A Method for Line Extraction in Noisy Photographs

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1. *Introduction*

Line (or edge) extraction is one of important fundamental techniques in image processing by computer and has been studied by many authors [1]~[3]. In this paper a method based on the principle of likelihood maximization for line extraction in noisy photographs is presented with a few examples including medical applications. The method consists of four steps; (I) Estimation of the state of each sample point by a kind of likelihood measure, (II) Extraction of connected components, (III) Selection of the points most likely to be on a curve, (IV) Correction. This method is different from the ones so far studied in the usage of average likelihood and connected components.

2. *Method for Line Extraction*

The method consists of the following four steps.

(I) As a model of input patterns, it is assumed that

input pattern=lines (curves) of uniform density
+homogeneous Gaussian noise

Then the state of each sample point in the input pattern——"on a line", or "not"——is estimated by a kind of likelihood measure calculated from the observed density values in the neighborhood of the point [4]. For the estimation of the state of a point P, for example, the average of the logarithms of likelihood ratios (ALLR)

$$l=\sum_{i,j}[\ln p(\boldsymbol{v}\mid S_1, \alpha_i)-\ln p(\boldsymbol{v}\mid S_0, \beta_j)] \qquad (1)$$

is calculated, where $p(\boldsymbol{v}\mid S_1, \alpha_i)$ is a multidimensional conditional probability density of observed density values $\boldsymbol{v}$ in the neighborhood of the point P when the state of P is "on a line (S_1)" and a curve α_i exists in the neighborhood of P, and $p(\boldsymbol{v}\mid S_0, \beta_j)$ is the one when the state of P is "not on a line (S_0)" and a curve β_j exists in the neighborhood of P. Then the state of P is assumed to be S_1 if $l\geqq T$ and S_0 if $l<T$, where the threshold T is predetermined basing upon admissible error probabilities (Fig. 1).

(II) Two sample points assumed to be "on a line (S_1)" are connected if they are adjacent, thus giving connected components (Fig. 2). These connected

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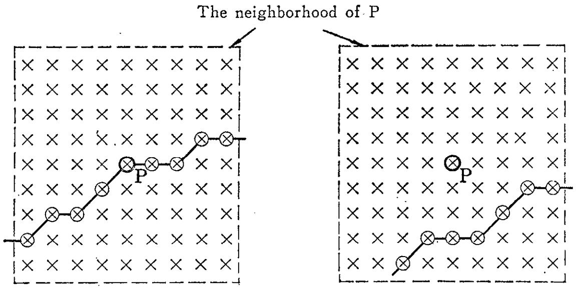
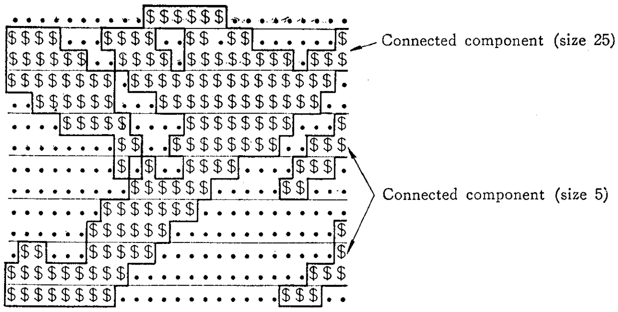


(a) (b)

×: "not on a line" ⊗: "on a line"

(a) State of P="on a line" (b) State of P="not on a line"

Fig. 1. The state of the sample point.



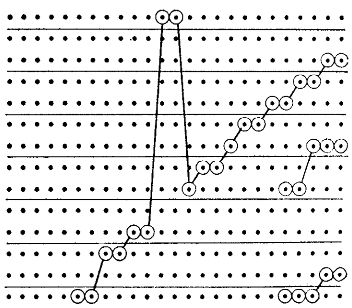
\$: The value of ALLR≧T. . : The value of ALLR<T.

Fig. 2. Connected Component.

components are sets of sample points which are likely to be on a line.

(III) In each connected component, points being most likely to be "on a line" can be selected by various algorithms, two of which are illustrated here. In the first method we select the point (x_i, y_{j^*}) such that $l_{ij^*}=\max_{j,(x_i,y_j)\in S} l_{ij}$ in each connected component S for each i, where l_{ij} is the value of ALLR calculated at the point (x_i, y_j). (ALGORITHM I) [5] (Fig. 3).

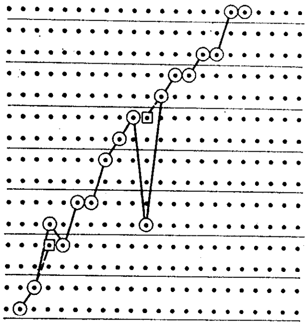
In the second method, we pick up the point most likely to be on a line



⊙: Sample point selected as is "on a line".

.: Other sample point.

Fig. 3. Curves extracted from the connected components in Fig. 2 by ALGORITHM I.



⊙: Decided as "on a line" before correction
▣: Decided as "on a line" by correction.
Fig. 4. Example of correction.

sequentially so as to satisfy the given smoothness criterion from the starting point suitably chosen for each connected component. (ALGORITHM II) [5].

(IV) The results are corrected according to given rules, if necessary (Fig. 4).

Generally speaking, some assumptions or a priori information about the direction of curves in the input pattern are required for application of ALGORITHM I. Although those assumptions are not necessary for ALGORITHM II, it is much more affected by noise than ALGORITHM I.

Concerning the step (I), theoretical discussion about the performance of the system is possible and error probabilities are estimated theoretically under appropriate assumptions [4].

3. *Experimental results*

Three examples of applications, (i) line extraction in artificial noisy figures (two lines of uniform density+normal random numbers), (ii) edge detection of rib images in chest X-ray films, (iii) curve detection for artificial binary patterns (circle+uniformly distributed noise) are shown below.

3.1 *Artificial noisy figure*

Input patterns are two smooth curves of uniform density corrupted by additive Gaussian noise with 0 mean and known variance. In this case calculation of ALLR is equivalent to the smoothing by the weight function in Fig. 5 [4]. Results for various values of variance of noise were compared and it was known that curves were satisfactorily detected for variance less than 0.62 when density of curves was 1.0 [4]. Concerning comparison between ALGORITHM I and II in the step (III), the former gave the better results than the latter for such simple patterns, especially for noise of large variance.

3.2 *X-ray films* [6]

The method was applied to recognition of rib images in chest X-ray films. In the step (I) of the method the same smoothing as 3.1 was employed, and in the step (II) ALGORITHM I was applied. Some results are shown in Fig. 6, 7.

1								1
2	1						1	2
2	3	2				2	3	2
2	3	4	4		4	4	3	2
1	1	3	7	15	7	3	1	1
2	3	4	4		4	4	3	2
2	3	2				2	3	2
2	1						1	2
1								1

Weights of blank mesh are 0.

Fig. 5. Weight function used in the step (I) of line extraction.

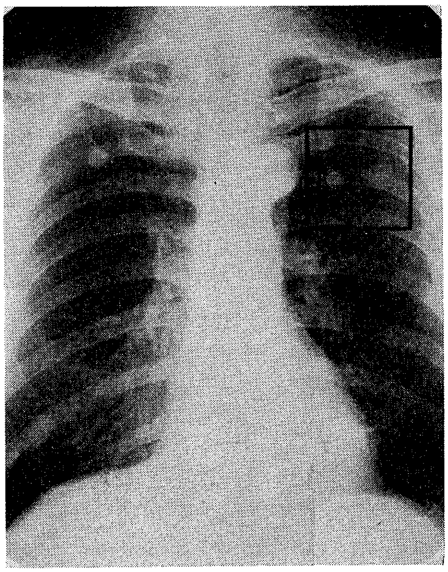
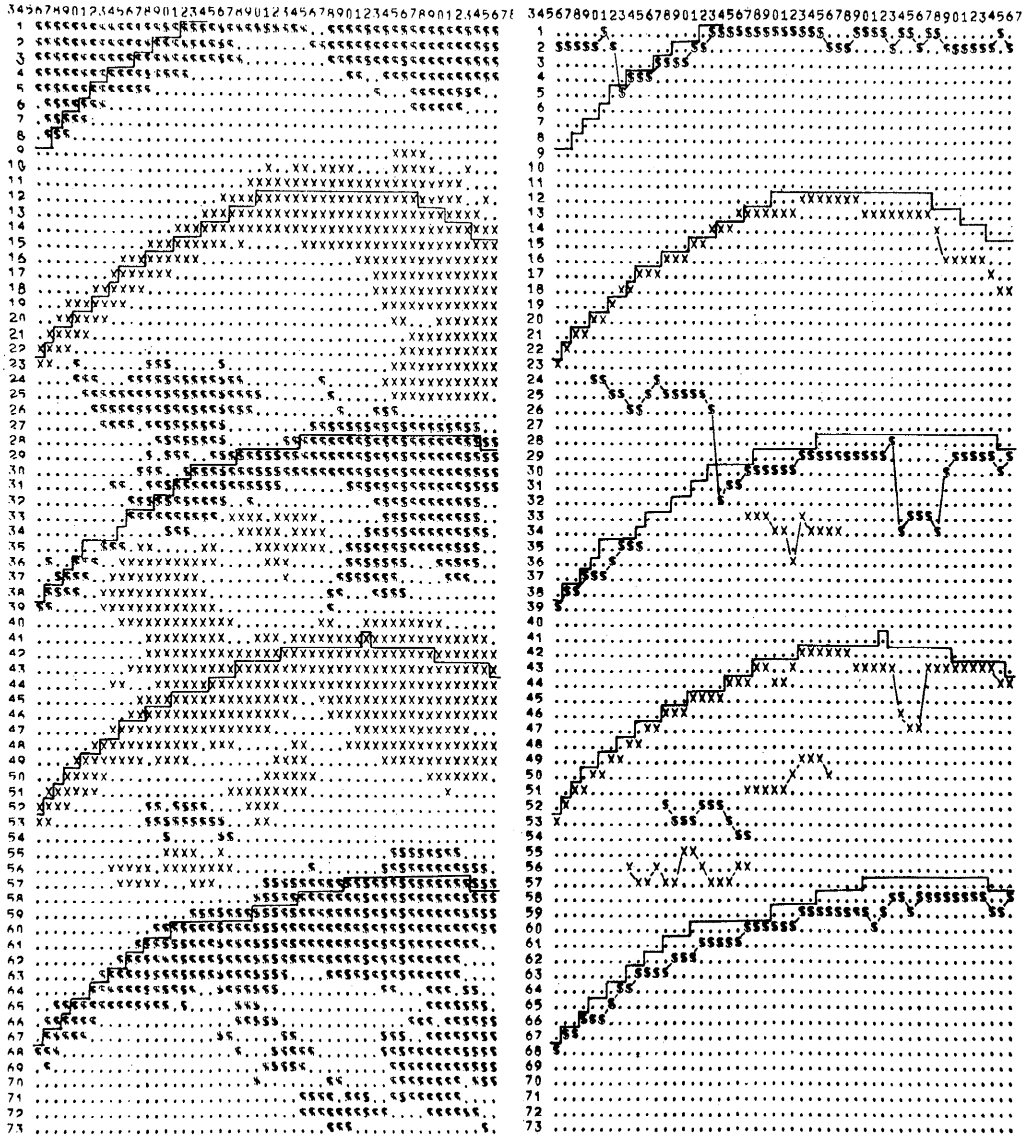


Fig. 6. Input pattern for experiment (ii) (squared part). Direct X-ray film (Squared part on the film is 5 cm wide and 6 cm long.) Sampling distance: 0.8 mm × 1.0 mm. Quantization of density: 1000 levels.

Details are presented in the reference [6].

3.3 *Binary Pattern* [5]

As the noise was assumed to be Gaussian in the previous discussion, application of the method to binary patterns may not be correct from theoretical viewpoint. But, in practice the method shown in 3.1 (smoothing by some weighting function) seemes to be applicable to binary patterns. An example is stated here. In the step (I) of the method two smoothed patterns, one was obtained from smoothing by the weight function in Fig. 5 and the other was by the one rotated by 90°, were calculated and the larger one was used as the value of ALLR. ALGORITHM II was used in the step (II). Some results of experiment are shown in Fig. 8~10.



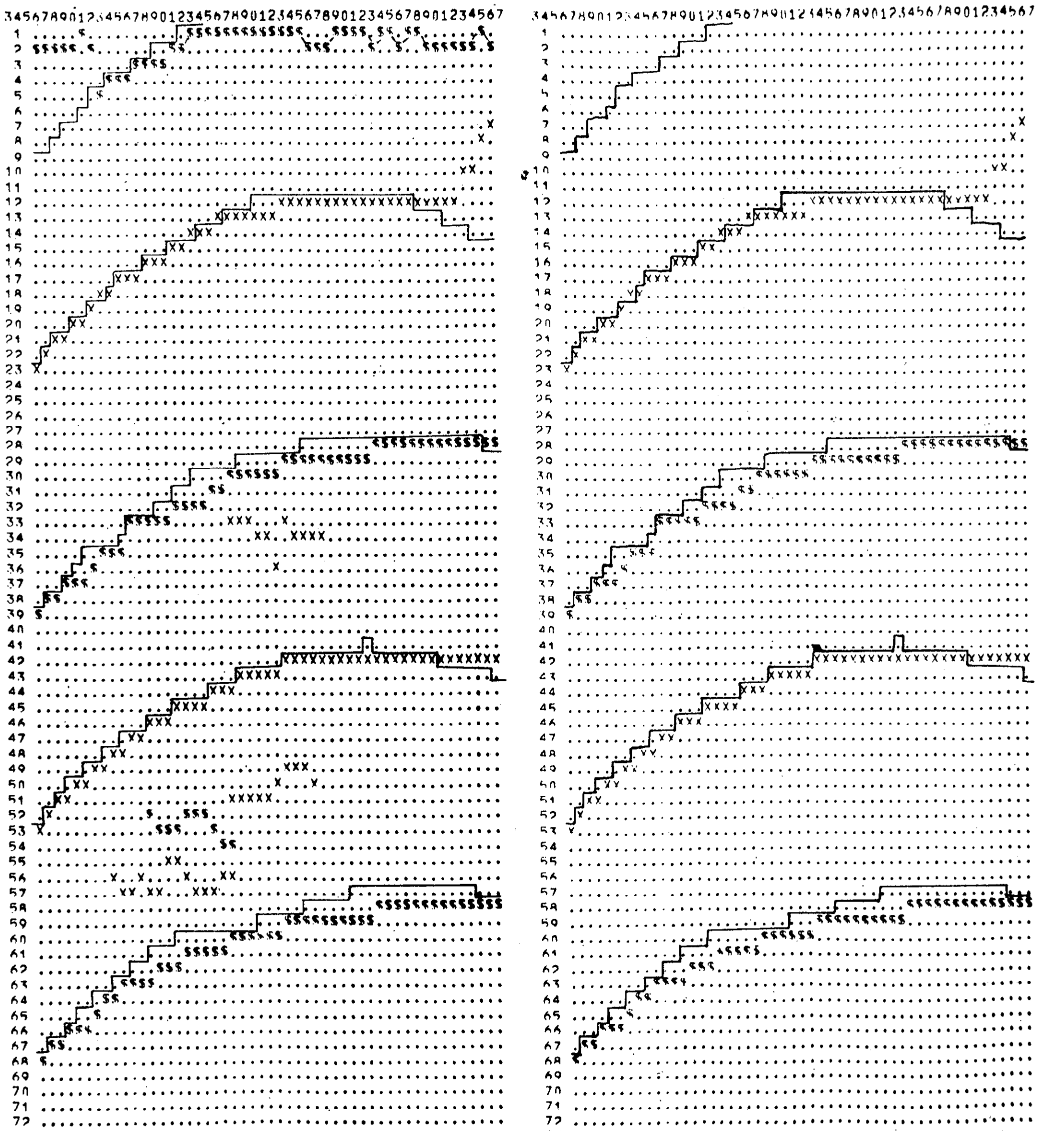
(a) Connected components corresponding to upper boundaries of ribs ($) and lower ones (X).
. : Other sample point.
⌟⌜ : Boundaries recognized by doctor.

(b) Extracted curves after the step (III) (ALGORITHM I was applied) corresponding to upper boundaries of ribs ($) and lower ones (X). Other symbols are the same as in (a).

Fig. 7 (a)~(d). Results of experiment (ii) chest X-ray film.

4. *Conclusion*

A method for line extraction in noisy photographs is proposed and studied experimentally. In this method the state of the point is estimated by a kind of likelihood measure as the first step. Then connected components are obtained and in the third step the points most likely to be "on a line" are selected. Sufficient results were obtained within the limits of the recognition experiments stated here.



(c) Extracted curves after the step (IV) (Correction). Symbols are the same as in (a) and (b).

(d) Final results of rib boundaries recognition. Symbols are the same as in (a) and (b).

Fig. 7.

All the experiments were performed by digital computer HITAC 5020E in Computer Center, University of Tokyo and FACOM 230-60 in DATA Processing Center, Kyoto University.

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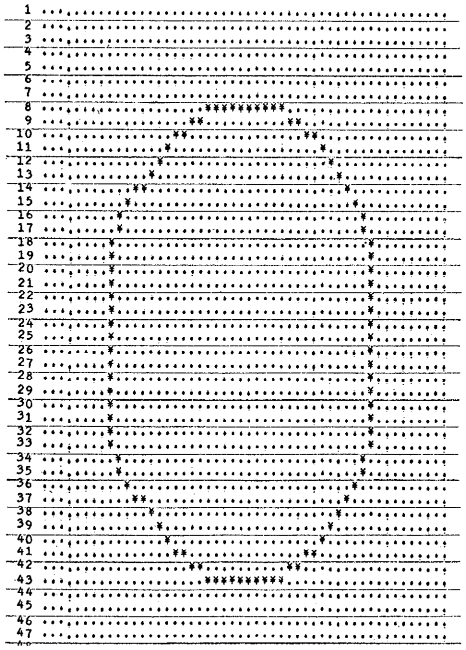
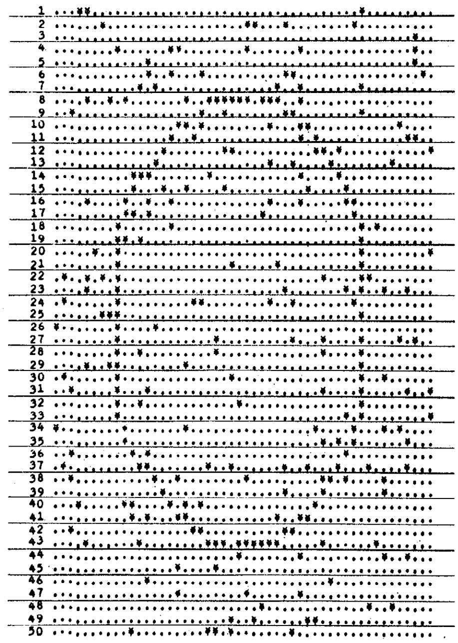


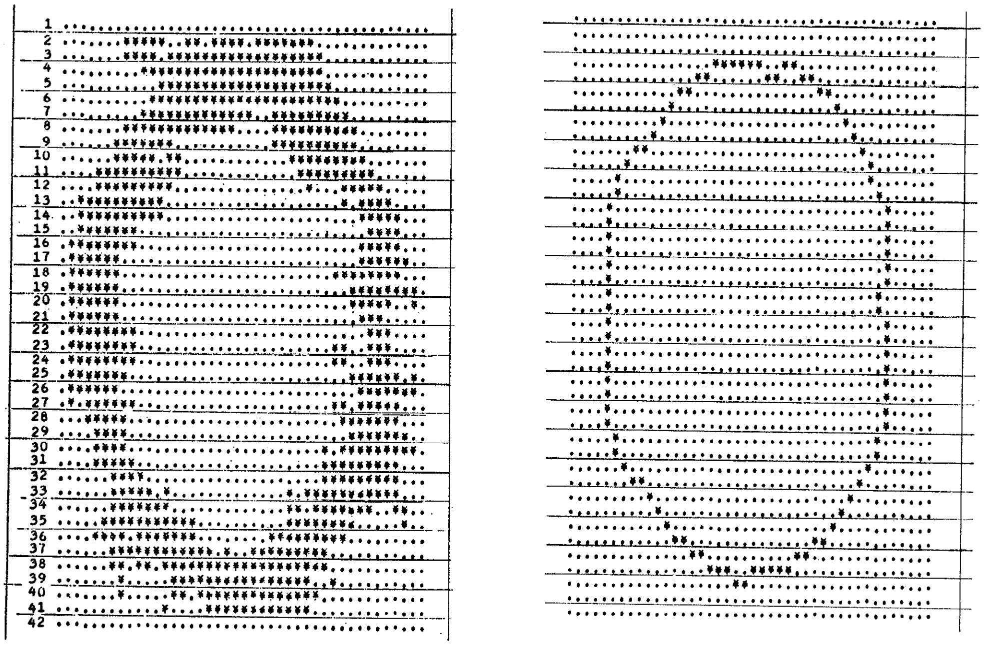
. : value 0. ¥ : value 1.

Fig. 8. The circle for the experiment (iii).



Probability that the value of each sample point in Fig. 9 changes (1→0 or 0→1) is about 0.075.

Fig. 9. Noisy input pattern for the experiment (iii).



(a) Connected component. (b) Recognized circle (ALGORITHM II was applied)

Fig. 10. Results of experiments (iii)—binary pattern.

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