회전과 변이에 불변한 지문 매칭 알고리즘

조 윤원*, 유 기영
gerry@purple.kyungpook.ac.kr
yook@bh.kyungpook.ac.kr
경북대학교 컴퓨터공학과

An Effective Rotational and Translational Invariant Fingerprint Matching Algorithm

Yun-Won Cho and Kee-Young Yoo
Dept. of Computer Engineering, Kyungpook National University

요 약

본 논문은 구조적 매칭 접근 방법이 회전과 변이에 얼마나 효과적인가를 보여준다. 이는 지문에서 보여주는 특징적 요소들 (코아, 델타 그리고 분기점) 사이의 거리와 각도들을 이용한다. 실제로 이 접근 방법은 회전과 변이가 허용된 한 입력 지문에 대해서 짧은 시간 내에 간단한 연산만으로도 높은 매칭 성공률을 보여준다. 또한, 현 자동화된 지문인식 시스템에서처럼 한 입력지문에 대해서 데이터베이스에서 최종 유력한 지문 10개를 검색하는 것을 목적으로 한다. 표본은 600명의 서로 다른 사람으로부터 채취된 지문을 4가지로 (궁상문, 우제상문, 좌제상문, 와상문) 분류한 각각에 대해서 약 98%의 매칭 성공률을 가진다. 실험은 150MHz, 586 퍼스널 컴퓨터에서 실행되었다.

1. Introduction

In this paper we describe and design AFIS (Automatic Identity Authentication System) which use fingerprint to establish the identity of an individual. Fingerprint identification is one of the most reliable and valid personal identification method for a long time. It refers to the process of matching a query fingerprint against a given fingerprint database while a verification system uses fingerprint only in identity authentication conducts only one-to-one comparison to authenticate. Its goal is to quickly and accurately determine whether a query fingerprint is present in the database and to retrieve those which are the most similar to the query from the database.

It is widely known that AFIS relies on exact minutiae of fingerprint to match fingerprint. In this paper, we show a structure matching approach is presented. Unlike a traditional matching approach, it is less mathematical but has very high accuracy of a matching in a short time[1,2]. Also, it is able to perform a matching fof translated as well as rotated fingerprint images. Since the candidates retrieved by the system usually need to be further examined by human experts to reach a final decision, a set of top 10 scoring reference fingerprints is obtained as a result of a matching[3,4]. In the following sections, we will describe in our matching method of AFIS. Section 2 mainly discusses the proper preprocessing for a matching and an efficient feature extraction algorithm. Section 3 presents our matching algorithm which is invariant to rotation and translation. Experimental results on a fingerprint database captured with inked images are described in section 4. Section 5 contains the summary and future work.

2. Preprocessing and A Minutiae Extraction

2.1 Preprocessing

Prior to any fingerprint matching, suitable representations (core, delta and minutiae) of a fingerprint are essential. Core and delta points are easily used for the steps of fingerprint classification and fingerprint matching because they are very stable and invariant to noise and deformation. Also, the location and number of core and delta points can make fingerprint classified for four basic types(arch, left loop, right loop, whorl). According to these four types, retrieval time can be reduced and overall system performance is enhanced.

To acquire these proper features, the raw digital image of a fingerprint itself does not meet these representational requirements so that this paper shows briefly about the preprocessing steps of a fingerprint matching first. Before considering the preprocessing steps, we can assume that the noise in an input image is already reduced considerably. The input image is first enhanced and the foreground/background regions are segmented. Then, Core and delta points are obtained using Poincare index method on a binarization image[3,5].

2.2 A Minutiae Extraction

The obtained binary ridge image needs further processing before the minutiae can be extracted[6]. First, extracted ridges should be thinned to have one pixel width. Then to maintain the continuity in ridges and remove the isolated and spur pixels, the thinning and morphological filtering should be performed[7]. The minutiae are then extracted from this thinned image, using the Crossing Number(*CN*) at a point P which is expressed as Equ.(1) and minutiae within a margin of 40 pixels of fingerprint image borders are extracted[8].

$$CN = \sum_{i=1}^{8} | P_i - P_{i+1} |, \ P_9 = P_1, \qquad (1)$$

where Pi is the pixel value(zero or one) in a 3×3 neighborhood of P, as shown in Table 1.

Table 1. 3×3 mask.

P_1	P_2	P_3
P_8	P	P_4
P_7	P_6	P_5

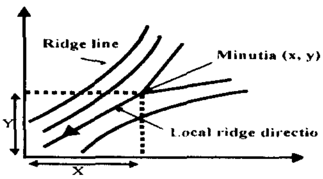


Fig 1. 3 attributes of bifurcation

Typically, there are two most prominent minutiae which are usually called; ridge ending and ridge bifurcation. However, in this paper we only consider minutiae as the ridge bifurcation because it is enough to show uniqueness, easy computability. Moreover, it is very stable and invariant to noise and deformation comparing to another. The value of *CN* for ridge bifurcation is 6. Each bifurcation has three attributes, the x-coordinate, the y-coordinate, and the local ridge direction in Fig 1. However, because these acquired minutiae may include the number of false minutiae, the post processing based on their structural characteristic and spatial relationships of minutiae is in great need. Especially, a spike within 7 pixels and a bridge are removed by a line following algorithm. The number of minutiae found in the corrupted portion of fingerprints should be considered as noise because it lows the computability and performance of our matching system.

3. The fingerprint matching algorithm

In order to have more a exact matching, the matching approach adopted in this system is divided into two stages, namely (1)matching by correlation using global angle among features(core, delta and minutiae) and (2)matching by correlation using local angle of minutiae.

For arch which has no core and delta points, only the structural and spatial relationships of minutiae can make some rotation and translation invariant. For loops and whorl, the existence of core and delta points helps two fingerprints to be invariant to rotation and translation.

3.1 The matching method for arch

First of all, for the matching by correlation using global angle among minutiae, we find one bifurcation and two other bifurcations which are nearest to it. We can link these three bifurcations and make one triangle. Then, the interior angle of it can be easily computed. This becomes the first object of matching between two fingerprints for arch. Secondly, for the matching by correlation using local angle of features, we need the directions of each bifurcation as shown in Fig 1. Then, we can make a new triangle by linking the directions of three bifurcations of a triangle found in the first stage. Also, we can acquire the interior angle of new triangle in second stage. This becomes the second object of a matching for arch. Hence, each group of three bifurcations has two triangles which are linked based on only three bifurcations and three directions of them as shown in Fig 3(a). Consequently, we believe that two fingerprints which have the most number of similar triangle are identical even though an input fingerprint allows some rotation and translation.

3.2 The matching algorithm for loops and whorl

For the matching by correlation using global angle among core and delta points and minutiae, we need to find out each registration line of two fingerprints in a database and an input. For loops the line between core and delta points should become it and for whorl the line between a middle point of two cores and left delta should be it. We compute the absolute angle of registration line, the absolute angle and distance between core and each minutiae.

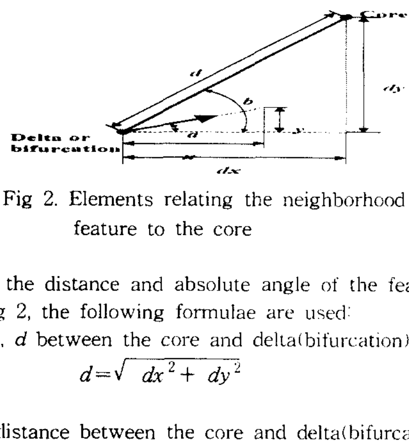


Fig 2. Elements relating the neighborhood feature to the core

To calculate the distance and absolute angle of the feature as shown in Fig 2, the following formulae are used:

The distance, *d* between the core and delta(bifurcation) is:

$$d = \sqrt{dx^2 + dy^2} \qquad (2)$$

where,

dx is the distance between the core and delta(bifurcation) in the *x* direction.

dy is the distance between the core and delta(bifurcation) in the *y* direction.

The absolute angle of the delta is:

$$\angle \varnothing b = \tan \frac{dy}{dx} \qquad (3)$$

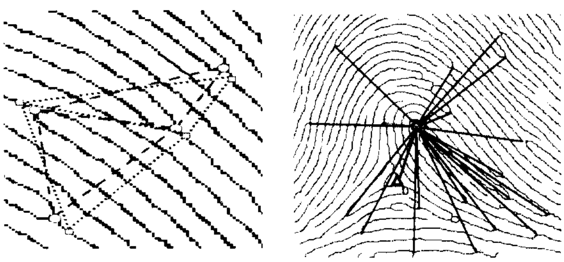
The directional angle of the bifurcation is:

$$\angle \varnothing a = \tan \frac{y}{x} \qquad (4)$$

Also, we count the number of ridges on registration line which is used to reduce the search space in the database for the matching system. Then, for the matching by correlation using local angle of features, we need the directions of each bifurcation in Fig 1.

When we map a fingerprint in a database to an input fingerprint, we first compare the number of ridges on the registration line in two fingerprints. Secondly, we need to compute the difference of absolute angle between two registration lines in two fingerprints then make a set of minutiae of a fingerprint in a database been rotated to it in an input fingerprint as their difference of absolute angle found above as. Then we can compare the absolute angle of each minutiae and distance between core and each minutiae. These above computations become the first stage of matching for loops and whorl. For the second stage, we use a similar method of the first stage using absolute angle of the directions of each minutiae instead absolute angle of each minutiae in Fig. 3(b). This matching algorithm is based on finding the most number of minutiae which has similar angle and distance in fingerprints between a database and an input.

Finally, in this paper we provide a ranked list of the most possible matches(usually the top 10 matches), which are then verified by human experts at last because of the large size of fingerprint database and noisy of fingerprint encountered in practice[4].



(a) (b)

Fig 3. (a)Arch (b)Loops and whorl

4. System performance evaluation

We have tested our system on 600 images(512*480) which are captured with inked and from each different people. The captured fingerprint images vary in quality. In this paper we give three grades(A, B, C) according to their qualities. In our database are considered 70% of the images are grade(A) and 20% are grade(B) which are reasonable quality similar to those shown in Fig 4(a) and (b), while about 10% of the images are grade(C) which is not of good quality due to large creases and smudge in ridges and dryness of impressed finger in Fig 4(c). These images are classified as the four basic fingerprint patterns before the matching is performed. A rotated and translated image is defined as a image with rotated by the degree of ±30 and shifted by 5.

And, we conclude two fingerprints are from a same finger if the error in the view of angle and distance is in the 5° and 6 pixel. The average required matching time is about 0.1 second on a 150 MHz, 586 personal computer. The images of grade(A) and (B) match successfully in the top 10 list and the matching accuracy of these images is about 98%. We observe the incorrect matches are due to fingerprint images with poor quality such as shown in Fig 4(c). The accuracy of these bad images is 78% so that it becomes a main reason to low the system performance. Therefor, we can improve these matching results by ensuring that the database does not contain such poor quality fingerprint images.

(a) (b) (c)

Fig 4. Fingerprint images

5. Conclusion

We have proposed the fingerprints identification system using the correlation in terms of distance and angle(global and local) among the features. This makes the scheme relatively robust even in distortions and can show two fingerprints are identical on top 10 list within some rotation and translation.

However, we concluded that the incorrect matches occur mainly due to a fingerprint image of poor quality. We should investigate an image enhancement algorithm and an adaptive morphological technique to extract the most efficient minutiae in future work.

Reference

[1] D. K. Isenor and S. G. Zaky, "Fingerprint Identification using Graph Matching", *Pattern Recognition*, Vol. 19, No. 2, pp. 113-122, 1986.

[2] B. Moayer and K. S. Fu, "A Tree System Approach for Fingerprint Pattern Recognition", *IEEE Trans. on PAMI*, Vol. 8, No. 3, pp. 376-387, 1986.

[3] Lin Hong, "Automatic Personal Identification using Fingerprint," Ph.D thesis, Michigan State University, 1998.

[4] N. Ratha, K. Karu, S. Chen and A. K. Jain, "A Real-time Matching System for Large Fingerprint Database", *IEEE Trans. on PAMI*, Vol. 18, No. 8, pp.799-813, 1996.

[5] V. S. Srinivasan and N. N. Murthy, "Detection of Singular Points in Fingerprint Images," *Pattern Recognition*, 25(2):139-153, 1992.

[6] N. K. Ratha, S. Chen, and A. K. Jain, "Adaptive Flow Orientation-Based Feature Extraction in Fingerprint Images,"*Pattern Recognition*, 28(11):1657-1672, Nov, 1995.

[7] Zhang, S. and K. S. Fu., "A Thinning Algorithm For Discrete Binary Image," *Processings of the International Conference on Computers and Applicaions*, Beijing, China. pp. 879-886, 1984.

[8] B. M. Mehtre. "Fingerprint Image Analysis for Automatic Identification." *Machine Vision and App.*, 6: 124-139, 1993.