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A Novel Rule-based Fingerprint Classification Approach

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ABSTRACT

Fingerprint classification is an important phase in increasing the speed of a fingerprint verification system and narrow down the search of fingerprint database. Fingerprint verification is still a challenging problem due to the difficulty of poor quality images and the need for faster response. The classification gets even harder when just one core has been detected in the input image. This paper has proposed a new classification approach which includes the images with one core. The algorithm extracts singular points (core and deltas) from the input image and performs classification based on the number, locations and surrounded area of the detected singular points. The classifier is rule-based, where the rules are generated independent of a given data set. Moreover, shortcomings of a related paper has been reported in detail. The experimental results and comparisons on FVC2002 database have shown the effectiveness and efficiency of the proposed method.

KEYWORDS

Fingerprint classification, Rule-based classification, Singular point, Core, Delta

1 INTRODUCTION

In last decades, fingerprint recognition has received great attention because of its unique properties like easy acquisition, universality, permanency and circumvention. The use of fingerprints for criminal verification, forensics, access control, credit cards, driver license registration and passport authentication is becoming very popular.

In huge databases, fingerprints are divided into some classes first, to reduce the search time and then matching phase took place. Many fingerprint classification methods rely on ridge flow or global features. After that, input data needs to be matched only with same class images.

In fingerprint classification algorithms, extracting the number and precise locations of singular points (SP), namely core and delta points are very important. Henry defined the core point as "the north most point of the innermost ridge line". A delta point is the center of triangular regions where three different direction flows meet [1, 2]. Figure 1 shows the five most common classes of the Galton−Henry classification scheme (arch, tented arch, left loop, right loop, and whorl):

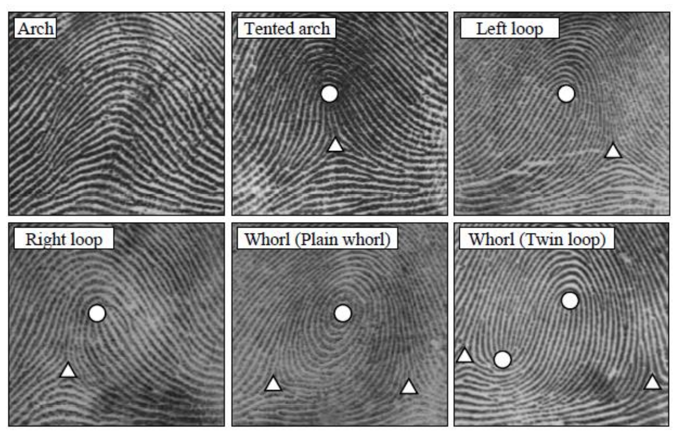

Figure 1. The five most common classes of Galton-Henry classification scheme

A fingerprint can be simply classified according to the number and positions of the singularities; this is the approach commonly used by human experts for manual classification, therefore several authors proposed to adopt the same technique for automatic classification [2-10]. Table 1 shows some of these rules. The key idea of proposed classification method in [3] is dividing fingerprint into small sub-images using singular point location, and then, creating distinguished patterns for each class using frequency domain representation for each sub-image. In [4], an algorithm based on the interactive validation of singular points and the constrained nonlinear orientation model is proposed. The final features used for classification comprises the coefficients of the orientation model and the singularity information. This resulted in very compact feature vector which is used as input to an SVM classifier to perform the classification. Some of singularity extraction methods are presented in [6, 8-9]. Qinzhi Zhang et al. in [10] used the pseudo ridge tracing and analysis of the traced curve, so their method does not rely on the extraction of the exact number and positions of the true singular points. Most of approaches using singularity points use combination of several features or classification methods that cause increase in time and complexity.

On the other hand, those methods relying on exact number of singularities and some simple rules as follows, don't have effective rules for accurate class separation. The quality of the fingerprint images may depends on many factors such as that caused by breaks, scars, too oily or too dry. Besides, in many cases we have a partial image, usually with the delta point outside the print. So, all of these factors make it extremely hard to classify such images according to the simple rules.

Table 1. Fingerprint classification rules using singular points [3, 7, 11]

Fingerprint class	Singular points
Arch	No singular points
Tented arch, Left loop, Right loop	One loop and one delta
Whorl	Two loops (or a whorl) and two deltas

In this paper, a rule-based classification approach has been proposed that classifies fingerprints into four classes, namely, whorl (W), right loop (R), left loop (L) and arch (A). This approach uses the number and location of singularity points for classification and is robust to transformation, rotation and scale variations. Our approach works on images with just one core too. The rule used for these kind of images has been presented and compared in detail with other methods.

The remaining sections of the paper are organized as follows. Section 2 presents the proposed method. Section 3 gives the obtained results of experiments. Finally, in section 4 some conclusions are drawn.

2 THE PROPOSED METHOD

The rules in Table 1. are not exhaustive. For example, in many fingerprint images of low quality as those of FVC databases, the delta is outside the borders due to low pressure at the surface or small sensors. In these cases, the delta is not in ROI (region of interest which is defined by the segmentation step). We must therefore use more robust approaches. However, a certain number of pictures have no core or delta in their ROI. We tried to use the general rules set out in section 1 and significant extensions in the proposed system. Our rules are shown in Figure 2.

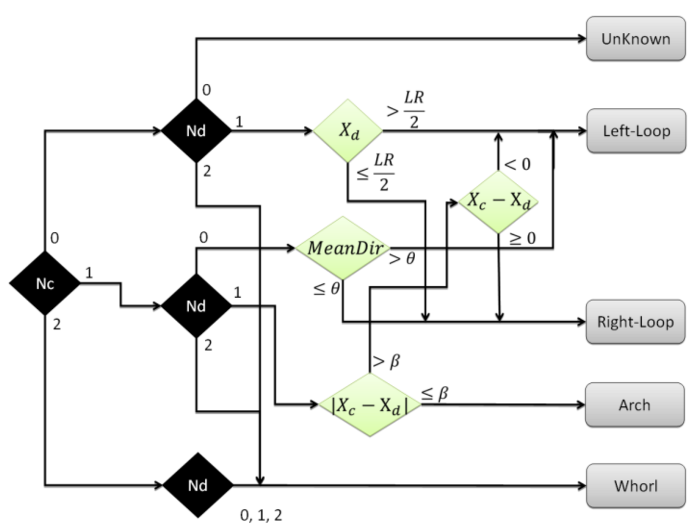

Figure 2. Proposed rules for fingerprint classification based on singular points information

In our system, arch and tented arch are considered as a class named arch. Extended rules are as follows. If no singular point is recognized, we have unknown class. Figure 3 shows a sample of unknown class in FVC2002 database. If a delta and no core is extracted, the location of the delta in ROI determines one of the left loop or right loop classes. If x coordinate of delta is less than half of ROI length, fingerprint class is left loop, and right loop otherwise.

If number of cores and deltas is equal to one, decision will be one of left loop, right loop and arch classes. To do this, we calculated differences between x's coordinate of core and delta with $|X_c - X_d|$. If the result is less than a certain threshold λ, it means arch class. Otherwise left loop or right loop is selected. In the case of $X_c - X_d \geq 0$, core lies on the right hand of delta and the class will be recognized as right loop and vice versa for left loop. If one core and two deltas or just two deltas are extracted, the whorl class will be the one.

In the case that we have no core and two deltas, the class is whorl. And if one core is extracted, the number of delta is important for determining the class type. In this situation, if the number of delta is zero, we should decide between right and left loop classes. As mentioned earlier, the general rules do not support this case. Some references proposed several methods to solve this problem. For example [7] is one of the recent ones that divided ROI to four regions and decided according to location of core in them. This rule is shown in Figure 4. But it's obvious that in real world, cores lie on wrong places sometimes. Rotation and translation create this situation often. This paper used FVC2002 DB1-A database, but many examples of violations for the proposed rule are found in this database. Some of these images are shown in Figure 5.

Figure 3. A fingerprint image without any singular point

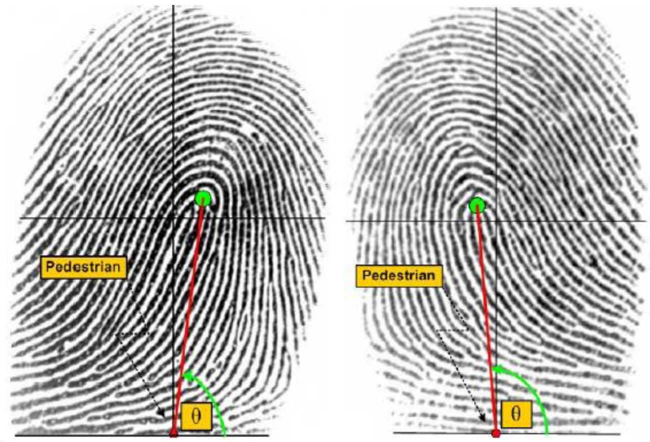

Figure 4. Two samples of the rule that is used in [7]

Figure 5. Some of images of FVC2002 that are misclassified by [7] rules

In the proposed approach, image direction in a neighborhood area of core is used for classification of these images. A neighborhood area of core has been extracted first. Then this area is divided into $B \times B$ blocks. Each block's direction is calculated using gradient method [12].

The overall direction that is average direction (MeanDir) of all blocks determines the class. MeanDir's range belongs to the lower half of unit circle. In the right loop and left loop classes, MeanDir belongs to lower-right and lower-left half of unit circle respectively. Figure 6 shows an example of proposed approach for two right-loop and left-loop cases. Size and location of the neighborhood area, and number of the blocks in the area were achieved by examination of one core left and right loop images in FVC2002 database.

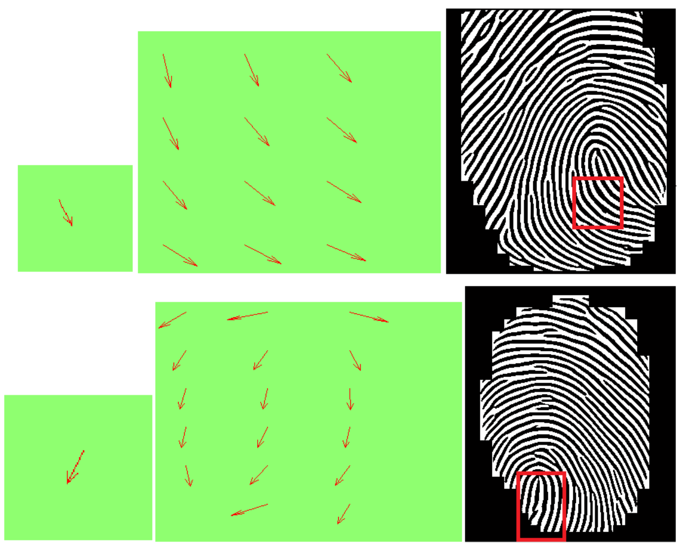

Figure 6. First row: Right loop class - Second row: Left loop class (a) Neighborhood area (b) Blocks direction in the area (c) Average direction of blocks (MeanDir)

3 EXPRIMENTAL RESULTS

The proposed algorithm is tested on FVC2002 DB1-A database and the results are reported. The fingerprint classification problem considered as a four-class problem, because fingerprint classes A (arch) and T (tented arch) have a substantial overlap, and it is very difficult to separate these two classes. The FVC2002 DB1-A database consists of 800 fingerprint images with size of 388×374 (500 dpi).

Table 2 shows the confusion matrix of our proposed method classification results on FVC2002 database and Table 3 shows the confusion matrix of [7] classification result on the same images. There are 35 left/right loop fingerprints that are misclassified by [7] that at least 24 of them have one core. In our rule-based classification algorithm, a new feature named MeanDir is used to separate left loop ad right loop classes. With this feature, just two images are misclassified by our algorithm (Figure 7). As we can see, the proposed approach has much better precision than [7]. Selection of neighborhood area and blocks size proved to be accurate by experiment.

Table 4 shows the comparison of our system performance with some other similar systems using FVC2002 DB1-A database. All of these systems used four class classification and the same database. The results show our system better performance over all the compared systems.

Figure 7. Two samples of one core images of FVC2002 that are misclassified by the proposed rule

Table 2. The confusion matrix of the proposed system classification result

Actual Class	Classified As: A	CT	LL	RL	UN	TOT
A	88	00	00	01	02	91
CT	00	90	01	02	00	93
LL	01	00	122	01	01	125
RL	01	00	01	119	01	122
Acc.	97.21					

Table 3. The confusion matrix of [7] classification result

Actual Class	Classified As: A	CT	LL	RL	TOT
A	77	01	05	08	91
CT	00	83	05	04	93
LL	02	00	108	15	125
RL	04	02	20	96	122
Acc.	84.5%				

Table 4. Comparison of the proposed system with other similar systems

Ref.	Features & Methods	Accuracy
[7]	Coordinate geometry of singularities	84.5%
[13]	Orientation image and singular points	68%
[14]	Singular point location	91.4%
Proposed System	Singular point and proposed feature	97.21%

4 CONCLUSION

This paper's focus was on rule-based fingerprint classification. This classification approach concentrates on the number and location of singularity points. This paper proposed a very accurate rule-based classification approach. This novel approach is invariant to translation, rotation and scale changes. Also, it can work with any number of possible singular points: none, one and two. For comparison purpose, the rules proposed in [7] has been presented. We showed that the proposed rules for images with one core was not accurate and did not work on many images in FVC2002 database that they used for experiments. Their approach did not covered the images with rotation and transition in FVC2002. Then a very accurate rule for this kind of images has been proposed. The experimental results showed that the proposed method outperforms [7] and others compared methods.

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