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Fingerprint Classification based on Simplified Rule set and Singular Points with an Image Enhancement Scheme

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Abstract— ***A rule-based technique using simplified rules is proposed to overcome the challenges faced by previous fingerprint classification techniques. Two features, namely directional patterns and singular points (SPs), are combined to categorize four fingerprint classes: namely Whorl (W); Loop (L); Arch (A); and Unclassifiable (U). The use of directional patterns has recently received more attention in fingerprint classification. It provides a global representation of a fingerprint, by dividing it into homogeneous orientation partitions. With this technique, We can improve the accuracy of the classification by integrating an image enhancement scheme. In addition, incomplete fingerprints are often not accounted for. The proposed technique achieves an accuracy of 93.33% on the FVC 2002 DB1.***

Index Terms— ***Singular point (SP), Core point, Delta point, Segmentation, Preprocessing.***

I. INTRODUCTION

Biometrics is the automatic identification and verification of an individual based on his or her physiological or behavioural characteristics. The ability to accurately identify or authenticate an individual based on these characteristics has several advantages over traditional means of authentication such as knowledge-based (e.g., password) or token-based (e.g., key) authentication [1]. Due to its security-based applications and the current world political climate, biometrics has recently become the subject of intense research by both private and academic institutions. There are several human characteristics that can be used as the basis for biometric systems [1]. For example, a person's face, retina, or voice can all be used to identify that individual with a high degree of accuracy. The use of fingerprints has several advantages over the other biometric methods, and therefore is one of the most researched and mature fields of authentication and identification. The uniqueness of fingerprints has been studied and it is well established that the probability of two fingerprints matching is too small.

A common use for fingerprints is identification where an individual's fingerprint is compared to all the fingerprints in a database [2]. For very large fingerprint databases, the identification process typically has an unacceptably long computational time. Reducing the number of comparisons that are performed improves the speed of the fingerprint identification process. Exclusive fingerprint classification is a common strategy used to achieve this. Furthermore, fingerprint systems are also relatively low cost and more accepted by the general public, as opposed to veins, hand geometry, palm prints and iris systems. Exclusive fingerprint classification is a common strategy used to achieve this [2]. Each subset of the database contains a specific type of pattern which is referred to as a class of a fingerprint. The Whorl (W), Loop (L), Arch (A) classes shown in Figure 1 are the most commonly used with occurrence probabilities of approximately 0.279, 0.317 and 0.029, respectively [3]. The common classes can be easily identified by observing the entire structure of the fingerprint through the use of global features.

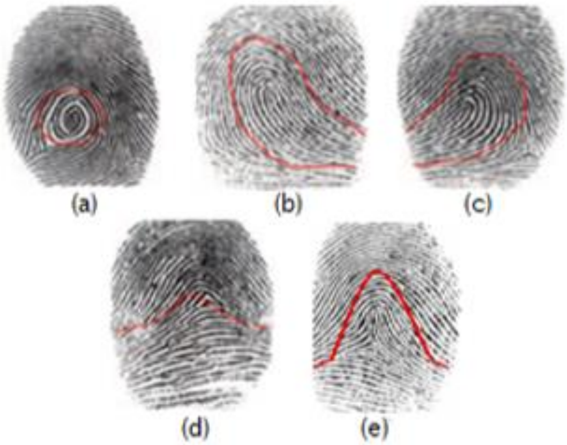

Figure 1. The common fingerprint classes, namely (a) Whorl (W),(b) &(c) Loop (L),(d) &(e) Arch (A) [4]

One of the most fundamental and important global features in almost all aspects of fingerprint processing, especially in classification, are fingerprint ridge orientation [5]. This is due to the fact that it contains the necessary information required to determine the fingerprint image class.

Due to its high dimensionality and computational cost [3, 6], most practitioners do not use orientation field directly but extract secondary features from these primary features and use these for classification. These are singularity features[4,7],ridge-structure features[8]and structural features [9, 10]. Ridge-structure features contain structural information about the global characteristics of a fingerprint [8], whereas structural features are derived from the relationships between low level elements, namely orientation value and the geometrical relation among regions[3].

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Conversely, singularity features are fingerprint landmarks which are categorized as loops and deltas[4,7],as shown in Figure 2. A loop is defined as the highest region of curvature that is located at the innermost curve of the fingerprint[11]. When ridges tend to triangulate while forming three sectors, it is considered a delta [4, 7]. The number and type of singular points (SPs) can be used to assist in determining the class of the fingerprint image.

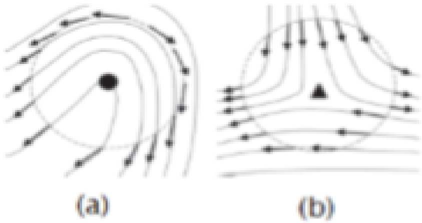

Figure 2. Fingerprint landmarks known as singular points (SPs) namely,(a) loop and (b) delta[7]

In this paper, a more simplified rule-set using singularity features and directional patterns with an image enhancement scheme is proposed to overcome the challenges faced by the complex pattern zones. The following sections present the details of the fingerprint classification system with enhancement scheme. Section 2 introduces the fingerprint classification methods and techniques to obtain singular points and directional patterns with an enhanced image. The details of the methodology are also presented in this section. Section 3 provides the experiments and performance of the proposed method. Conclusions and future works are drawn in Section4.

II. METHODS AND TECHNIQUES

In this section, the Image enhancement stage, Preprocessing stage, Region segmentation to obtain the directional patterns, the Detection and alignment of the SPs, and the Rules for classification are described.

A. Image Enhancement

A fractional differential mask based image enhancement scheme is used here as the image enhancement scheme. This image enhancement scheme is used to improve the clarity of the image. This technique uses the method in [12].

B. Preprocessing

In ideal cases, fingerprint images include the foreground (ridges and valleys) and the background. Before processing the images, the ridges and valleys must be separated from the background by performing segmentation using the method in [13].

C. Region Segmentation

The orientation field is computed using the method described in [14] and stored in a matrix Orient(r,c). The orientation axis is in the lower two quadrants, with 0 on the right axis and π on the left axis, moving clockwise. To reduce noise found in the image Smoothing is applied to the orientation field. The orientation fields are then grouped into three ranges. An example is shown in Figure 3. Equations 1 to 3 are formulae used to obtain the directional pattern. The region is discriminated using the step4 calculated in Equation1,where n is the number of regions. For this paper, n is equal to three.

$$\Delta\phi = \pi / n \qquad (1)$$

The range of each region can be calculated using Equation 2, where i = 1...n.

$$Range_i = [(i-1)* \Delta\phi]:[i* \Delta\phi] \qquad (2)$$

The region number as shown in Figure 3 at position (r,c) can be obtained from Equation 3, where Orient is the orientation value at position (r,c).

$$Region_{num}(r,c)=\lceil Orient(r,c)/ \Delta\phi \rceil \qquad (3)$$

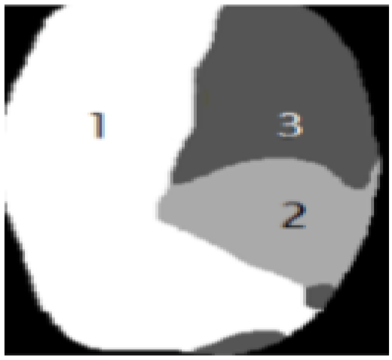

Figure 3. Regions of the directional pattern for three orientation ranges [15]

D. Singular point Detection

In a directional pattern of a fingerprint, the point of intersection between all three regions are known as SP. Loops and deltas are identified by the direction in which the regions change from 1st region to 3rd region. As shown in Figure 4, regions which change in an anti-clockwise direction are loops and regions which change in a clockwise direction are deltas[15].

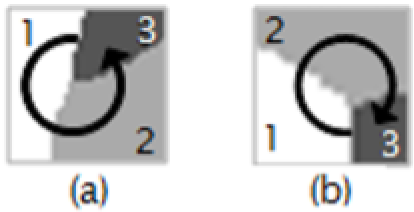

Figure 4. Patterns of (a) loop and (b)delta[15]

Directional patterns of a fingerprint image can vary when the image is rotated. To maintain consistency and a Simplified rule set, the image is rotated accordingly after locating Singular Points. When a single loop and delta are detected, the angle between the loop and delta is obtained and the pattern is rotated in such a way that the SPs are vertically aligned forming 180^0. When there is only one loop then the angle of the loop is rotated by θ to achieve a loop direction of 90^0. Since even a 5^0 rotation can change the directional pattern, the accuracy of the loop direction is very important.

The Balance Arm Flow method by Guoetal. [7] is used to track the points along Balance Arm, to determine the loop direction.

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The Balance Arm is defined as the innermost ridge line, which enters the fingerprint, curves and exits the fingerprint.

E. Rules for Classification

The proposed fingerprint classification algorithm is derived from the directional patterns of a fingerprint and the number of SPs found. Table 1 shows the initial coarse classification that can be achieved using the number and type of SPs for each class[15].

Table1. Summary of the number of SPs for a specific class.

Type of Class	No. of Deltas	No. of Loops
W	2	2
A	0	0
L	1	1

III. EXPERIMENTAL RESULT

Matlab is used to implement the proposed fingerprint classification technique. To illustrate the accuracy of the proposed method described in the previous section, fingerprint images from the Fingerprint Verification Competition (FVC) 2002 [16] and 2004 database (DB) 1 [17] were used. Each database contains a total of 880 optical scanner fingerprint images consisting of eight impressions of 110 fingers. The reason for selecting the FVC datasets, was that they contain flat fingerprints which often contain missing SPs and can therefore be used to test the algorithm's rule for incomplete fingerprints[15].

In some cases the orientation field is distorted by extreme causes of noise, resulting in a loss or an addition in the amounts of regions in a directional pattern. Since these errors are related to extraction of orientation field and not the fingerprint classification method, these fingerprint images have been excluded to provide a more accurate indication of the classification's accuracy level. Therefore, the FVC 2002 DB1 were reduced to 75 images.

The algorithm yields high accuracy in terms of the number of correctly classified images. Most of the errors are due to the small interclass variability between Loop-type fingerprint classes and Arch-type fingerprint, which is a common problem in all classification schemes. The loss of the fingerprint edge because of the presence of noise makes it difficult to differentiate these classes. Another cause of error is between a single loop W and Loop-type fingerprint, where the SP lies too close to the edge of the image. However, these errors are small and the proposed scheme achieves a high accuracy of 93.33% on the FVC 2002 DB1. The current method outperforms the implemented algorithms, as shown in Table 2.

Table 2. Accuracy results of the proposed algorithm compared to algorithms in the literature.

Author	Database	Average Accuracy	No. of Classes
KaruandJain[18]	FVC2002DB1,2004DB1	51.50%	5
Msizaetal.[4]	FVC2002DB1,2004DB1	70.08%	5
Jung&Lee[19]	FVC2002DB1,2004DB1	80.1%	4
Guoetal.[7]	FVC2002DB1,2004DB1&DB2	92.7%	4
Webb and Mmamolatelo[20]	FVC2002DB1,2004DB1	91.45%	5
Kribashnee Dorasamy[15]	FVC2002DB1,2004DB1	92.54%	5
Proposed Method	**FVC2002DB1,2004DB1**	**93.33%**	**4**

IV. CONCLUSION

A novel fingerprint classification method has been presented based on Simplified rules using directional patterns and SPs with an image enhancement scheme. Accuracies achieved, 93.33% on the FVC 2002 DB1 , out- perform methods found in the literature. It was found that the directional patterns are more important in determining the fingerprint class, as they characterize classes globally and therefore are less sensitive to distortion of ridges in the fingerprint. The two challenges faced are the small interclass variability between Arch and, Loop classes, and noisy Whorl images with a single loop. Since the method is complex and requires extensive image enhancement techniques to improve the system's accuracy, we use an image enhancement scheme for better results. For future works, rules for incomplete fingerprints can be extended on, since the method thus far does show potential in addressing fingerprints with missing singular points.

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