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Automatic fingerprint identification

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Abstract

The present system for identifying latent fingerprints left at the scene of a crime still depends on the skill and patience of trained fingerprint technicians because of the low quality of the latent fingerprints. An image processing & feature extraction technique has been established in order to detect minutiae (ridge endings and ridge bifurcations and ridge counts useful for latent fingerprint identification. The algorithm of the latent fingerprint identification using these features has been evaluated. Each feature is detected from the gray scale image of fingerprints and described by minutiae positions, minutiae directions and inter-minutia ridge counts. In the latent fingerprint identification, minutiae pairs are selected according to the similarity between latent fingerprints' features and registered fingerprints' features in a file. The similarity between two fingerprints is obtained through the comparison of selected minutiae pairs. In our experiments, we attempted the feature extraction of 500 registered fingerprints and 200 latent erprints, and the matching between them. The experiments were carried out using a high speed microcomputer, a flying spot scanner, a color display, and a tablet unit, which connected with a general purpose computer system (NEAC 2200/200).

Introduction

Fingerprint identification is the most reliable way of identifing a human being. Consequently, the fingerprint identification technique has been applied to the law enforcement system. However, in order to cope with the continuously increasing number of recorded fingerprints collected by law enforcement people and many inquiries for crimical identification, it has become necessary to develop an automatic fingerprint processing system.

Several identification strategies based upon the matching of minutiae, such as ridge ending or ridge bifurcation of fingerprints as shown in Fig. 1., have been developed for automatic fingerprint identification systems.[(1)(2)(4)(5)(6)] Since minutiae are simple patterns it is easy to detect them automatically. Consequently, minutiae matching strategy is suitable for automatic fingerprint identification systems. However, minutiae positions and directions tend to be influenced by fingerprint image distortion, then they are probably insufficient for latent fingerprint identification. In fact, fingerprint technicians have been using other fingerprint features in addition to minutiae for a long time. Recently, an experiment using ridge count in addition to minutia was reported on.[(3)] But since all these features are often influenced by the rotation of fingerprint, they themselves cannot be used for fingerprint identification without modification.

We have developed a new automatic fingerprint identification system to be well-suited for latent fingerprint identification. There were two important points to consider. To begin h, in order to improve the automatic latent fingerprint identification capability, gistered fingerprints perse must be reliable and stable. Various features must be accurately extracted from fingerprints on cards. For this purpose it was necessary to develop a very sophisticated image processing technique. Second, features used for the identification of low quality fingerprints such as latent fingerprint should be free from the distortion, rotation and translation of the fingerprints. In order to give practical solutions to these points, we developed a new description and extraction technique for the relationship among minutiae. The relationship is free from the distortion, rotation and translation of fingerprints.

Image processing techniques and an identification expriment are explained in the following sections. The general purpose computer NEAC 2200/200 was used in these experiments. Special equipment-a high speed micro computer (6Kwords; 32bits/words; 250ns), a flying spot scanner, a color display, a dot pattern printer and a tablet unit were connected to the computer. Almost all simulation programs were taken care of by the micro computer.

Picture Processing

A blockdiagram of feature extraction including picture processing, minutiae extraction and relation extraction is shown in Fig.2.

The card, on which a fingerprint is inked, is placed under a flying spot scanner. The scanner measures the light intensity of the fingerprint card, using matrix 512x512 picture elements distributed over 25.6mm square as shown in Fig. 3. The light intensity measured by the scanner is element by element quantized to one of 6 bit values. The quantized pattern is smoothed in order to eliminate the effect of noise caused by the scanning operation. As the smoothed pattern becomes dim, it becomes necessary to be sharpened by a weighting filter.

A sharpened pattern is divided into 64x64 areas, each containing 8x8 picture elements. At an inner representative element of area, a picture element $P_{r.d}$'s in a neighboring 31x31 picture elements is defined as the value of r-th continuing element in direction d. The value V_d of each area is calculated as follows.

$$V_d = \sum_{r=0}^{12} |P_{r+3.d} - P_{r.d}| + \sum_{r=0}^{-12} |P_{r-3.d} - P_{r.d}|$$

Value V_d is expected to be small in ridge direction, and to be large in orthognal direction of ridge direction. Therefore, the direction d_{kl} of kl-th area is determined to be direction dm that V_{dm} is minimum in V_1 $V_2 \cdot\cdot V_7$ and V_8.

Also, difference ΔV_{kl} between values V_{dm+4} and V_{dm} represents the strength of the direction property, i.e., the clarity of the ridge pattern in the area.

After all the value $(d_{kl}, \Delta V_{kl})$ are decided on 64x64 areas, the value d_{kl}, is smoothed by the distribution of the 25 values $(d_{kl}, \Delta V_{kl})$ over 5x5 areas.

Figure 4 shows the extraction results of the direction and the clarity of areas. In the Fig. 4., the meanings of marks and background tone are as follows:

(a) short line mark; definit direction
(b) symbol * mark; indefinit direction
(c) heavy tone background; clear area
(d) light tone background; unclear area
(e) black background; a place where areas of various directions meet i.e., core point or delta.

The slicing filter for the binary ridge detection processes the six bit gray scale with the area direction information described above. This slicing filter consists of eight different weighting filters, whose weights are designed to be an integral operator in the same direction as the ridge and an differential operator at a right angle direction to the ridge. Figure 5 is a sketch of the weighting filter with d-direction, where the areas represented by + and - are the positive and negative weighting areas, respectively.

Minutiae Extraction

Since ridge width is not significant for minutiae detection, ridge pattern is thinned from its outer edge by a 3x3 binary bit window. After several thinning operations, a skeleton pattern is obtained.

The ridge skeleton pattern representation is ideal for minutiae detection logic and ridge tracing algorithm for skeleton pattern correction and minutiae direction detection. The predetection of minutiae is carried out using a 3x3 binary bit window. At this stage, areas containing (a) only white background, (b) ridges which could not be thinned because of their thick width or (c) too many minutiae, are newly included in the unclear area category. In clear areas the direction of a minutia is determined by tracing the ridge skeleton pattern from the minutia point to several other points on the ridge skeleton.

The skeleton pattern is corrected by means of the topological characteristics of the ridge. Typical correction cases are as follows: (Fig. 6) (a) a short line, (b) a pipilla line, (c) a short bridge, (d) a break in the ridge, (e) a small hole and (f) bifurcation recovery.

After the ridge skeleton correction, all areas are classified into clear and unclear egories by examining the minutiae counts in each area.

The skeleton pattern is applied to detect the position (x,y) and direction d of each minutia at the clear area.

Relation Extraction

The center of a fingerprint cannot always be decided exactly by the method which will be explained in registration section, because there are often found some idiosyncratic patterns such as arch fingerprints, ambiguiety in the central area of fingerprints, or lack of the central area as in fragment latent fingerprints. Accordingly, even if in the two fingerprints taken from the same finger, their coordinate systems do not always coincide. Minutiae positions and directions change according to the diference between coordinate systems. Therefore, it is necessary to adjust the difference. The best solution here is to find the relationship among the minutiae.

We developed a new definition and detection algorithm with regard to the relationship. In this method, the relationship between minutias is expressed by four ridge counts. Each ridge count is measured between minutia M and its nearest minutia MI in a quadrant of a local coordinate system which is represented by the position and direction of minutia M. In figure 7, each ridge count RI (i=1,2,3,4) is measured between minutia M and its nearest minutia MI in the I-th quadrant of a local coordinate system.

This relation description has many advantages as follows:

(a) The description is not dependent on the coordinate system of a fingerprint. It is thus free from the translation and rotation of the fingerprint.

(b) Because the description uses ridge counts it is also free from the distortion of the fingerprint.

(c) The description cannot strongly be influenced by the noise because, even if one ridge count in the I-th quadrant is false, the other three ridge counts are parhaps true in many cases.

(d) It can reconstruct the original structure of the fingerprint to some degree.

(e) It can determine an indirect relation by quating at secondhand.

Registration

When monitoring a color display, an operator can correct or assign coordinate system parameters (core point and cross point of the innermost loop ridge and 2.0mm radius circle centered on the core point) of the fingerprint. The detection of the core and the cross point cannot thoroughly be done within the capability of present pattern recognition although some automatic core and cross point detection experiments have been successfully conducted.

After correcting or assigning the coordinate system parameters, the (x,y,d) data are transformed into the (X,Y,D) coordinate system by the assigned coordinate system parameters. Figure 8. shows the results of a feature extraction and a coordinate system extraction. Each straight line shows an interval at which the ridge counting is carried out.

Figure 9 shows a fingerprint image, its ridge pattern, its skeleton pattern and its feature extraction results. Figure 10 shows another example.

Input of Latent Fingerprint

The image processing of latent fingerprints involves several problems,—poor quality images, fragmentary images and inferences caused by background surfaces as shown in Fig. 11. Consequently, the present automatic image processing and feature extraction often prove to be useless. However, if the ridge pattern, which was drawn by the fingerprint technician, is put into a computer it is perhaps easier to extract the features of the fingerprint. From this point of view, we have developed a semi-automatic feature extraction system. The fingerprint technician traces ridges of an enlarged latent fingerprint with a color pencil, and draws traced ridges on the tablet. The drawn locuses of the ridge patterns are put into a micro computer and the corresponding features are automatically figured out by the minutiae extraction and relation extraction algorithm already described.

Matching

Our matching process consists of two stages. The first process is coordinate system adjustment. After search (latent) fingerprint minutiae were chosen, their possible counterparts were selected from registered fingerprint minutiae on the basis of the relationship. Then an average transformation value between several determined minutiae pairs is calculated. Each search fingerprint minutiae is translated and rotated onto its counterparts to the degree of the average transformation value.

The second process is precision matching. In this process, all information sources including minutiae positions, minutiae directions, inter-minutia relationship and area information, are used in order to calculate the similarity score between a search fingerprint and its counterpart registered fingerprint.

After this process, the candidate fingerprint table(*) is readjusted according the similarity score. The left graph in Fig. 12. shows a monitor display of a matching situation. The left vertical axis represents the number of registered fingerprints, the horizontal axis shows the value of similarity score. The horizontal line perpendicular to the vertical axis represents the matching score against each registered fingerprint. The lower right table in Fig. 12. shows the contents of the candidate fingerprint table.

(*) A table on which various candidates fingerprints are listed in order of the similarity score.

Experiments

500 latent fingerprints were first chosen at random. Minutiae were extracted from the corresponding registered fingerprints by the autmatic minutiae detection system and stored in the disk file containing registered fingerprints. The performance of the minutiae extraction, based on resuts from 100 fingerprints, is summarized as follows:
(a) area of correct minutiae detection: 93.4%, (b) area of false minutiae detection: 6.3%
(c) area of minutiae missed: 0.3%.

Matching experiments were conducted on 200 latent search fingerprints and 500 registered fingerprints. These latents fingerprints and their candidate fingerprints were identified in one (or two) trials with 96.5% accuracy.

Conclusion

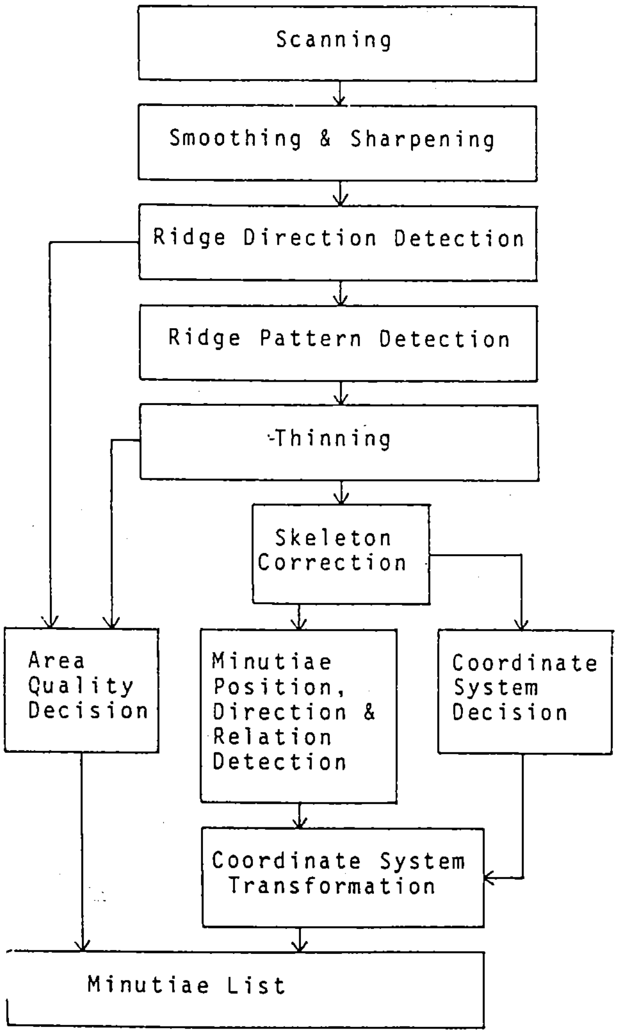

Fig. 2. Automatic feature extraction

Fig. 4. Direction and clarity of area

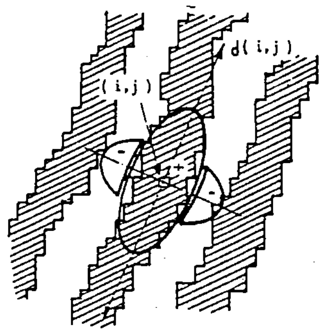

Fig. 5. Ridge detection filter

We attempted an automatic minutiae extraction from the fingerprints on cards, a semi automatic minutiae extraction from the latent fingerprints left at the scene of crimes, and a matching between search fingerprints and registered fingerprints.

In this attempt, in addition to minutiae positions and directions, area information and inter-minutiae relationships were also automatically figured out.

After the coordinate system adjustment using the inter-minutia relationship, the precision matching was used for correlating minutiae.

200 latent fingerprints were compared with 500 reference fingerprints whose minutiae were automatically extracted. The identification accuracy was 96.5% on the average.

We now plan to exeperiment with more varieties of fingerprints in order to confirm the reliability of our method.

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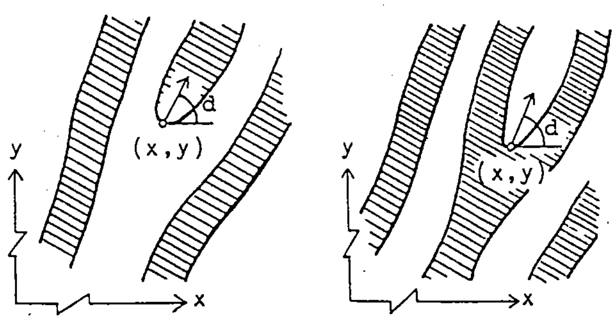

Fig. 1. Minutia

Fig. 3. Original fingerprint image

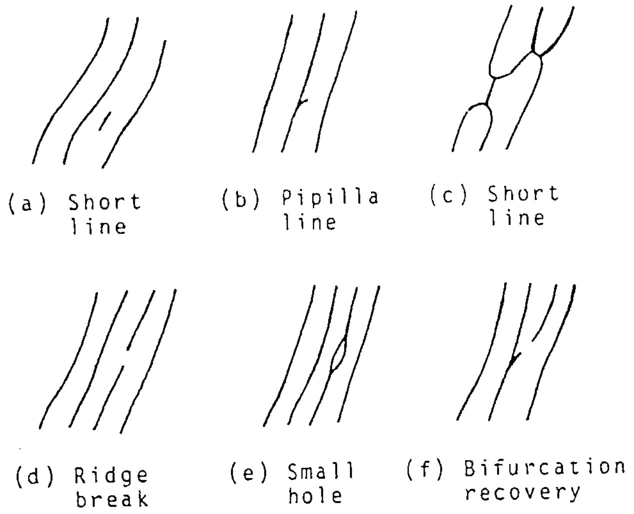

Fig. 6 Skeleton pattern correction

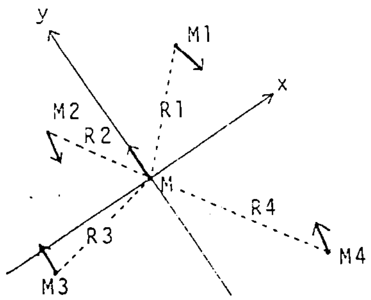

Fig. 7 Relationship

Fig. 11. Latent fingerprint

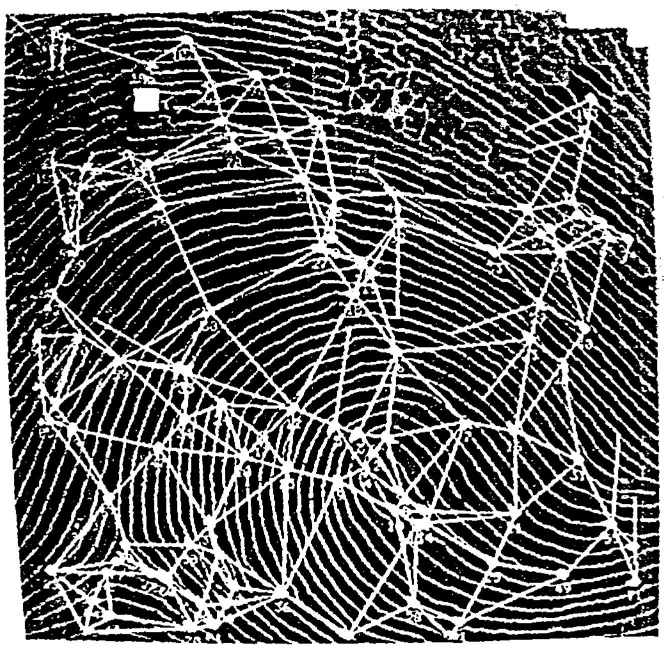

Fig. 8. Feature extraction result of Fig. 3

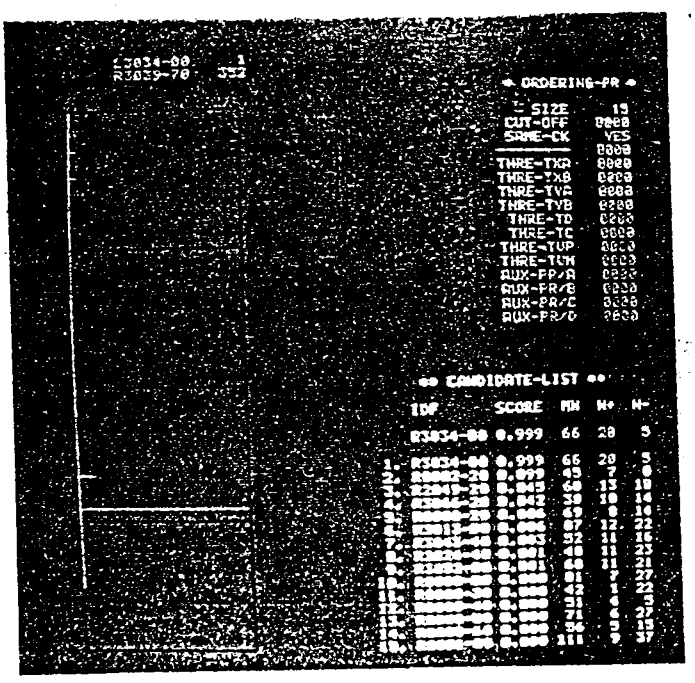

Fig. 12. Matching monitoring and Candidate fingerprint table

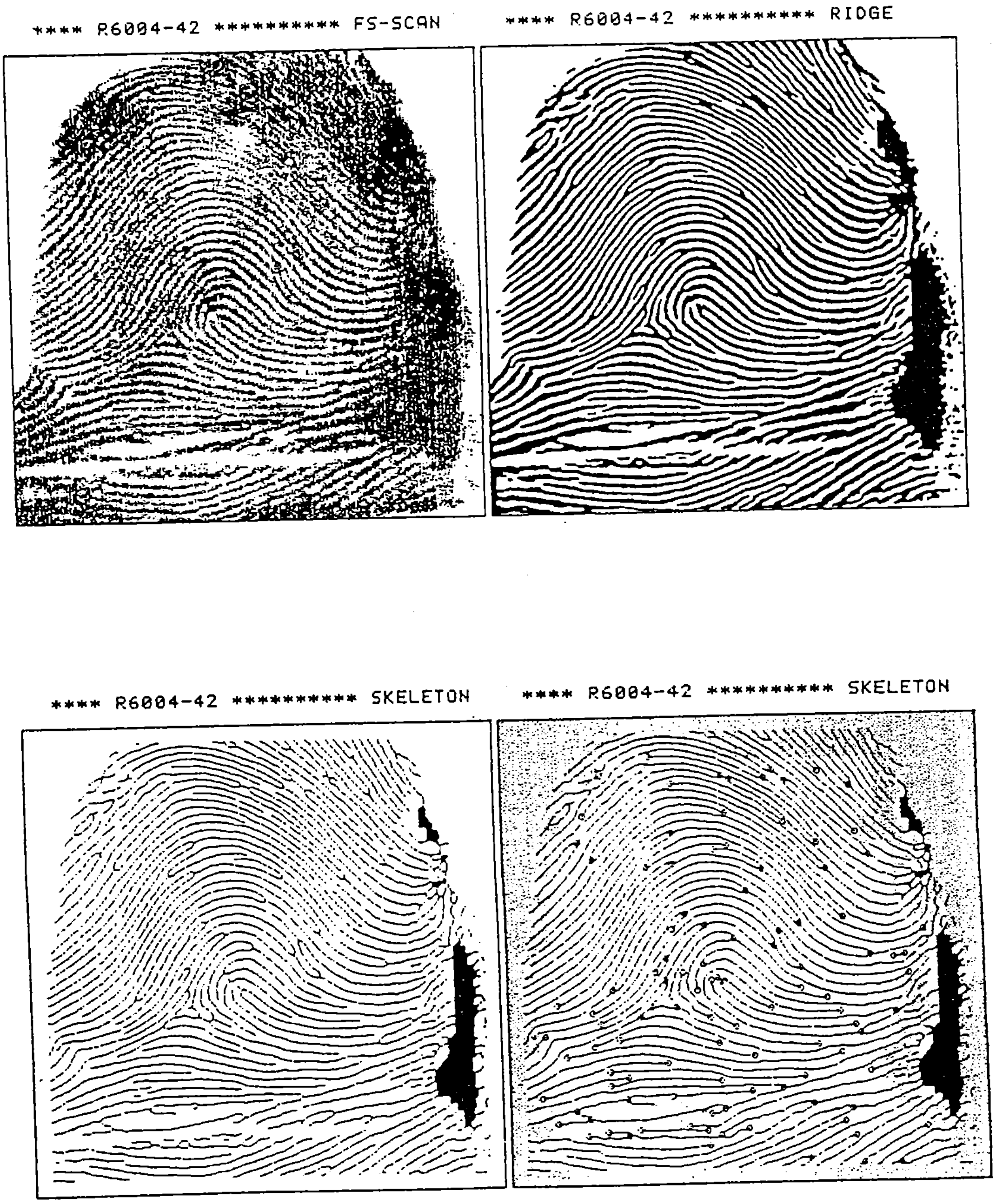

Fig. 9. Feature detection process of a fingerprint

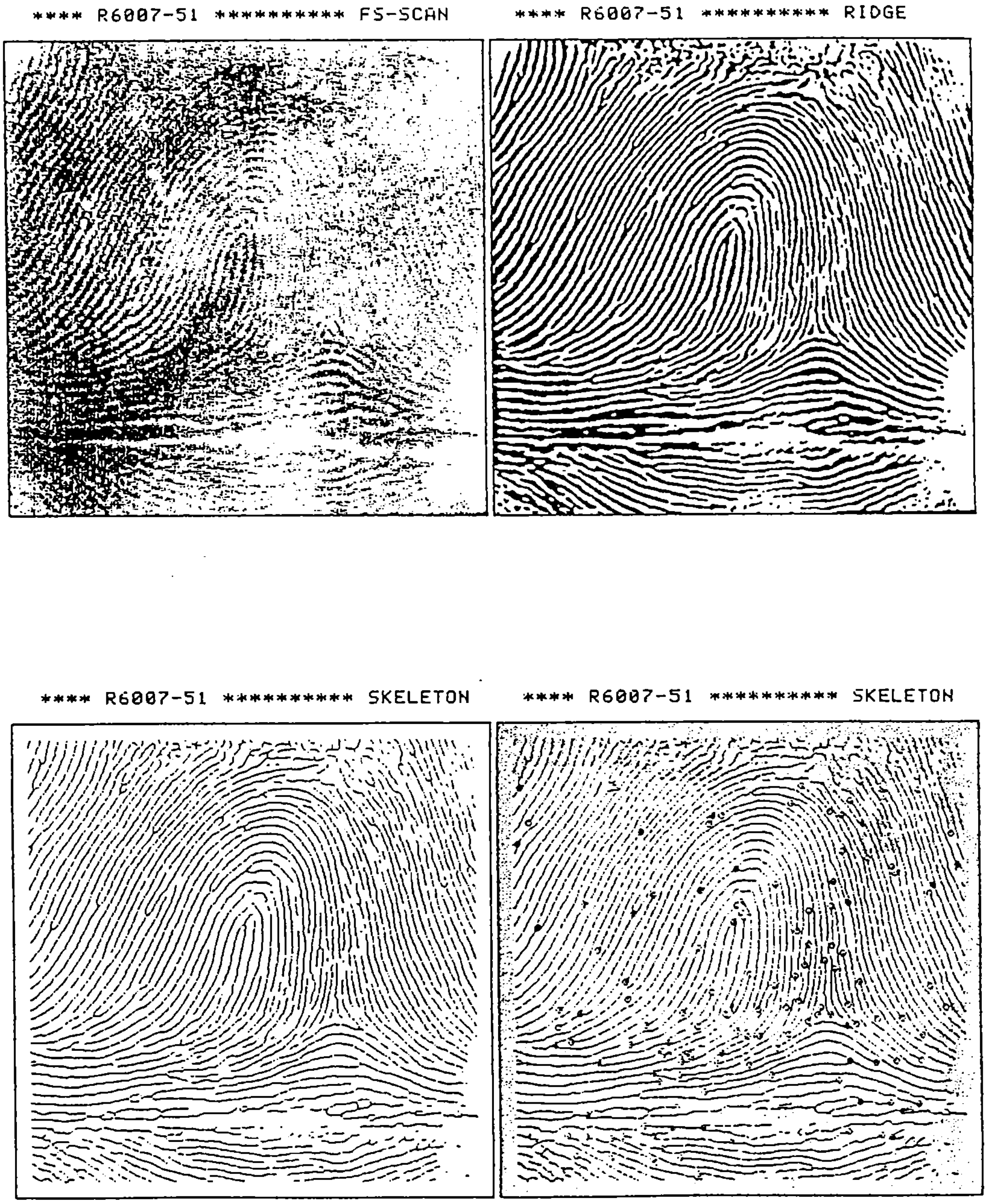

Fig. 10 Feature detection process of another fingerprint