An AFIS Using Fingerprint Classification

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Abstract

Fingerprints have been used as biometrics for personal identification or verification since a century ago. Although no exactly the same fingerprint from distinct identities was found, a perfect system for automatic fingerprint identification does not exist. This paper implements an automatic fingerprint identification system (AFIS) with the use of fingerprint classification and minutiae pattern matching. A minutiae pattern is composed of various minutiae extracted from a fingerprint image. Each minutia is represented by its relative location, a type: ending or bifurcation, and the ridge direction. Our system is tested on a database composed of 308 300×300 left index fingerprint images contributed by 77 persons via a Veridicom FPS110 reader. A 80% recognition rate is achieved. Each matching takes $5 \sim 9$ seconds CPU time on a PC with K6-400 CPU and 128 MB SDRAM running a Windows 2000 OS.

Keywords: *Classification, Fingerprint, Identification, Minutiae Matching*

1 Introduction

Fingerprint used for access control, criminal verification, and credit card and passport authentication is getting more and more popular. Whereas, a perfect automatic fingerprint identification system (AFIS) has not been discovered yet due to an unexpected variety of changes when a fingerprint is sensed [4]. This paper implements an automatic fingerprint identification system which receives a fingerprint image as input to match a previously registered ones in the database and responds either "accept" or "reject" according to a designer-specified policy [3]. Our paradigm of AFIS is shown in Figure 1. The remaining of this paper depicts the details of this paradigm and shows experimental results.

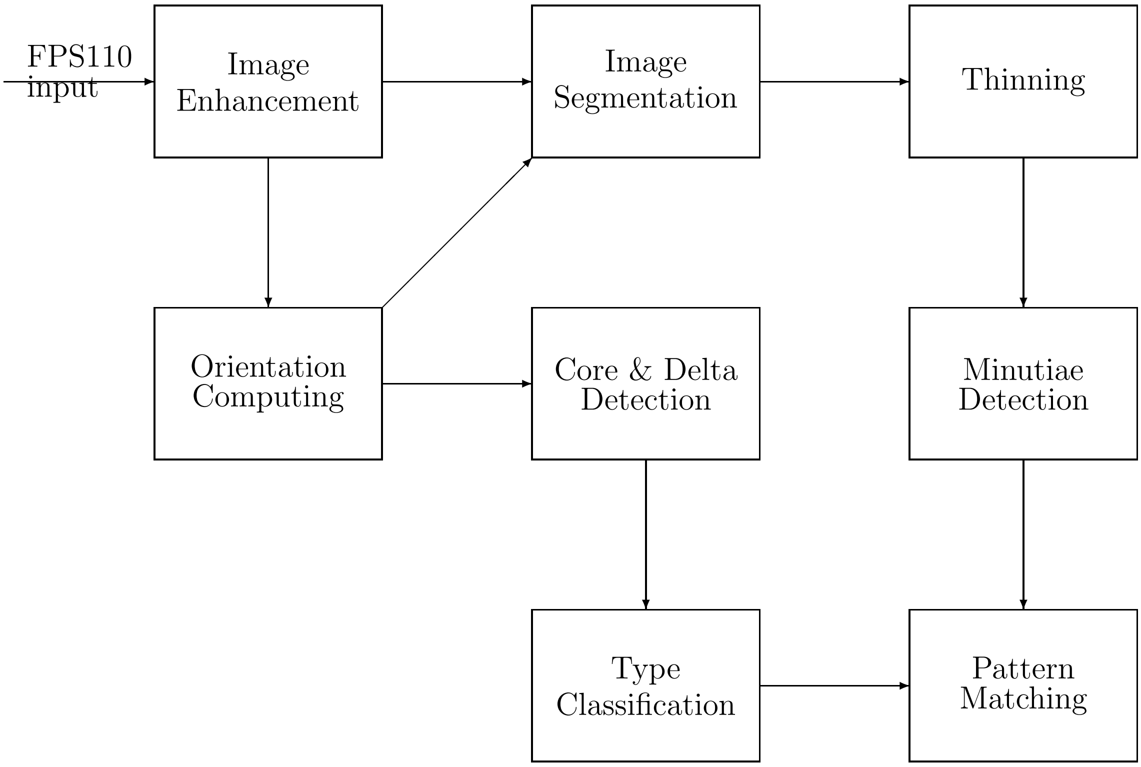


Figure 1: An AFIS Paradigm

2 Image Enhancement

Our AFIS starts with taking a fingerprint image of size 300×300 with 256 possible gray levels by using a Veridicom FPS110 reader of resolution 500 dpi. Although a life scan techinique was investigated to improve the quality of acquired fingerprint images, the moisture and scars of a finger could distort the acquired fingerprint image. Our AFIS uses an ad hoc strategy according to previous experience to enhance the quality of a fingerprint image.

Suppose that each pixel (i, j) has a gray value $g(i, j)$, we define a potential direction index at (i, j) as $S_v(i, j) = \sum_{k=-n}^{n} |g(i, j) - g(i + k, j + k)|$, where $n = 8$, and $v = 0, 1, \ldots, 7$. The smaller S_v, the more probably directed a ridge is. We then partition the image into non-overlapping 8×8 blocks and either accentuate or attenuate the pixel values according to an index of block direction by a majority of votes to get a transformed image, called a *block direction image*. Some block directions may be inconsistent with its surrounding blocks due to the noise, we apply some smoothing process associated with an ad hoc rule to achieve a block direction image [1][5]. Finally, a nonlinear transformation on pixel values of the block direction image based on thresholding is applied to get the *enhanced fingerprint image* as shown in Figure 2(b).

3 Simple Image Processing

We apply a simple thresholding process [6] on the enhanced image followed by a post-smoothing operation to get a binary image with ridge pixels represented by 1 and valley pixels represented by 0. A thinning algorithm proposed by [7] is then applied on the segmented binary image to get the skeleton of ridges with unit-width followed by isolated pixel removal and broken ridge re-connection. We achieve this result with a *thinned image* as shown in Figure 2(c).

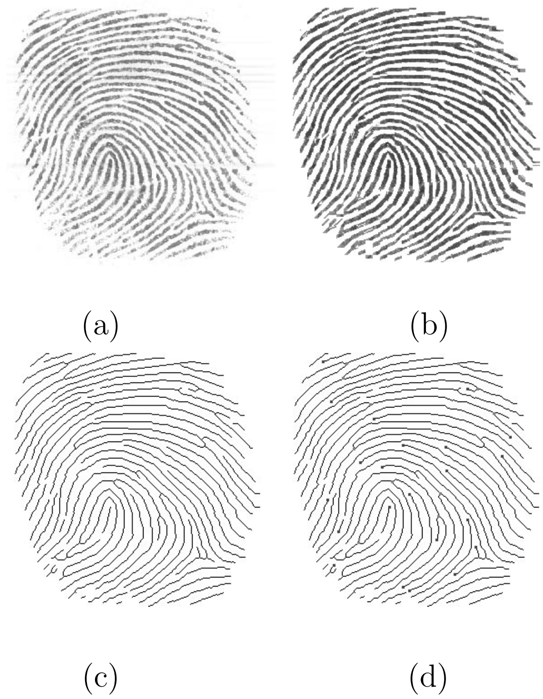


Figure 2: Minutiae Extraction: (a) Original, (b) Enhancement, (c) Thinning, (d) Minutiae Locating

4 Minutiae Points Locating

From a thinned image, we can classify each ridge pixel according to its 8-connected neighbors. A ridge pixel is called an *isolated point* if it does not have any 8-connected neighbor, an *ending* if it has exactly one 8-connected neighbor, an *edgepoint* if it has two 8-connected neighbors, a *bifurcation* if it has three 8-connected neighbors, and a *crossing* if it has four 8-connected neighbors.

Two kinds of minutiae (pixels), ending or bifurcation, are first located by checking the 8 neighbors of a ridge pixel. Due to broken ridges, hair effects, and ridge ending beyond the margins, a post-processing is used to remove the following spurious minutiae with the result shown in Figure 2(d). Spurious minutiae include (a) endings that are beyond the margins, (b) two close endings with the same ridge direction, (c) ending and bifurcation that are connected and close enough (say, within 7 pixels), (d) bifurcations that are too close. Figure 3 demonstrates these examples.

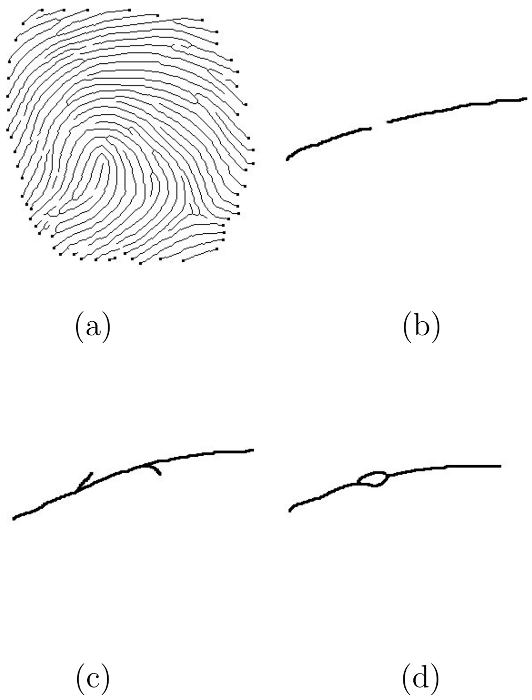


Figure 3: False Minutiae: (a) Beyond margins, (b) Broken ridges, (c) Minutiae are too close, (d) Too close minutiae

5 A Coarse Classification of Fingerprints

Since a minutiae-based matching procedure consumes a huge amount of time, we classify each fingerprint into one of the four types: left loop, right loop, whorl, and arch, and search in the database only for those fingerprints whose type coincides with that of a requested one. The type classification is based on the number and distribution of singular points, core and deltas [2][3][6]. A left loop might contain a delta located on the right and/or down of the core which is convex. A right loop might contain a delta located on the left and/or down of the core which is convex. A whorl contains cores without deltas in the surroundings. An arch has a delta almost right below the core. This coarse classification can significantly prune mismatch comparisons and speed up minutiae patern matching.

6 Minutiae Pattern Matching

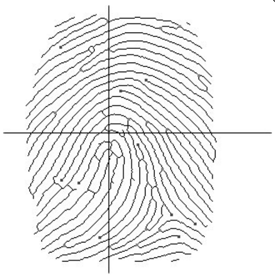
Minutiae pattern matching is an important but difficult task. The performance is quite different from one database to another database. Since our database consists of 308 left index fingerprint images of size 300×300 from 77 persons, each contributed 4 times of his or her left index fingerprint preattentively via a Veridicom FPS110 reader. Only minor rotations and translations from one fingerprint to another may exist. Our simple pattern matching procedure is described below. Given a test minutiae pattern P, we first search one from the database which matches the type, say, a Q. We now give a a matching score, the larger, the better match. We first place the core (pixel) of a candidate fingerprint image on the top of the given one. Then the matching score is calculated by

$$S = \frac{1}{2M} \sum_{j=1}^{M} [(1 - \frac{r}{R}) + (1 - \frac{\alpha}{A})]_j \quad (1)$$

where M is the number of potential type-matching minutiae (pixels) within a disk of a certain user-specified radius, R, under a rotation with a certain angle A (here $A = \pi$). r measures the distance between a pair of potentially matched minutia points, α is the angle of rotation. Figure 4 characterizes the matching result with a score 12.56 for (b) and (c) (the matched pair) vs. 5.52 for (b) and (d) (a dismatched one).

(a)

(b)



(c)

Figure 4: Minutiae Matching: (a) A minutiae pattern, (b) Matched one, (c) Dismatched one

7 Experiment and Discussion

We tested our proposed AFIS on a database consisting of 308 left index fingerprint images of size 300×300 which were contributed from 77 individuals, each contributed 4 times of his or her left index fingerprint with a pre-attention on impressing their fingerprints on the surface of the reader almost at a fixed spot via a Veridicom FPS110 reader. So only a slight of rotation and translation from one fingerprint to another may exist for each person. To evaluate our AFIS, one fingerprint image is matched with the remaining 307 images in the database, if one of the other 3 fingerprint images was matched within the highest 3 scores, we accept the match, otherwise, we reject it. Among the 308 matches, we accept 245 and reject 63 matches, therefore a near 80% acceptance rate is achieved with most of the mismatched ones occurred due to poor quality of input fingerprint images.

We implement an AFIS to achieve a fair acceptance rate. The performance of an AFIS could be significantly different from one database to another one. Our system adopts a nonlinear transform by considering the ridge direction to enhance an input of fingerprint image and includes the result of a coarse fingerprint classification for minutiae pattern matching. It takes around $5 \sim 9$ seconds for each identification. Other techniques of *enhancment* and *minutiae matching strategies* to improve the performance are under investigation [8][9][10]. In [10], Chang has demonstrated that applying the normalization based on an assigned variance and Sobel edge operators could increase the recognition rate from 80% to 87% on the same database.

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