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TWO NOTES ON DIGITAL EDGES AND LINES

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ABSTRACT

This report consists of two independent parts. The first is entitled "Non-maximum suppression of gradient magnitudes makes them easier to threshold"; it shows that, besides reducing thick responses to thin, the application of non-maximum suppression to digital gradient magnitudes also improves the form of the edge response histogram, making the choice of thresholds easier. In the second, entitled "A note on collinearity merit", measures of collinearity merit based on distance and angle are defined. They yield reasonable results for edges extracted from an aerial photograph.

NON-MAXIMUM SUPPRESSION OF GRADIENT MAGNITUDES MAKES THEM EASIER TO THRESHOLD

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ABSTRACT

Besides reducing thick responses to thin, the application
of non-maximum suppression to digital gradient magnitudes
also improves the form of the edge response histogram, making
the choice of thresholds easier.

One problem with derivative-based edge detectors is that their response is blurred, or spread out rather than sharp. (For the response of a Sobel detector taking horizontal differences, see Figures 1b, 2b, 3b.) This occurs both because the edges themselves may be unsharp, and because the edge detector itself may involve some averaging of gray levels. Non-maximum suppression is a commonly-used technique for overcoming this difficulty, reducing thick edge detector responses to thin lines (Rosenfeld and Kak, 1976). See Figures 1c, 2c, 3c.

Another problem with such edge detectors is that the histogram of edge response values is virtually featureless, making it very difficult to choose a good threshold for separating valid edges from noise. (See Figures 1e, 2e, 3e.) It seems not to have been previously remarked that non-maximum suppression can be helpful here as well. Histograms of edge responses <u>after</u> non-maximum suppression have a much better form, often showing pronounced bimodality, or at least an inflection, when the original histogram had no such properties. (See Figures 1e, 2e.) This makes the selection of thresholds a much simpler and more reliable process. Figures 1d and 2d show the results of thresholding edge detector responses after non-maximum suppression, using threshold levels chosen by examining their histograms. As seen, the results appear quite good.

This effect occurs because the non-maximum suppression removes a whole sub-population of near-edge points, thus making it easier to separate valid edge responses from noise. Of course, such technique will not work as well with pictures which have many different types of edges, for example, Figure 3. However, it is still possible to pick the strongest edges, those which separate house roofs from shadows.

Reference

A. Rosenfeld and A.C. Kak, Digital Picture Processing, Academic Press, New York, 1976, p. 275.
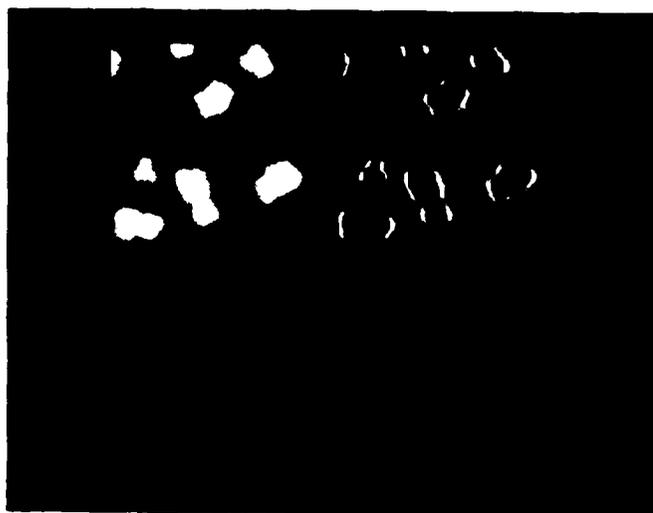
Figures 1a – 1d.   (Photomicrograph of chromosomes)
Clockwise from top left: (a) Original gray level.
(b) Absolute value of Sobel detector (horizontal dif-
ferences). (c) Same as b, but with non-maxima along
horizontal direction suppressed.   (d) Same as c, but
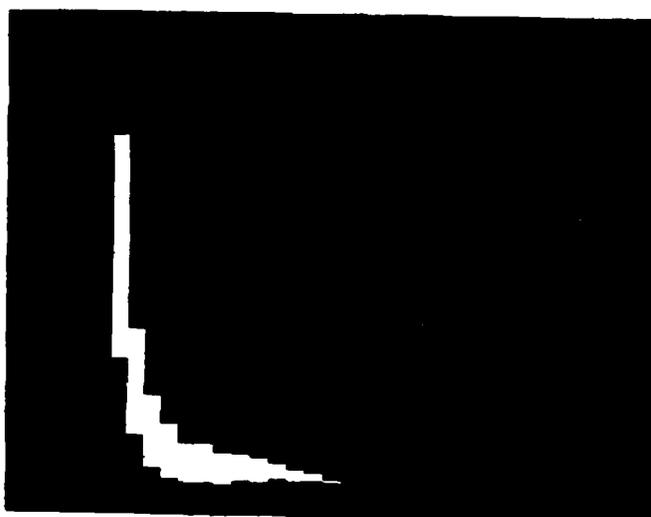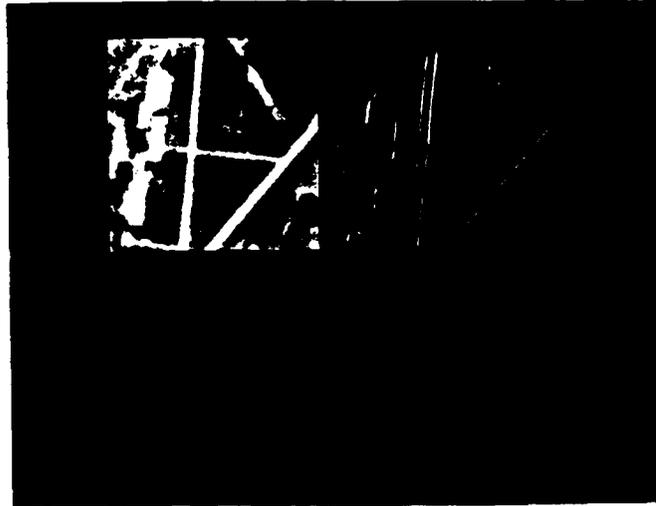thresholded at level 6.

Figure 1e.   Comparison of histograms of 1b (upper)
and 1c (lower), for levels greater than 1.

Figures 2a - 2d. (Aerial photograph of an airfield).
Captions analogous to Figure 1, but 2c is thresholded
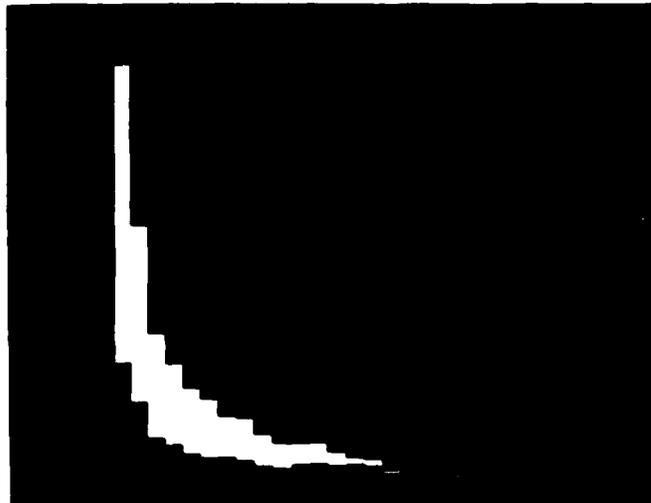at level 12.

Figure 2e. Comparison of histograms of 2b (upper) and
1c (lower), for levels greater than 1.

Figures 3a - 3d. (Aerial photograph of suburban houses).
Captions analogous to Figure 1, but 2c is thresholded
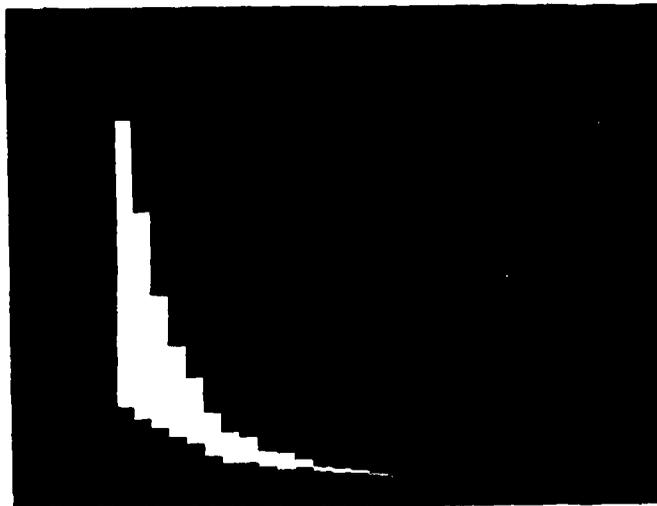at level 12.

Figure 3e. Comparison of histograms of 3b (upper)
and 3c (lower), for levels greater than 1.

A NOTE ON COLLINEARITY MERIT

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ABSTRACT

Measures of collinearity merit based on distance and angle are defined. They yield resonable results for edges extracted from an aerial photograph.

1. Introduction

Straight edge and line features are often important in the description of an image. Local operators of various types can be employed to detect edge and line segments [1], but it is still necessary to determine sets of these local features that are globally straight, i.e., collinear. Hough transforms [2], in principle, map sets of collinear segments into single points in Hough space; but in practice, due to inherent errors in estimating the slopes and distances from the origin of the segments, the Hough transform of a collinear set will generally be a cluster of points, and it is necessary to examine the original segments in order to establish their collinearity.

This note presents a simple approach to finding sets of collinear segments based on computing a figure of merit for the collinearity of each pair of segments. The pairs whose collinearity merit exceeds a given threshold define an equiavalence relation on the segments. For suitable choices of the threshold, the resulting equivalence classes are in good correspondence with subjective judgments of collinearity.

The figure of merit described here is similar to that used by VanderBrug [3] for linking curve segments based on the smoothness with which their ends can be connected; but it is applied here to straight line segments, rather than to arc ends. On other line segment grouping tasks (linking antiparallel pairs; clustering collinear segments on the basis of proximity) see Scher [4,5].

2. Collinearity merit

Our measure of collinearity merit depends on two factors: distance and angular difference.

It seems evident that the distance factor, m_d, should depend on the lengths of the segments. For example, the segments in Figure 1a have a higher merit than those in Figure 1b, even though the distance in each case is exactly the same. To provide for this dependence, we define

$$m_d = \frac{L_1 + L_2}{L_1 + D + L_2}$$

where $L_{1,2}$ are the segment lengths and D is the distance between their nearest endpoints. In this formula, when D=0 we have m_d=1, and as D increases, m_d decreases.

The angular difference factor can be measured in two ways. One approach is to use the product of cosines

$$m_a = \cos\theta_1 \cdot \cos\theta_2$$

where θ_1 and θ_2 are the angles that the segments make with the line joining their nearest end points (see Figure 2). This product is 1 when the segments are exactly collinear, and decreases as one or both of them deviate from collinearity.*

The m_a factor, however, has some undesirable properties; for example, it has the same value for the cases in Figures 3a and 3b, whereas intuitively, Figure 3b should have a higher rating. A factor that has higher values for 3b than for 3a is

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*This assumes that θ_1 and θ_2 are less than 90°; if they are greater, it may no longer be obvious which are the closer ends, and we take the collinearity merit to be zero.

$$m_a' = \frac{D'}{L_1 + D + L_2}$$

where D' is the distance between the farthest endpoints of the segments. However, this factor alone would not yield the desired results, since it gives a high score to a pair of segments that are parallel but offset (Figure 4). For this reason, we used the product of m_a and m_a' as the measure of angular difference merit. Our final figure of collinearity merit is

$$m_c = m_d m_a m_a'$$

3. Examples and concluding remarks

The figure of merit just defined was measured for pairs
of line segments extracted from two portions of an aerial
photograph (Figure 5). To simplify the computation, m was
computed only for those pairs of segments that map into nearby
points in Hough space (distances from origin within 20% of
picture size; slopes within 45°).

Figure 6 shows the line segments in the two images, with
pairs of segments for which $m \geq t$ joined by lines, for t = 1.0,
.8,.6,.4,.2, and 0. We see that for high values our composite
figure of merit seems to provide a reasonable basis for linking
pairs of segments that are approximately collinear.

References

1. A: Rosenfeld and A. C. Kak, Digital Picture Processing,
    Academic Press, New York, 1976, Sections 8.2-3.

2. A. Iannino and S. D. Shapiro, A survey of the Hough trans-
    form and its extension to curve detection, Proc. PRIP-78,
    32-38.

3. G. J. VanderBrug and A. Rosenfeld, Linear feature mapping,
    IEEETSMC-8, 1978, 548-555.

4. A. Scher, M. Shneier, and A. Rosenfeld, A method for
    finding pairs of anti-parallel straight lines, TR-845,
    Computer Science Center, University of Maryland, College
    Park, MD, Dec. 1979.

5. _____, in progress.

Figure 1a

Figure 1b

θ_1
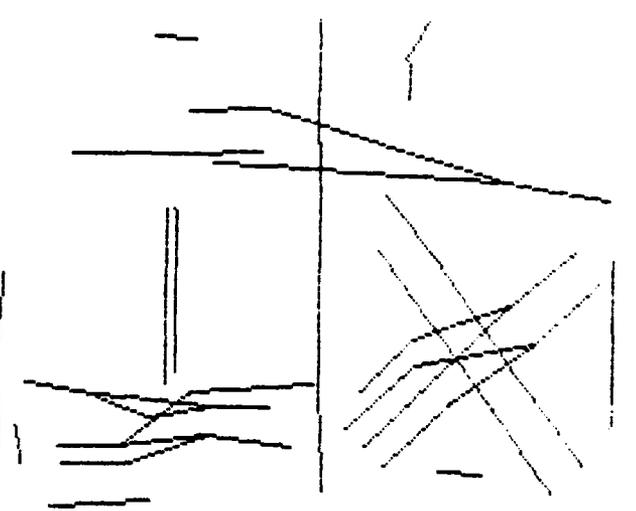
θ_1
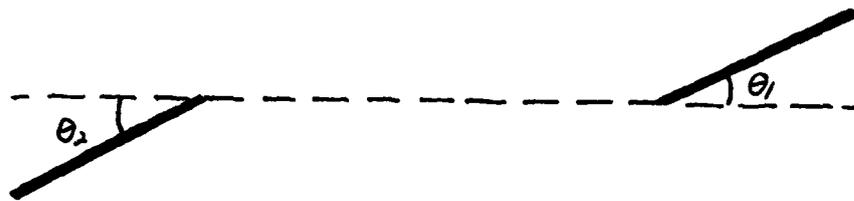
Figure 2

Figure 3a

Figure 3b
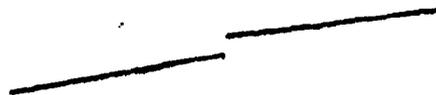
Figure 4

Figure 5a

Figure 5b
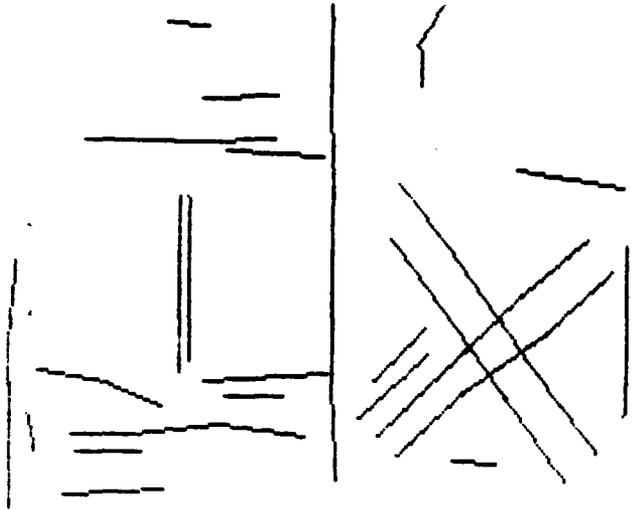
.60
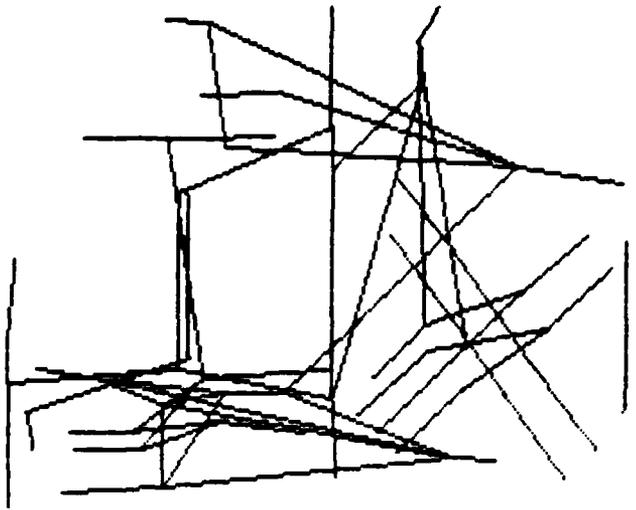
.00
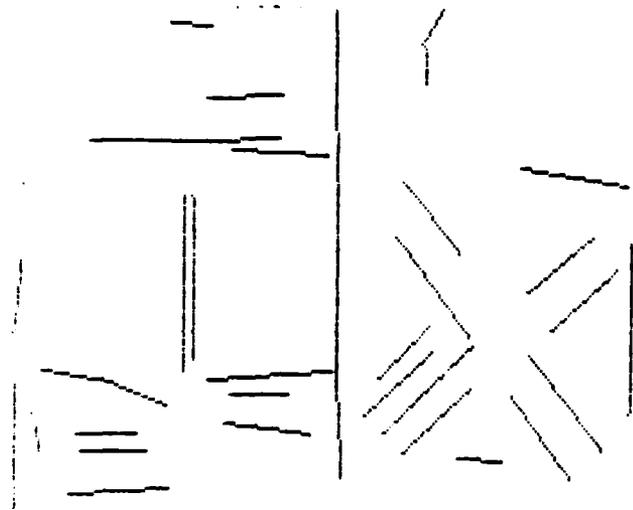
.80
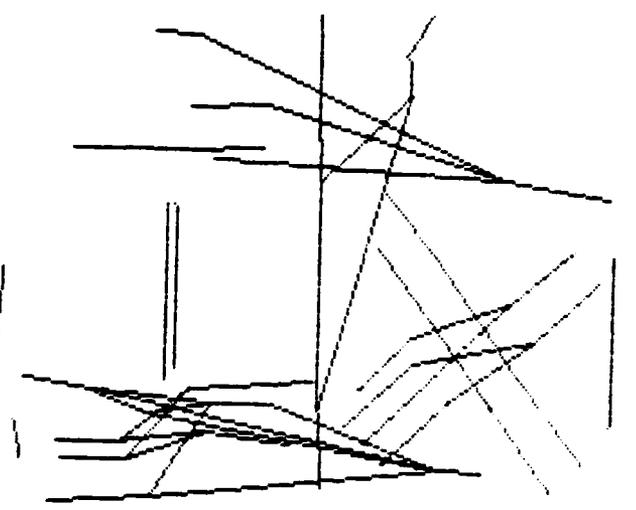
.20
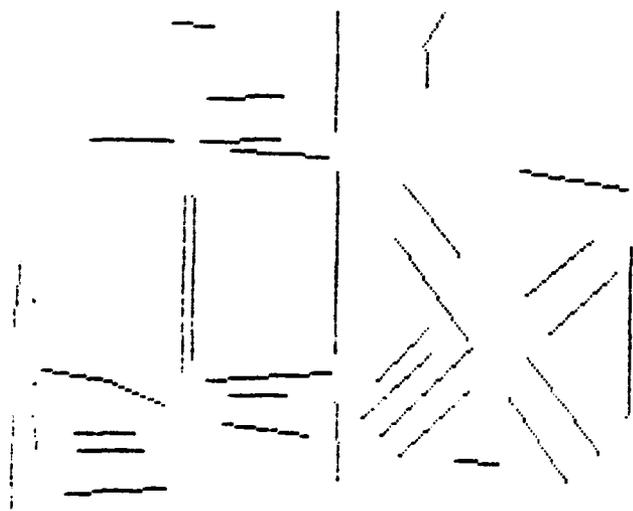
1.00

.40

Figure 6a
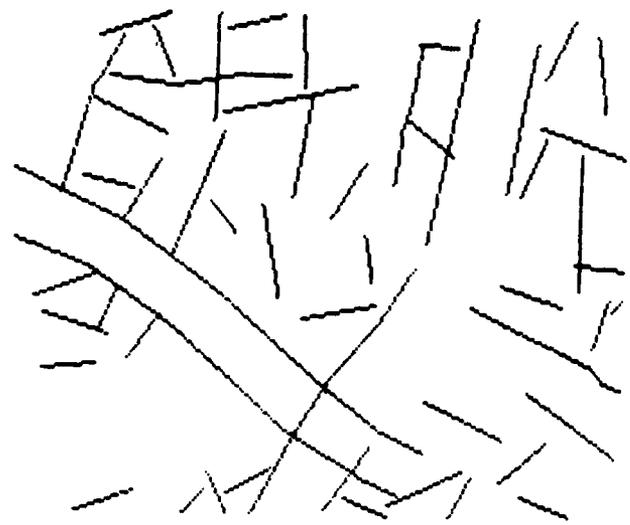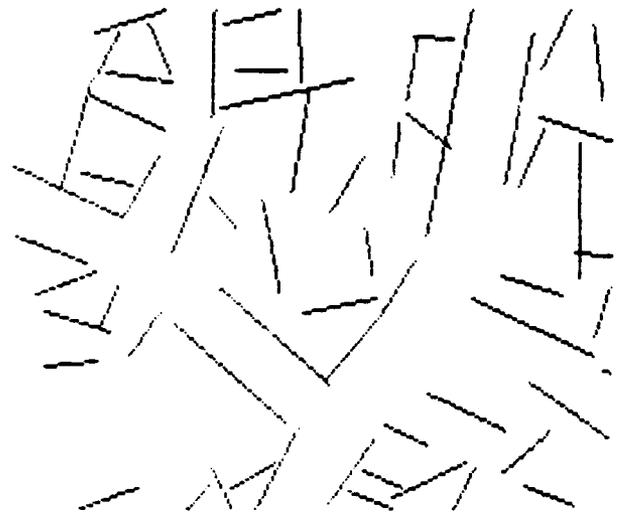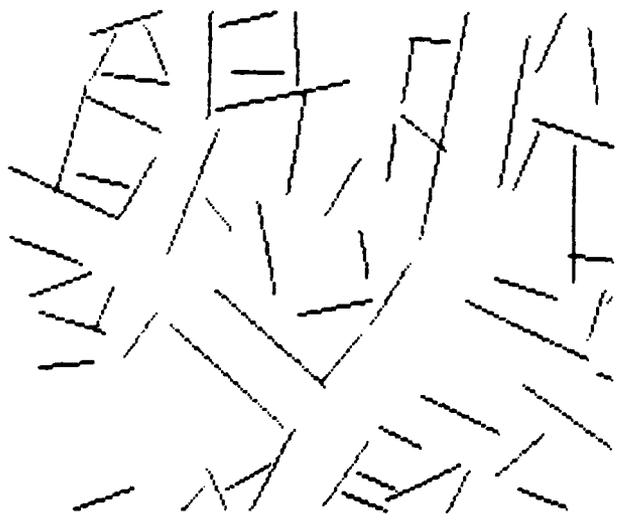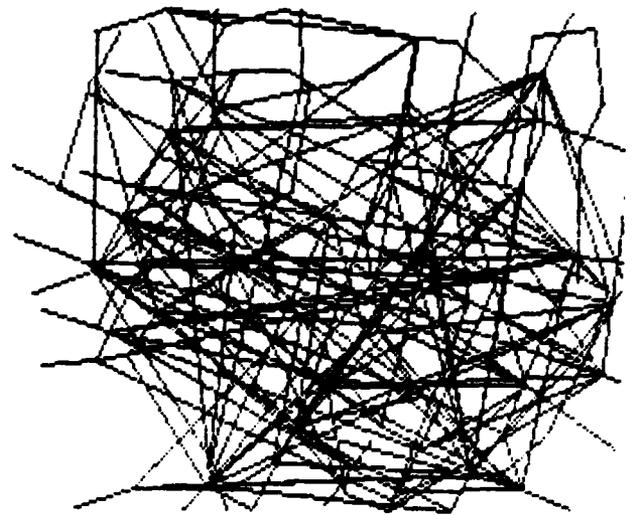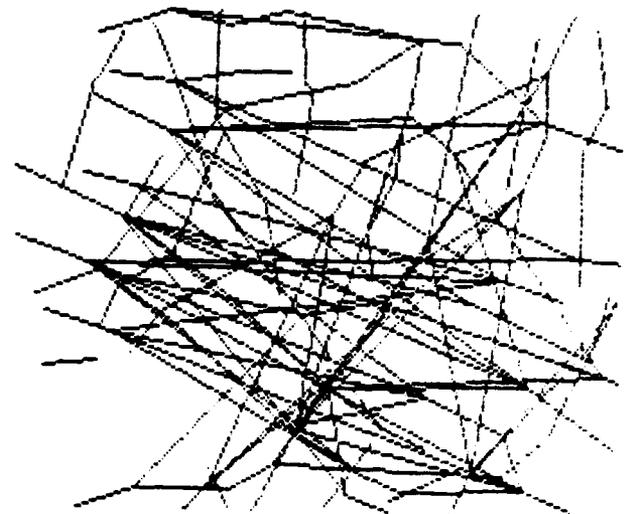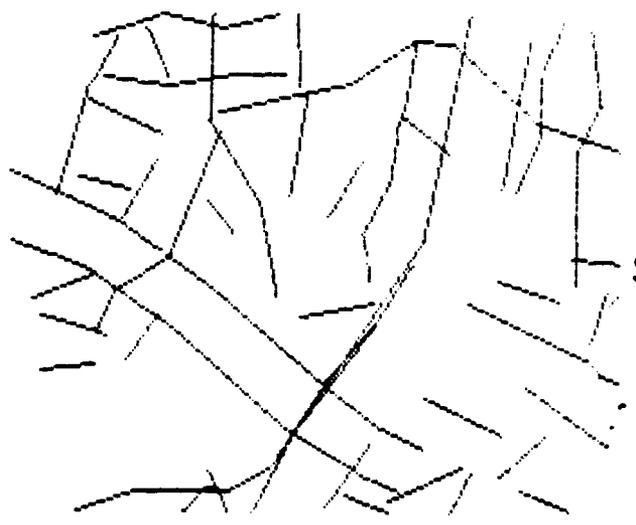
Figure 6b

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