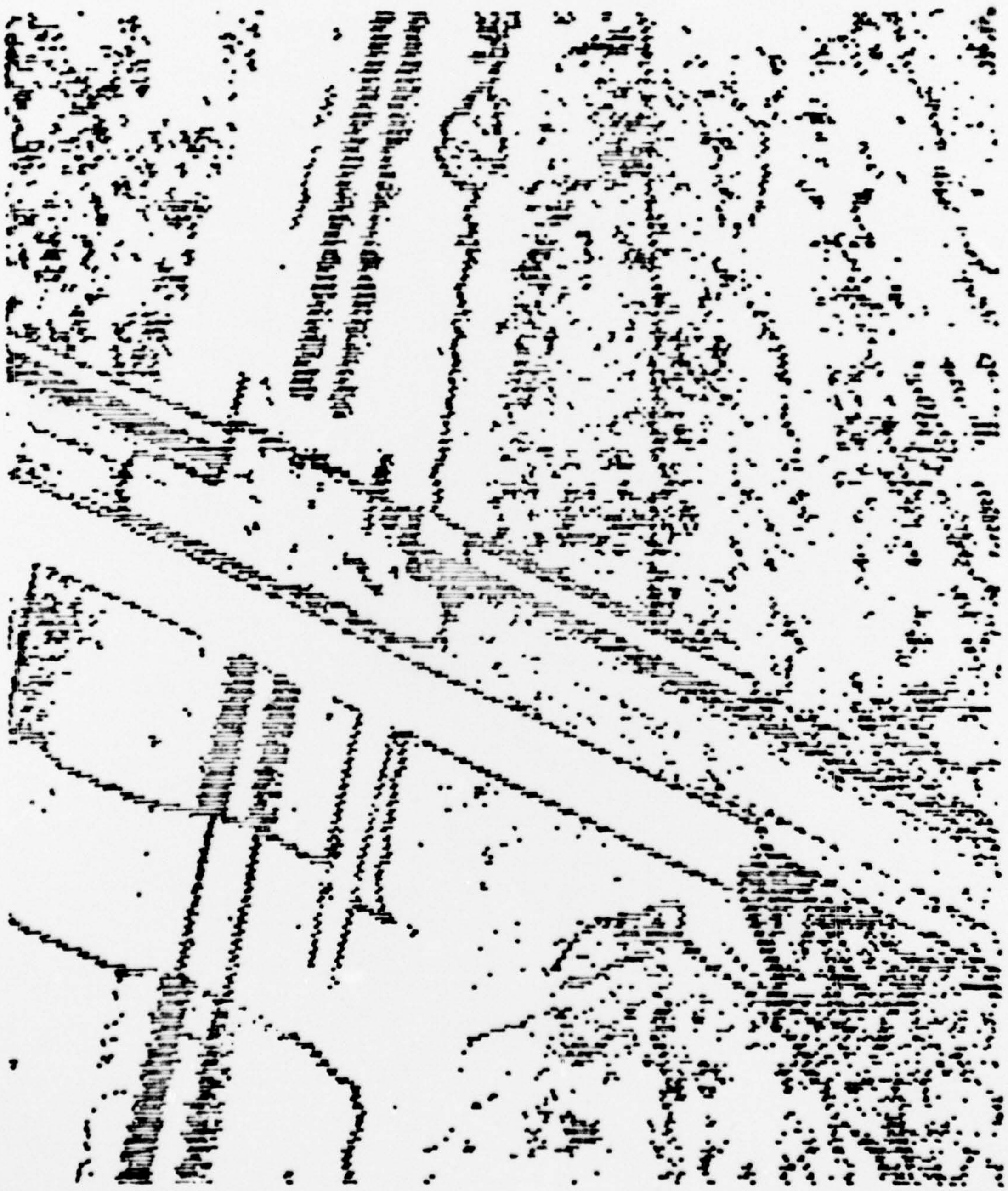


Fig. 11 Full picture of File 2: modified gradient with threshold 30 followed by 9 to 1 compression of threshold 3.

Fig. 12 Full picture of File 5: modified gradient with threshold 30 followed by 9 to 1 compression of threshold 3.

Fig. 13 Full picture of File 7: modified gradient with threshold 30 followed by 9 to 1 compression of threshold 3.

Fig. 14 Full picture of File 9: modified gradient with threshold 45 followed by 9 to 1 compression of threshold 3.

Fig. 15 Full picture of File 10: modified gradient with threshold 35 followed by 9 to 1 compression of threshold 3.

Fig. 16 Full picture of File 11: modified gradient with threshold 30 followed by 9 to 1 compression of threshold 3.

Fig. 17 Full picture of File 13: modified gradient with threshold 50 followed by 9 to 1 compression of threshold 3.

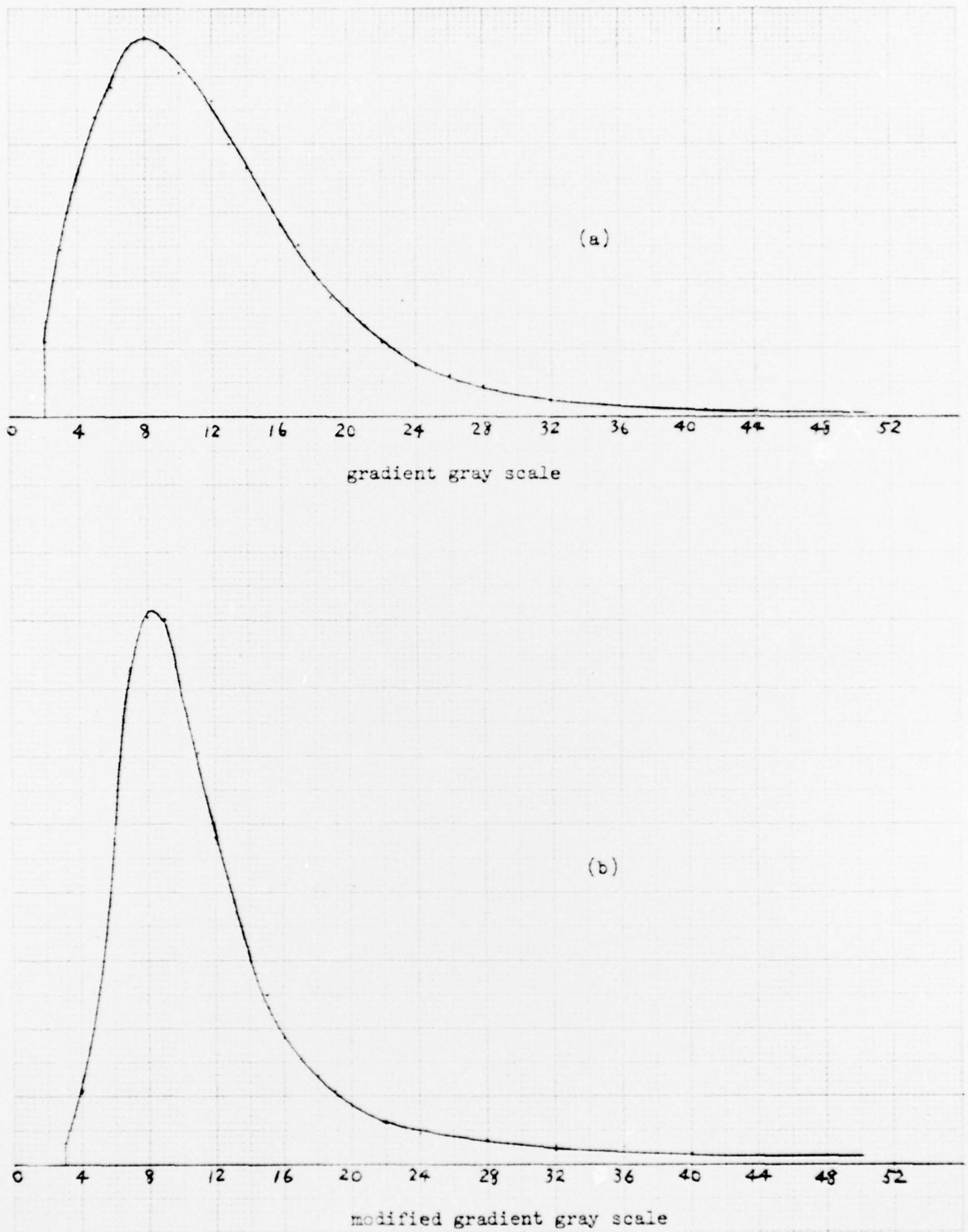


Fig. 18 Histograms of (a) gradient picture and (b) modified gradient picture for the target area of File 7. The vertical scales are the same. The total numbers of picture elements considered are the same also.

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The modified gradient operation considerd in this report takes the product of four conventional gradient operations in four different directions. Such modified procedure is shown by extensive computer results to provide great improvement in noise reduction and boundary extraction over the conventional gradient operation. Furthermore, the procedure is computationally simple and insensitive to rotation of images. Computer results of modified gradient operation followed by image compression are also presented.

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