A NEW FAST AUTOMATIC TECHNIQUE FOR FINGERPRINTS RECOGNITION AND IDENTIFICATION

S. M. ALI*
M. S. AL-ZEWARY*

SUMMARY: Because automatic image analysis depends greatly on image segmentation, a new fast edge algorithm is proposed to trace ridge lines of the fingerprint images. Edge line skeleton method, based on edge point categorization, is also introduced. Fingerprint image core point is detected by an adaptive technique suggested in this work. The core is based on slicing the edge lines into four groups representing the four possible directions (i.e. vertical, horizontal and two diagonals). A set of 34-measure features are proposed for recognizing and identifying fingerprint images.

Key Words: Pattern recognition, fingerprint recognition, fingerprints identification.

INTRODUCTION

The last three decades has witnessed considerable interest and rapid advance in research and development and automatic pattern recognition machines. Examples are; recognition of handwriting, recognizing the spoken words, interpretation of remotely sensed photographs which may be used to detect crop-disease, geographic studies, weather prediction, and military purposes... etc. Generally, the design of an automatic pattern recognition system involves several major problem areas; the first is the form of the data that should be extracted from the scene. The second problem concerns the characteristic features which can be obtained from the extracted data and the reduction of the dimensionality of pattern vectors. The last problem involves the determination of optimum decision process which are needed in the identification and classification process. It is worth to mention that the extracted features, generally, have forms that bear no resemblance to visual features often used by human beings.

However, fingerprints have been used as a mean of identifying individuals for a very long time. There are some evidence suggesting that ancient Egyptians and Chinese have used fingerprints to identify criminals and record business transactions.

Today, the use of computers for fingerprint matching and identification is highly desirable in many applications. Examples include building security systems and police work. In fact, despite the fingerprints represent-

*From Department of Physics, College of Science, University of Baghdad, Al-Jaderiya, Baghdad, Iraq.

ing unique patterns, they possess some similarities in their structures, making the identification of complicated patterns difficult (1). In this communication, we introduce a complete fingerprints identification system, outlined in (Figure 1), consisting of the following stages; edge lines detection, edge lines thinning, core point detection feature extraction, and fingerprint image recognition and identification.

FINGERPRINT EDGE LINES DETECTOR

A number of different techniques has been reported in the literature to approach the computation of edges and boundaries in digital images. Five of these techniques, which we believe represent the most comprehensive attempts proposed so far, are selected and discussed in detail in our former presentations (1).

The selected edge techniques were, gradient and template matching operators method (2), locally threshold and connected method (3), Marr-Hildreth technique (4), band-pass filter edge technique (5), and fuzzy set concept edge technique (6). As a result of the investigation, it has been found that the discussed edge techniques have distinct advantages and disadvantages; some of them proved unsatisfactory in giving connected edges, while others led to a detection of large number of false contours. Despite the unsatisfactory results obtained by the mentioned edge algorithms, they fried to satisfy one or all of the following conditions; Making the algorithm automatic, simple, and fast. We think that our presented edge method satisfies these conditions. The procedures involved in our edge technique can be summarized by the following; Given an image of fingerprint f(x,y), the average value for each image point is computed, using 3x3 window, given by;

$$\hat{f}(x,y) = \frac{1}{9}\sum_{i=-1}^{1}\sum_{j=-1}^{1} f(x+i, y+j)$$

Image edges E (x,y) can then be detected as;

$$E(x,y) = \begin{cases} 1 & \text{If } f(x,y) \leq \hat{f}(x,y) \\ 0 & \text{Other wise} \end{cases}$$

Figure 1: Fingerprint image recognition and identification system.

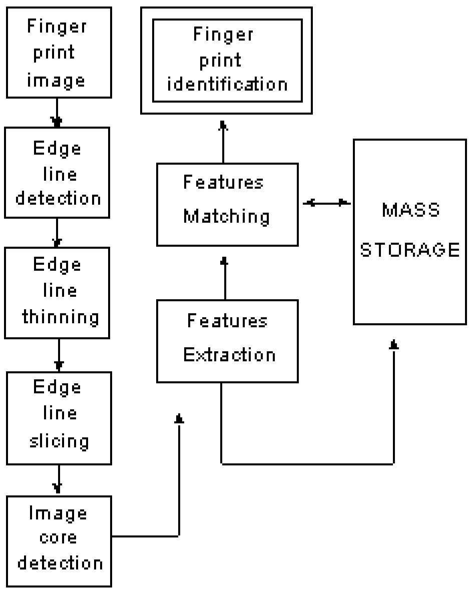
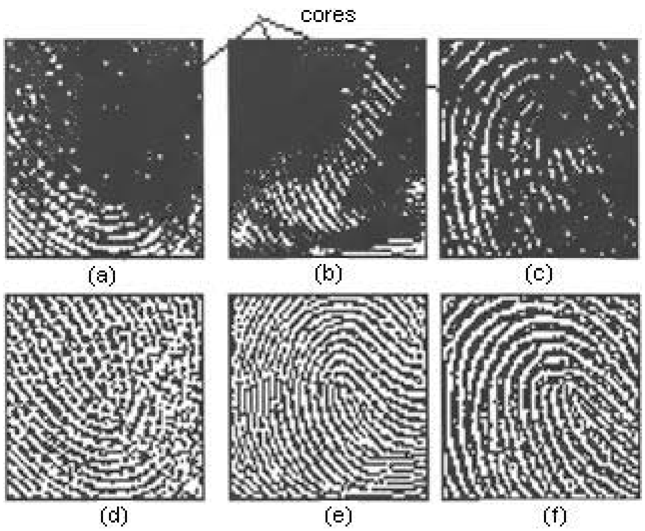


Figure 2: a-c) Samples of test images and d-f) the edge images.



The edge points have been adopted to satisfy the above condition because; dark (inked) lines are representing the true fingerprint pattern. Samples of fingerprint images and their edge results are shown in Figure 2.

Edge Lines Thinning Algorithm

As it is clear, despite the edge results shown in Figure 2, they are very similar to the visual perception of human observer, the edge detector produced thick lines which, in turn makes the recognition process complicated. To overcome this problem, edge lines must be skeletonized, using the following edge lines thinning process;

a) Edge image points must be categorized as described by Ali and Burge (7), into; *isolated* (I), *end points (E), segment points (S),* and *junction points (J)*. The categorization, as illustrated in Figure 3, is described in terms of two characteristics of a given edge point 'P';

-N(P) representing number of edge points in the 8-neighborhood.

-T(P) number of transitions 'cyclically' from edge to not or vice versa.

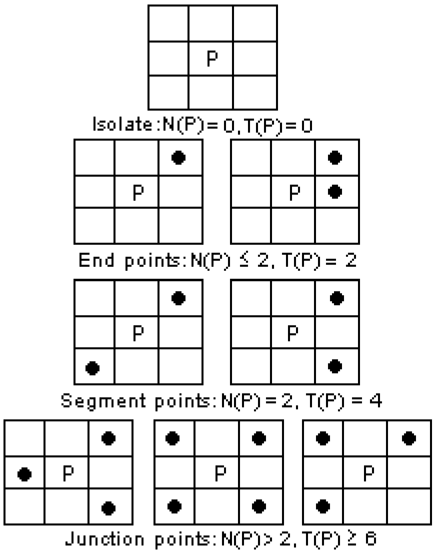
b) Edge thinning is performed by retaining only those edge points categorized as *E*, *S*, or *J*.

Figure 4; demonstrates the edge thinning results, for edge images shown in Figure 2 (d-e), respectively.

Recognition of Core Point

The advantages gained from the conversion of gray tone image of fingerprints into binary edge versions is to simplify the extraction of the features for recognition purposes and making the interpretation more reliable. However, the measured features must be invariant to some image deformations which, usually, fingerprint images being influenced; e.g. image rotation and translation effects. To achieve this, the measured features may be taken at fixed distance from certain considered image point. Generally, fingerprint core is used to represent this standard point. The fingerprint core is located within or on the innermost curve, pointed in Figure 2a-c. Different techniques have been reported in the literature (8). Published methods are found either too complicated or/and time cumbersome. In our present work, a new adaptive core detecting will be introduced which avoided much of the complexity involved by others. The edge fingerprint image, by our tech-

Figure :3 Edge point categorization.



nique, is sliced into four parts, each involved segments of straight lines representing pieces of the curves in the edge image. The straight lines taken one of the following directions, i.e. 0°-horizontal, 45°-diagonal, 90°-vertical, and 135°-diagonal, shown in Figure 5. Now, an edge image point is considered as to be core point if it is satisfied the following conditions;

a) It must be cross-point; i.e. more than one slice line passing through it.

b) Within a given window, the total sum of differences between orthogonal lines must be minimum; i.e.

$$\frac{|\ \# - (0^\circ) - \#(90^\circ)\ | + |\ \#(45^\circ) - \#(135^\circ)\ |}{\text{Total } \# \text{ (edge points in the window)}}$$

should be minimum.

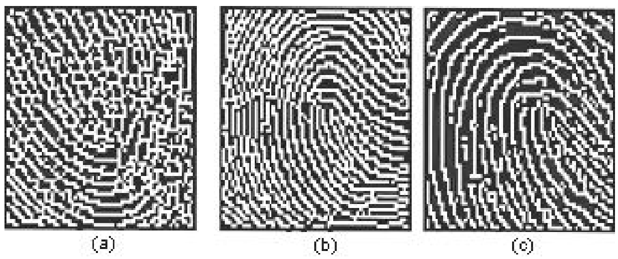
Where, # ( ) is the number of edge points with the given direction.

Our experience showed that an appropriate size for the core detecting window is 11x11 which involves a suitable number of edge points and, at the same time, not too large to make the computation time cumbersome.

Recognition Features

Our efforts will be devoted to develop an algorithm for identifying fingerprint images to satisfy the following conditions; A minimum size of data should be adopted, the algorithm is running fast and, no threshold value is required. Accordingly, the following vital information was identified;

Figure 4: Illustrations of thinning algorithm on edge images show in Figure 2 d-e.

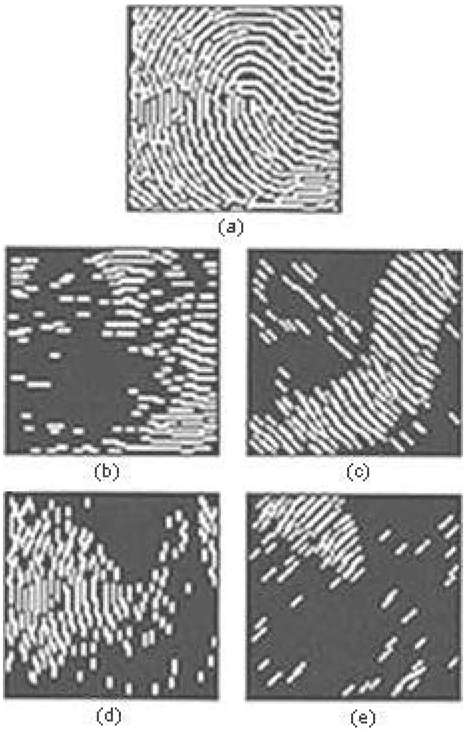


1. From the four sliced images (Figures 5 b-e), maximum line in each has been detected. The distances between mid point of these lines and the image core were measured and used as recognition features.

2. Junction points have been classified as; *Bi-junctions*, *Tri-junctions*, and *Quad*-junctions corres-ponding to the number of sliced lines passing through each. Distances between these point and the image core were computed and used as recognition features. To minimize the size of the adopted feature data, only the nearest 10-junctions to the core of each type has been considered.

These 34-measured distances might be stored or compared with other stored features when the processed fingerprint image has to be identified. It must be noted that; if 10-junctions of any type have not been found then, distances of only those found are recorded while the rest of the 10-values should be defined as zeros. Moreover, to avoid any image rotational effect, the measured features, mentioned above, were arranged in a descending order (i.e. from farthest to nearest to the core point). The following dissimilar formula has been used, introduced here, to measure the distances between matched images:

Figure 5: a; Thinned edge image, and b-e; their four sliced parts.



$$Dis = \sum_{i=1}^{34} S\%(i) \left[\frac{|p(i) - I(i)|}{p(i)} \right]$$

Where, p(i) and I(i) represent preserved and identified distances, respectively. S%(i) are weighting factors assigned for measured matching features as follows;

1. S% = 1% for distances of maximum lines in the 4-sliced directions.
2. S% = 2% for Bi-junction points.
3. S% = 3% for Tri-junction points.
4. S% = 4% for Quad-junction points.

Consequently, if all the p(i) elements were existed the maximum dissimilar coefficient will not exceed 94%. Therefore, normalized cross-correlation coefficient can be computed and used to measure the simmilarity between matched images, given by;

$$COR = 1 - \frac{DIS}{94}$$

As we can easily guess that; in case of exact similar matched images the dissimilar value will be DIS = 0 and, consequently, the cross-correlation will be COR = 1. However, our matching algorithm is designed to identify the processed fingerprint as to be the stored file that gives highest matching correlation, even if COR < 1.

CONCLUSIONS

The work outlined in this work has led us to develop an easy and fast algorithm that can be implemented to recognize and identify fingerprint images. Despite the good results shown by the introduced technique, further works are still required to enhance the performance of the method. For examples, image filtration may be adopted to remove the noise and the inking effects. Matching accuracy may be increased by adopting more measure features based on bifurcation and ridgeending points. Edge stair case effects, which were introduced by the thinning algorithm, may be prevented by introducing extra-constrained conditions. However, the algorithm have been implemented on a large number of test image files, using IBM PC-286 computer, and showed very promising results.

REFERENCES

1. Al-Zewary MS : Computer processing techniques for fingerprints image identification. MSc thesis, College of Science, University of Baghdad, 1996.

2. Abdou IE, and WK Pratt : Quantitative design and evaluation of enhancement/tresholding edge detectors. Proc IEEE, Vol 67, 5:753-763, 1979.

3. Robinson GS : NOTE: Edge detection by compass gradient masks. Comp. Graph. Image Process. 6:492-501, 1977.

4. Marr D and E Hildreth : Theory of edge detection: Proc R Soc, Lond, 207:187-217, 1980.

5. Geuen W : A fast edge detection algorithm matching visual contour perception in image sequence processing and dynamic scene analysis. NATO ASI series. Ed by TS Huang, vol F2, 483-492, 1983.

6. Verma MR, AK Majumdar, and B Chatterjee : Edge detection in fingerprints. Patt Recog, vol 20, 5:513-523, 1987.

7. Ali SM and RE Burge : NOTE: A new algorithm for extracting the interior of bounded regions based on chain coding. Comp Vision Graph, Image Process Vol 43, 256-264, 1988.

8. Kameswara Rao CV and K Black : Finding the core point in fingerprint. IEEE Trans Computer, C-27, 1:77-81, 1978.

Correspondence:
Saleh Mahdi Ali,
Department of Physics,
College of Science,
University of Baghdad,
Al-Jaderiya, Baghdad,
IRAQ.