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Fingerprint classification technique using gradient-based method for singular points detection

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Abstract*—The recent advances in technology caused increased of fingerprint recognition systems uses. To identify or verify the people, usually the fingerprint recognition systems composed of a huge database that contains a large number of Fingerprints. Fingerprint classification is the efficient technique used to improve the performance of fingerprint recognition systems by reducing mathematical complexity as it reduces the response time of the system. This paper proposed a fingerprint classification technique. A rule based classifier used to classify fingerprints based on singular points detection. The orientation field estimation using Prewitt operator in gradient computing was applied with the classifier. In this study, the conducted experimental used the Fingerprint Verification Competition (FVC 2004) database (Set B) with 320 fingerprint images. The results showed that the maximum accuracy achieved was 53.75% and the minimum accuracy achieved was 16.25%.

***Keywords*: Fingerprint classification, Singular Points Detection, Prewitt Operator, Rule Based Classifier, FVC2004 database..**

I. INTRODUCTION

Fingerprint recognition system (FPRS) is one of the most popular biometrics systems [1], Fingerprint recognition systems use to prove the identity or verifies of the person based on the fingerprint. FPRS has usually contained the database, composed a large number of fingerprint images, it is very significant that FPRS produces the results with less execution time. This is called computation time. Fingerprint classification is very important in any fingerprint recognition system that has a huge database. A huge fingerprint database will be long response time, which is not desirable for real time applications. Hence in order to reduce number of comparisons fingerprint classification is used. Fingerprint classification provides an important indexing mechanism in a fingerprint database. Through classifying a fingerprint image into one of the existing predefined classes. This will be followed by reduce search time and computation complexity of a fingerprint recognition system by reduces comparisons of fingerprint in database.

There are many classification systems used to classify fingerprints, the famous classification system is the Henry classification system, which includes five fingerprint classes; Arch, Tented Arch, Left Loop, Right Loop, and Whorl. Each class contains Singular Points (SPs), SPs are defined as the locations in the fingerprint with the greatest ridge orientation variance as defined [2], SPs known as cores and deltas. The Fingerprint images are classified into classes according to the SP [3].

In this paper, we introduce a technique for fingerprint classification based on gradient method for orientation field estimation algorithm. This paper has been organized as follows. Section II provides a literature survey on fingerprint classification methods. Section III introduces the proposed technique. Section IV explains the requirements for fingerprint classification technique experimentation. Section V displays the experimental evaluation discussion for experiments, section VI present the conclusion, finally VII present future work directions.

II. LITERAURE SURVEY

Several theories have been proposed to fingerprint classification approaches, some focusing on the classification stage, others on the Feature Extraction stage, the performance of a fingerprint classification system is based on the extracted features from the fingerprint image. Many approaches have been designed for fingerprint classification stage. Mridula (2014) refers to these approaches; Statistical approaches (Rule-based approach), Structure-based, Syntactic or grammar-based and Neural network-based [4]. Most previous studies, as well as current work, focus on using Statistical approaches based on singular points using.

Alshemmary (2012) describes the interest in neural networks in recent years has caught the attention of those involved to use the neural network approach in fingerprint classification, then she proposed her approach to classification fingerprint based on singular point based neural network approach[5]. The results achieved intermediate performance on fingerprint classification adopting a neural network for the poor quality of fingerprint images.

Chua, Wong and Tan (2015) present a fingerprint singular point detection algorithm and a rule-based fingerprint classification method, uses a quantization

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approach on the orientation field of the fingerprint image and seeks to locate the core and delta points via the changes of the gray levels around a 2x2 window. The accuracy rate was between 86.5% and 92.15% for four and five class on NIST images [6]. Furthermore, the next studies focus on reviews the literature related to fingerprint classification as presented in [7], [8], [9], [10], and [2]. Hadi (2018) used support vector machines(SVMs) technique for fingerprint classification, Sobel operator used for gradient computed in orientation field estimation, the experimental resulted shows that classification accuracy for SVM is 97.6 for 5 classes in NIST database and 97.6% for another database composed of 100 people, also, they compare classification classifier for the same databases by apply K Nearest Neighbors (KNN), it has given an accuracy of 82.2% for five classes,79.75% for four classes, KNN do not perform good classification by comparing it with SVM, because of learning and training phase is very fast which cannot be powerful to noise[11].

Jan and Ali (2018) proposed method applies the Gabor filter to enhance the image, Haar and Daubechies wavelet transformations are used to extract the global features of the fingerprint image, and a multilevel neural network for classification, the experimental resulted shows that classification accuracy for FVC2006 is only 87% for 4-category problem on the same data-base when images are of good quality, but when applied to images of poor quality the accuracy is less than 30%[12].Table I shows comparative study between works for fingerprint classification.

Finally, most of the authors in previous studies, classified fingerprints into five classes (Arch, Tented Arch, Left Loop, Right Loop and Whorl).

Table I. Datasets and fingerprint classes

Paper	Classifier Used	Classes	Dataset Used	Accuracy
(Alshemmary, 2012)	Backprobagation Neural Network	5 Class 4 Class	NIST databases	92.7% 95.9%
(Chua, Wong, & Tan, 2015)	Rule Based Technique	5 Class 4 Class	NIST-4	86.5% 92.15%
(Maheswari & Chandra, 2012), (Mathuria & Cotia, 2013), (Abbood & Sulong, 2014), (Mridula, 2014), (Galar et al., 2015)	Reviews the literature related to fingerprint classification			
(Hadi, 2018)	Support Vector Machines (SVMs)	5 Class 4 Class	(NIST SD4)	97%, 97.6%
[12]	Multilevel Neural Network	5 Class 4 Class	FVC2006	87% less than 30%(poor quality)

III. THE PROPOSAL MODEL

As shown in Fig. 1 the proposal model is divided into five steps. The first step: to enhance the effect of sensor and gray level background by make the level values lie within a given set of values. The second step: to extract the region of interest (ROI), mean and variance is used to segmentation. The Third step: to compute orientation field estimation by apply Prewitt operator in gradient compute. The fourth step: to singular point detection by applies Poincare index algorithm. The full details of the four steps are presented in [13]. Finally, the fifth step: to classify fingerprint classes based on the number and location of singular points by apply Rule based classifier.

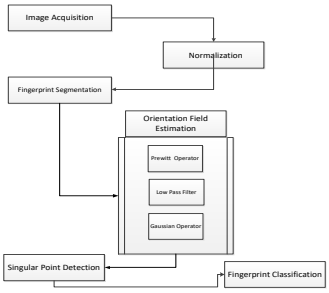

Figure 1. The proposal model for fingerprint classification

Rule-based classifier uses a set of conditional sentences rules for classification. The rule based approach codifies the human expert knowledge of manual classification as describe [10]. In this study, the fingerprints classified into five classes (Arch, Tented Arch, Left Loop, Right Loop and Whorl). The classification rules and the main steps in Rule-based of this study are following:

1. If the number of core points (Nc) =2 or the number of delta points (Nd) =2 then the class of fingerprint is whorl.
2. If the number of cores points (Nc) =0, and no delta points (Nd =0) then the class of fingerprint is arch.
3. If the number of core point (Nc)=1, and the number of delta point (Nd) =1:
    a. If the core point found at the left of the delta point, then the class of fingerprint is Left Loop.
    b. If the core point found at the right of the delta point, then the class of fingerprint is Right Loop.
    c. If core and delta are vertical aligned, then the class of fingerprint is Tented Arch.
4. If none of above, then the fingerprint image is considered not classified.

IV. EXPERIMENATATION

Fingerprint Verification Competition (FVC 2004) database (Set B) was used in the fingerprint classification experiments of this study. FVC2004 is consists of 320 fingerprint images divided into four datasets (DB1, DB2, DB3 and DB4) [14]. The graphical user interface is implemented. Fig. 2 shows the screen shout of the graphical user interface of the fingerprint classification system.

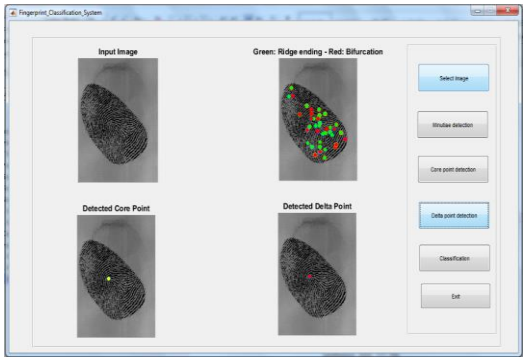

Figure 2. The graphical user interface for fingerprint classification system

V. THE RESULTES

The fingerprint classifier performance is based on classify fingerprints into following classes; Left Loop, Right Loop, Arch, Tented Arch, and Whorl. The rule-based classifier based on the number and location of the extracted singular points used to classify fingerprints. The images in the database were categorized manually to ensure the correct results of the classification. Table II shows the results of the manual classification results of the fingerprint images in database. Every number in the table represents the number of people who have a particular type of fingerprint classes. Everyone has (8) different samples from his/her fingerprint. Thus, the number of different fingerprints in database is (40), and the number of the fingerprint images is 320.

Table II. Datasets and fingerprint classes

Data Set	Left Loop Class	Right Loop Class	Arch Class	Tented Arch	Whorl Class
DB1	5	2	1	0	2
DB2	2	5	0	0	3
DB3	2	1	0	0	7
DB4	4	4	0	1	1
Total	13	12	1	1	13

Determining the fingerprint class based on the classification rules that depend on the detection of the core points and delta points in every fingerprint image. Table III shows the results of singular points detection for the different fingerprint classes. It shows the number of (correct detected, forged detected, and non-detected) of core points and delta points for every fingerprint class. The forged detected case of the core point or delta point, means that the SPs is detected in the wrong place, while the non-detected case means that the core point or delta point is missing in the fingerprint image.

Table III. The number of detected and not detected SPs of Fingerprint Classes

Data Set	SPs	Detected		Non Detected
		Correct Detection	Forged Detection	
Left Loop	Core Point	90	13	1
	Delta Point	44	28	32
Right Loop	Core Point	77	18	1
	Delta Point	16	40	40
Arch	Core Point	0	3	5
	Delta Point	0	3	5
Tented Arch	Core Point	8	0	0
	Delta Point	7	1	0
Whorl	Core Point	78	25	1
	Delta Point	24	66	14

The performance of a fingerprint classifier is usually measured from confusion matrix. A confusion matrix simply is a table that summarizes the findings of fingerprint classifications into actual classes and predicts classes. Table IV presents the confusion matrix of a fingerprint classification system for all datasets in FVC2004 database.

Table IV. The confusion matrix for FVC2004 Set (B)

Actual Class	Assigned Class							
	Class	Actual Number	Left Loop	Right Loop	Arch	Tented Arch	Whorl	Not Classified
	Left Loop	104	59	10	0	2	0	33
	Right Loop	96	20	30	1	5	0	40
	Arch	8	1	2	5	0	0	0
	Tented Arch	8	2	0	0	6	0	0
	Whorl	104	24	40	1	12	13	14

Fig.3 illustrates the accuracy of fingerprint class's results showed in table IV. It can be observed that Tented Arch class has the highest accuracy among all classes by 75%, then Arch class accuracy by 62.5%. The Right loop class accuracy recorded 31.25%. The low in the accuracy is resulted due to the large number of forged detected and non-detected of delta points. The Whorl class recorded the lowest accuracy by 12.50% due to the large number of forged detected of core and delta points in this class.

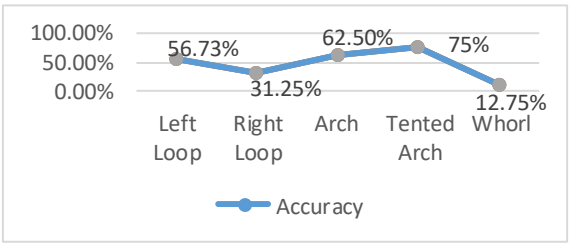

Figure 3. Accuracy for fingerprint classes for FVC2004 Set (B)

Table V shows the accuracy results for each datasets in the database.

Table V. Accuracy results for DB1, DB2, DB3 and DB4

Data set	DB1	DB2	DB3	DB4
Accuracy	33.75%	37.5%	16.25%	53.75%

From table V, DB4 achieves highest accuracy by 53.75%, this is attributed to the high quality of the fingerprint images in this dataset, it considered a good compared to the rest of the datasets. DB3 present the lowest accuracy for fingerprint classification by 16.25% due to the low quality of the fingerprint images in this dataset.

VI. CONCLUSION

This paper presents an experimental study for fingerprint classification technique to classify fingerprint classes based on singular points detection. In this study, the Prewitt operator was used to compute gradient in orientation felid to detection the singular points (core and delta).

The results show low accuracy in some datasets due to the low-quality fingerprint images in FVC 2004. The low-quality fingerprint images led to a decrease in the performance of the fingerprint classification. The fingerprint classification technology failed with very poor-quality images as shown in Table III. The inaccurate classification is due to the forged detection and non-detection of Singular points. From these results it is clear that the main limitation is the lack of SPs in fingerprint images, especially delta points.

VII. THE FUTURE OF WORK

It is very important to conduct experiments to measure the influence of the fingerprint images quality on fingerprint classification that based on singular points detection.

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