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Feature Extraction and Classification of Fingerprints using a Novel Fuzzy Neural Network

MEHDI HARIRI, SHARIAR B. SHOKOUHI
Department of Computer and Electrical Eng,
Islamic Azad University and Iran University of Science & Technology
Zanjan, IRAN. Tehran, IRAN

Abstract: - Fingerprint feature extraction and classification is always an interesting subject, in this paper besides of using effective methods for extraction of features a Fuzzy Neural Network has been introduced for classification and identification. For generating input patterns to feed the matching network, the algorithm extracts singular points and minutiae of each pattern by using the optimum segmentation and recovering methods. So for each pattern, a fingerprint feature image, let call it fingerprint feature map, has been found. Then this feature map is encoded and applied to the intelligent classifier. The learning speed and matching capability are improved by using the feature coding method. Necessary time for feature extraction and classifying of 100 different fingerprints with 220*176 dimensions and 315 dpi resolutions is less than 20 second. Also necessary space for storing image bank becomes small, up to 2.54Kbyte per each feature map. The FNN is a clustering system with 5 feed forward layer and supervised learning algorithm.

KEY-WORDS: - Fingerprint, Feature extraction, Minutiae, Coding, Classification, Fuzzy Neural Network

1 Introduction
Nowadays Biometric is very important identification method to generate security in new correlated societies and fingerprint with its unique capability is the most reliable and authentic personal identification method [1, 2].

Because of variety and complexity of fingerprint, many researches have been done a lot of work and so many articles in different contexts (recovery, feature extraction, classification and various matching and identification algorithms) have been proposed.

Chang and Sulong proposed some of the current fingerprint recognition approaches by defining them in two groups, classifier and feature extractor [3].

Mohamed and Nyongesa presented the fingerprint classification system according to the well known Henry system with using linguistic terms and simple fuzzy rules [4].

In this research we used FNN that made of Fuzzy Neurons (FN) with fingerprint classification and identification capability. As this network process on feature maps of fingerprints, we propose an extraction and feature coding method with participating of each feature for applying to the network.

2 Fingerprint feature extraction
The process of segmentation and recovering is shown in Fig. 1.

2.1 Fingerprint Acquisition
For Fingerprint acquisition we use inkless live-scan scanner, fully electronically technique. This scanner has capacitive sensor made by CMOS technology [5].

2.2 Segmentation and Binarization
Processing and filtering of the crude captured image, that each ridge and furrows region completely recognize and partitioning without trait variety of original image.

Some of these methods are: segmentation with constant threshold [4,6], regional average threshold [4], gray levels variance and edge detection with Marr filter. We applied adaptive filters for fingerprint segmentation. These filters make not only fingerprint binarization but also matching ridge [8]. Fig.2 shows the results of processing fingerprint with this filter.

2.3 Generating Point Directional Image
One of the most important fingerprint characteristics for classifying is "having its ridge directional length".

As the direction of minutiae points one of the important parameters to encoding feature map for matching, we must generate fingerprint directional image.

According to the precision and application, ridge directional extraction can be done in two forms, blocky and dotty.

Some of the blocky ridge directional extraction methods are: calculation of block direction using variance. [9], block directional computing with sub directional patterns [10], and block direction computing by using directional masks.

Dotty ridge directional extraction methods are: Gray levels variety [7], gradient computing in perpendicular direction and directional computing with directional masks.

Because of using features in point mode, we extract directional information in dotty method like Fig.3.

2.4 Block Directional Image for Singular Point Extraction

For fingerprint feature extraction including number and position of singular points (delta, core, and whorl) and then classification, global information about the direction of ridges is sufficient. The ridges have been stored in block forms so block directional images have been generated.

Two types of calculating for each block have been proposed. One is averaging between different point lengths inside a block: according to equation (1).

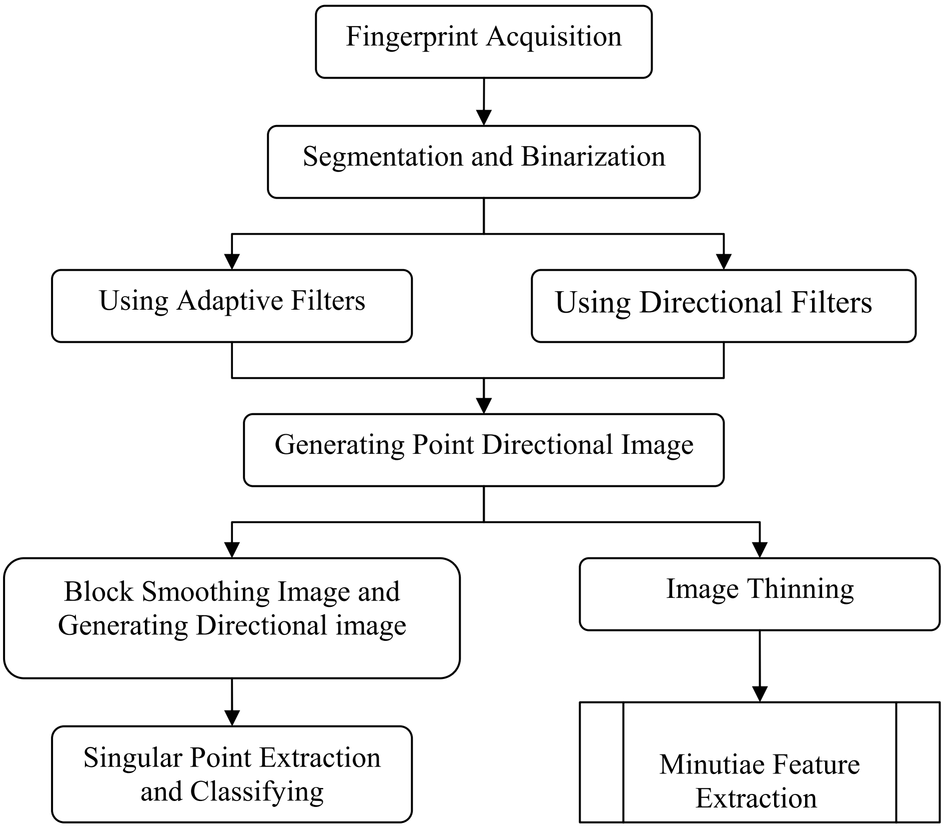


Fig.1: Fingerprint feature extraction steps

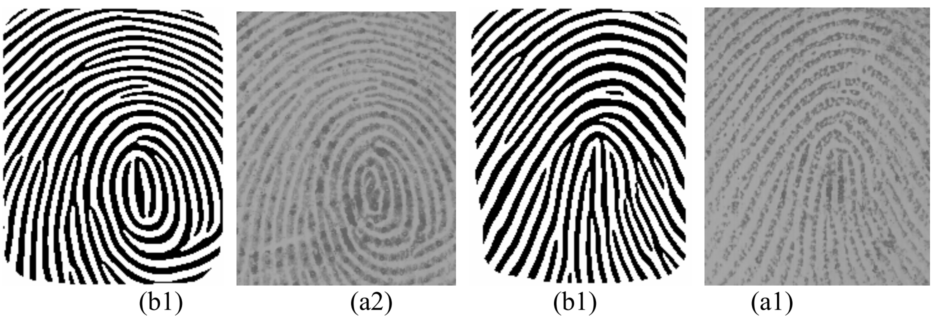


Fig.2: a) Crude input fingerprint, b) Recovered images with adaptive filter.

(d) (c) (b) (a)

Fig. 3: a) Crude input image, b) Point directional image, c) Input recovered image, d) Point directional image acquired from recovered image

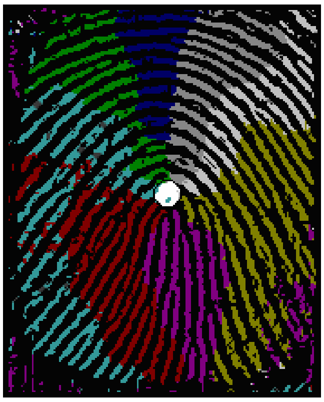


Fig.4: Smoothing directional image with (8*8) block form with a core.

$$d_{ave} = \frac{\sum_{i=1}^{8} n_i d_i}{\sum_{i=1}^{8} n_i} \quad (1)$$

And finding dominant direction exists in block, according to equation (2).

$$dave = \left\{ d_j \,\middle|\, n_j = \max_i (n_i) \right\} \quad (2)$$

As shown in figure (5) block directional image, in singular points, ridges contact each other like small whirlpool. So after generating block directional image, Eddy regions have been assumed singular point candidate. With using its relative rotate around each point (in 3*3 window) at clockwise direction, which is adherent to type of singular point and follow from special rule [11], we can be able to recognize the type.

2.5 Smoothing and Thinning Point Directional Image

After acquiring directional image at ridge length, with using image smoothing methods and comparing compatibility of various directions, we can usually correct noise defects and fill ridge blanks according the direction of its region. Because of dissimilarity of ridge width at fingerprint in feature (like: end ridge, branch point, etc) extractor faces complexity in processing. The smoothed and corrected image is shown in Fig 4.

The thinning method has been applied to reduce ridge width to one pixel. The Sherman thinning method is considered. The thinned pictures are shown in Fig 5.

2.6 Minutiae Feature Extraction from Point Directional Image

After thinning we can extract minutiae. According to the Spinoza [13] method, we put a (3*3) block on each pixel of ridge and process neighbor pixels around central pixel of the block in 8 directions.

If this processed point is end ridge (1 gray level) according formula (3), its neighborhood only has similar amount (1) and others are zero (0).

$$\sum_{i=0}^{7} N_i = 1 \qquad p(x,y) \text{ Is an end point} \quad (3)$$

But if it was branch point, numbers of neighbor pixels with similar amount of central pixel were more than 2.

$$\sum_{i=0}^{7} N_i > 2 \qquad p(x,y) \quad \text{is a branch} \quad (4)$$

a) Minutiae position in fingerprint

Position of each fingerprints feature presents with its length and width. In our images, minutiae length is between 0 and 175(0<x<175) and its width limitation is (0<y<219).

b) Minutiae direction

Minutiae direction is extracted for each minutia from point directional thinned image with mentioned methods. For this purpose we choose 16 various direction (0-15) in which each sector is 22.5 degree. Here more than ridge length in each point, minutiae direction is desirable as well. In this section complementary angles are different, according to Fig.6.

c) Types of minutiae

We are facing with two types of minutiae, 1. end ridge points, 2. branch points as it shown in Fig. 7.

3 Coding the features

Direction and type of each feature has been considered by different bits, 4 bits for direction and one for type. As the direction is more important than the type so the most significant bits are considered for the direction and the least significant bit for the type which is shown in table (1). Also three types of classification can be found for fingerprints based on the minutiae, as shown in Fig. 8.

For whorl we can consider the minimum loop and also the center of it for the whorl point. Also we can consider a whorl as two cores with one center, so two bits are necessary for coding as shown in table (2). With this coding, end ridge points have odd numbers and branch points have even number between [0-31]. All of the coding summarized in Table (3):

ER:				D_3	D_2	D_1	D۰	۱	End ridge code
BP :				D_3	D_2	D_1	D۰	0	Branch code

Table 1: Coding for end ridge and branch points

Arch	0	1	0	D	D_2	D_1	D_0	M
Core	1	۰	0	D	D_2	D_1	D_0	M
Whorl	1	1	0	D	D_2	D_1	D_0	M

Table 2: Feature coding for finger type

$$ER:\{1,3,5,...,31\}$$
$$BP:\{0,2,4,...,30\}$$
$$Arch:[64-75] \quad Core:[128-159] \quad Whorl:[192-223]$$

Table 3: Available codes for different types of features

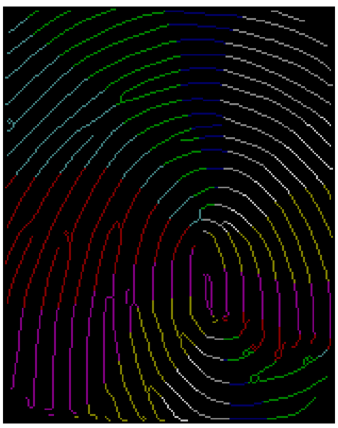
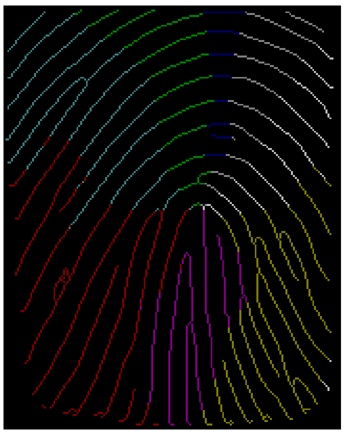



Fig. 5: Thinned images of fingerprint

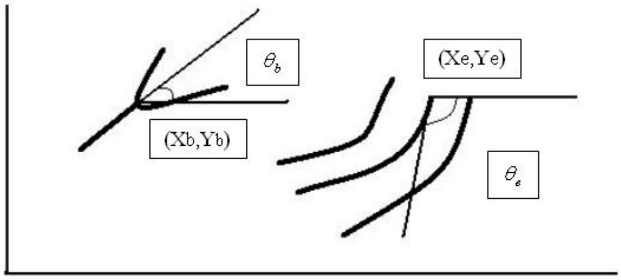
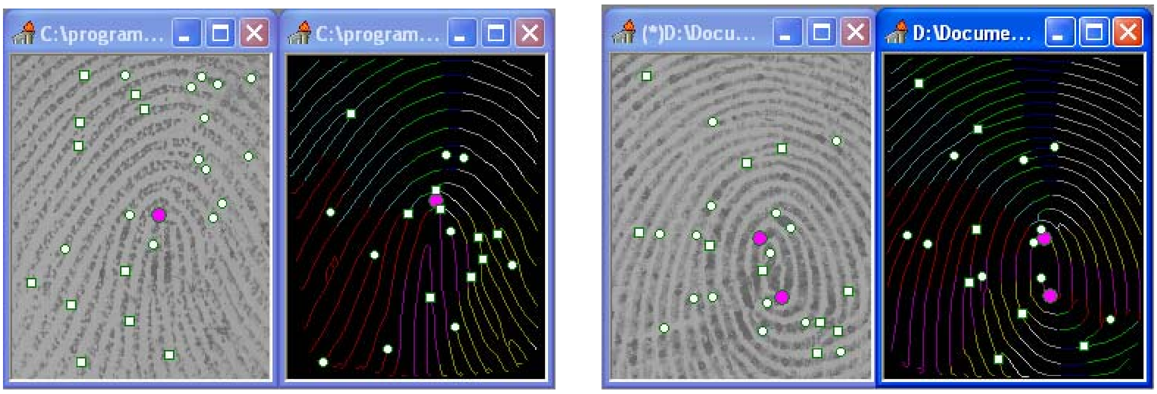


Fig. 6: Extracted characters of fingerprint minutiae



(a) (b)

Fig. 7: Extraction of features from the, a) thinned directional image, b) the original directional image

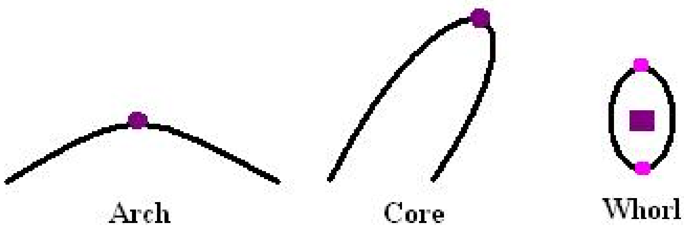


Fig. 8: Three types of minutiae

4 Fuzzy-Neural Network

Figure (9) shows the proposed FNN which three first layers have the same structure of the proposed network by Hong [14]. In this network we define a special class for each fingerprint group from a special person. This class is completed with so many processed and coded fingerprint images from a person and therefore the network understands all of the possible deficiencies on the images. During the learning process all of the related data have been found and saved in a sub-class. If the algorithm can not find a suitable subclass for the image a new class will be defined for it. The FNN has been optimized by three factors, β: fuzzy limitation, α: similarity factor, and T_F: error limitation of the network.

5 Results and conclusion

As explained we reduced the fingerprint image to the necessary features which they can be used for learning and matching process in the FNN. So the processing time and volume have been reduced considerably. With this technique we processed 100 fingerprint images (176*220) only in 120 seconds for the learning steps. For the pattern with only one closed singular point the accepted error is between %20-%30 and rejected error is %15-%20. Also for the patterns with two separable singular points the accepted error is %10-%15 and rejected error about %10. The processing time for comparing and classifying new image is about one second.

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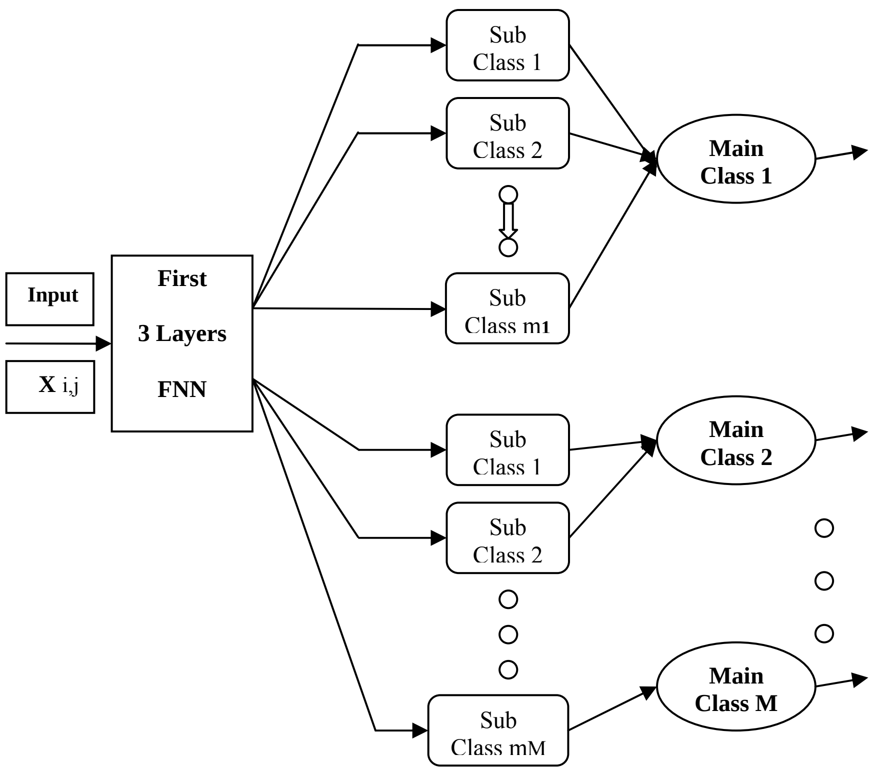

Fig. 9: Optimized Fuzzy Neural Network with two extra layers