A HYBRID FUSION METHOD OF FINGERPRINT IDENTIFICATION FOR HIGH SECURITY APPLICATIONS

Yilong Yin, Yanbin Ning, Zhiguo Yang

School of Computer Science and Technology
Shandong University, Jinan 250101, China
ylyin@sdu.edu.cn , ningyanbin009@163.com , yzhgdd@163.com

ABSTRACT

Though fingerprint identification is widely used now, its imperfect performance for some high security applications, such as ATM, the access control of nuclear power stations and exchequers, etc, is still a challenge. In high security applications, an extremely low false accept rate and as low as possible false reject rate are desired at the same time, which is called Double Low problem in this paper. It is to be noted that even a fingerprint system with very low equal error rate can not achieve such a Double Low goal. It is difficult to solve Double Low problem only by improving the performance of a certain individual fingerprint identification algorithm, and the fusion of various fingerprint identification algorithms becomes a promising way. In this paper, a hybrid fusion method of fingerprint identification is proposed to solve Double Low problem. Firstly, minutiae-based and ridge-based matching algorithms are used orderly, which is a kind of serial fusion strategy. Secondly, a rank-level fusion is used, which is a kind of parallel fusion strategy. Experiment results on FVC2002DB1 and FVC2002DB2 indicate that only 6.6% fingerprints are falsely rejected on the average under zero false accept rate with our method, while 14.8%, 9.4% fingerprints are falsely rejected under zero false accept rate with the serial fusion strategy and the parallel fusion strategy, respectively.

Index Terms—fingerprint identification, hybrid fusion, serial fusion, parallel fusion, high security application

1. INTRODUCTION AND MOTIVATION

During the recent years, fingerprint identification has received more and more attention and been widely used in various fields due to its university, distinctiveness, permanence and acceptability [1].

Efforts for fingerprint identification are mainly focused on: (i) Improving the performance of one or more steps of automatic fingerprint verification system. The steps include segmentation, enhancement and matching, etc. (ii) Using multiple sources of a fingerprint to get a higher accuracy. These sources include multiple sensors, multiple features, multiple matchers, multiple fingers, multiple impressions of a same finger, etc. (iii) Combining fingerprint with other biometrics traits to construct a more robust and effective biometrics system. These efforts mainly aim to decrease equal error rate (EER) of a biometrics system and can indeed improve the performance of identification.

EER is used as the most important parameter to evaluate the performance of a fingerprint system now and it can indicate the general performance of a fingerprint system fairly well. A very low EER usually denotes that a fingerprint system has very high performance [2, 3].

However, it is not always suitable to mainly use EER to evaluate the performance of a fingerprint system. Some high security applications, such as ATM, the access control of nuclear power stations and exchequers [4, 5], etc, have special demands to the performance of a fingerprint system. In these applications, if an authentic person is mistakenly rejected, it just is troublesome. While, if an impostor is mistakenly accepted, it may be a disaster. Two kinds of errors will cause different amount of losses. The second error is far more serious than the first one. It is a cost-sensitive problem in fact. To meet the demand of such high security applications, an extremely **low** false accept rate (FAR) and as **low** as possible false reject rate (FRR) are desired at the same time, which is called **Double Low** problem in this paper.

Even a fingerprint system with a very low EER could not achieve such a Double Low goal. A system with low EER might have a bad performance in high security applications for its FRR will rise acutely when its FAR becomes very low. For example, to a minutiae-based fingerprint system with EER of 2.7 %, its FRR can reach 15.8% when its FAR is zero on FVC2002DB2! This can not meet the demand of high security applications obviously.

Fig.1 shows a ROC curve of a fingerprint system. Unlike common applications, only the part of ROC curve in the shadow is concerned for high security applications.

In fact, Double Low problem exists all the time and has important applications. However, we pay little attention to it and few efforts are taken about it until now.

It is difficult to solve Double Low problem only by improving the performance of a certain individual fingerprint identification algorithm for the limitation of techniques, and fusion of various fingerprint identification algorithms becomes a promising way.

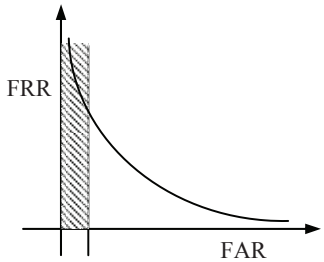

Fig. 1. ROC curve.

To solve Double Low problem, a hybrid fusion method is proposed and two popular fingerprint matching algorithms, minutiae-based algorithm and ridge-based algorithm [3], are used in this paper.

2. THE PROPOSED HYBRID FUSION METHOD

The framework of the proposed method is shown in Fig. 2.

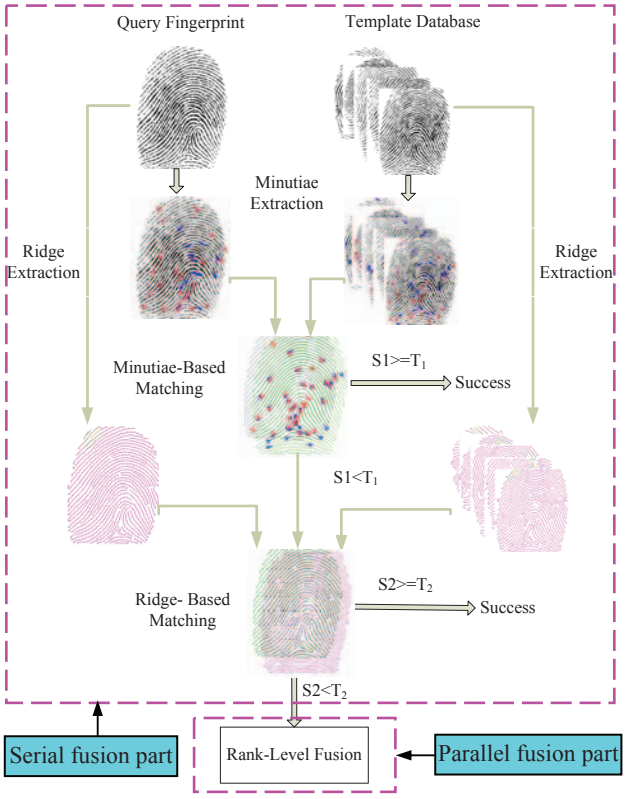

Fig. 2. Framework of the proposed hybrid fusion method.

As shown in Fig. 2, the proposed hybrid fusion method consists of two parts. The first part is a serial fusion in which minutiae-based matching algorithm and ridge-based matching algorithm are used orderly. The second part is a rank-level parallel fusion which fuse the two matching algorithms. Firstly minutiae features are extracted after a query fingerprint image is acquired. Then minutiae-based matching is used to match the query fingerprint with all fingerprints in the template database and multiple matching scores are acquired. The maximum matching score is compared with a threshold T_1. The identification is successful if the maximum score is higher than T_1. Otherwise, we will deal with the query fingerprint with ridge-based matching algorithm. In the same way, the identification is successful if the maximum matching score is higher than another threshold T_2. Otherwise, we identify the query fingerprint with rank-level fusion method. In this part, for every query fingerprint, the minutiae-based matching score and the ridge-based matching score are all required. The results of identification are obtained according to the rule of rank-level fusion. The following is detailed descriptions of the two fingerprint matching algorithms and the rule of rank-level fusion used in the proposed hybrid fusion method.

2.1. Minutiae-based matching algorithm

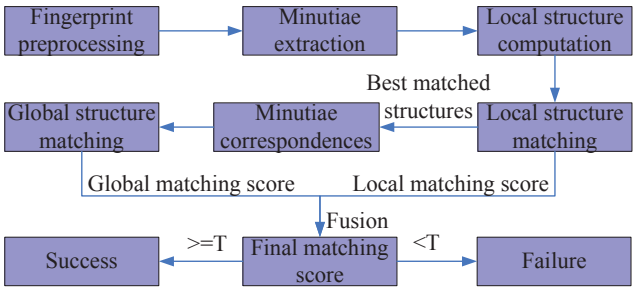

Fig.3. Framework of minutiae-based matching algorithm.

There are already some minutiae-based matching algorithms. In our proposed hybrid fusion method, we choose a typical minutiae-based matching algorithm which matches the fingerprint minutiae using both the local and global structures of minutiae [6], whose framework is shown in Fig. 3. The local structure of a minutia is rotation and translation invariant because it consists of the direction and location relative to some other minutiae. It is used to find the correspondence of two minutiae sets and to increase the reliability of the global matching. Moreover, the local structure can tolerate some deformation because it is formed from only a small area of the fingerprint. So the local structures can be directly used for matching and the best matched local structures will provide the correspondences for aligning the global structure of the minutiae. The global structure of minutiae reliably determines the uniqueness of fingerprint. The aligned global structure together with the result of the local structure matching finally determines whether the two fingerprints are acquired from the same

finger. Therefore, the local and global structures of minutiae together provide a solid basis for reliable and robust minutiae matching.

2.2. Ridge-based matching algorithm

The ridge-based algorithm [7] chosen in this paper consists of three stages: preprocessing, alignment and matching, whose framework is shown in Fig. 4. In the preprocessing stage, ridges are extracted by sampling equidistantly from the thinned image. The relations between ridges and minutiae are established. In the alignment stage, a set of N initial substructure pairs is found using a novel approach. In the matching stage, for each of the N initial substructure pairs, ridge matching is performed to produce a matching score. Finally, the maximum of the N scores is used as the final matching score of the two fingerprints. The alignment algorithm focuses on how to choose a reliable local feature pair as the datum mark of matching. This is accomplished firstly by defining a substructure that contains as much local information (one minutia and several ridges) as possible, and secondly by finding the substructure pair which have the most consistent substructure pairs around. In the matching algorithm, during the process of ridge matching, minutiae are also paired, and the matching score is computed according to both the matched minutiae and the matched ridges.

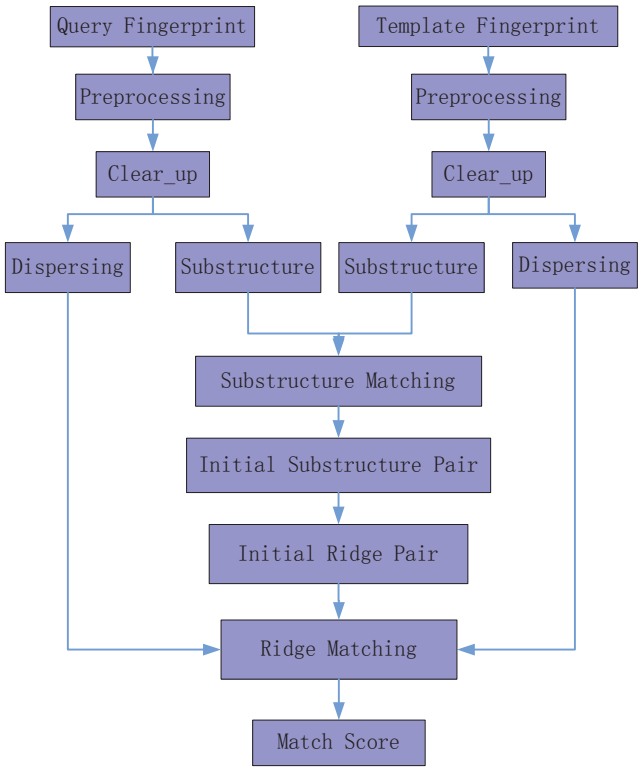

Fig.4. Framework of ridge-based matching algorithm.

2.3. Rank-level fusion

Unlike a fingerprint verification system, a fingerprint identification system typically outputs a ranking or a candidate list instead of a match score or a Boolean value. So, the rank 1 template fingerprint is more similar with the query fingerprint than the rank 2 template fingerprint, and so forth. Rank-level fusion [8] is a kind of parallel fusion and is used when the output of matchers is the rank of the "candidates" in a template database. This kind of method is expected to assign a higher rank to a template fingerprint that is more similar to the query fingerprint. The goal of rank-level fusion method is to combine ranks assigned by various fingerprint matchers to derive an "integrative" rank for each identity. There are three rules usually used to combine ranks assigned by different matchers, namely, the highest rank rule, the Borda count rule, and the logistic regression rule. However, the above three rank fusion rules are relatively loose and they are unsuitable for applications of high security because the demand of Double Low is very strict. Therefore in this paper, we increase the restricting condition of fusion and use a far more rigorous rank fusion rule with which the query fingerprint is regarded to be successfully identified only when its identities corresponding with the highest rank of different matchers are same. As to two matchers of minutiae-based and ridge-based used in this paper, the rule can be called the double highest rank fusion.

3. EXPERIMENT RESULTS

In this section, we design an experiment to testify the effect of the proposed method for the high security applications. We select two fingerprint databases, namely, FVC2002DB1 and FVC2002DB2, used in this experiment. In each selected fingerprint database above, there are one hundred fingers and eight hundred fingerprint images, and every finger corresponds to eight fingerprint images. We select one image of each finger to constitute the template database and the other seven images to constitute the query database for above two selected databases. As to each selected fingerprint database, the template database has one hundred fingerprints and the query database has seven hundred fingerprints. We do the experiment with two individual methods, two fusion methods and the proposed hybrid fusion method on template databases and query databases. The detailed explanation of the front four methods is as follows:

(i)Two individual methods: One is the minutiae-based matching algorithm and the other is the ridge-based matching algorithm. They are called individual method 1 and individual method 2 in this paper, respectively.

(ii)Two fusion methods: One is the serial fusion method of the minutiae-based matching algorithm and the ridge-based matching algorithm, and the other is the rank-level parallel fusion method of the two individual methods. They

are called fusion method 1 and fusion method 2 in this paper, respectively.

Extremely low FAR is a relative and theoretical conception. For the sake of comparing the performance of above five methods quantificationally, a certain reference value of FAR must be fixed above all. We select zero FAR as a datum mark to compare the performance of above five methods. So the threshold T_1 and T_2 are the minimum thresholds to assure zero FAR for minutiae-based matching algorithm and ridge-based matching algorithm respectively. Experiment results are given in table 1.

Database	The individual method 1	The individual method 2	The fusion method 1	The fusion method 2		The hybrid fusion method	
	FRR	FRR	FRR	FRR	FAR	FRR	FAR
FVC2002DB1	22.9%	56.1%	17.6%	12.1%	0	8.3%	0
FVC2002DB2	15.8%	47.4%	12.0%	6.7%	0	5.0%	0
Total	19.1%	51.8%	14.8%	9.4%	0	6.6%	0

Table 1. The performance of five methods.

As shown in Table 1, using the individual method 1 and individual method 2, 19.1%, 51.8% fingerprints are falsely rejected under zero FAR on the average on FVC2002DB1 and FVC2002DB2, respectively. Using the fusion method 1 and the fusion method 2, 14.8%, 9.4% fingerprints are falsely rejected under zero FAR, respectively. Using the proposed hybrid fusion method, only 6.6% fingerprints are falsely rejected under zero FAR.

Though FARs of five methods in Table 1 are all zero, it is to be noted that, for the individual method 1, the individual method 2 and the fusion method 1, thresholds T1 and T2 themselves are selected under zero FAR, while for the fusion method 2 and the proposed method, zero FARs and FRRs of 9.4% and 6.6% are practically acquired by the rigorous fusion rule, respectively. The uniform precondition of zero FARs for five methods makes it feasible to compare their performances.

4. CONCLUSIONS AND FUTURE WORKS

In this paper, Double Low problem is illustrated and its characteristics are analyzed. A hybrid fusion method is proposed and its implementation is described. Experimental results indicate that the proposed hybrid fusion method has better performance than existed methods and it can solve Double Low problem to some degree. We consider that the proposed hybrid fusion method can not only be used to fuse different fingerprint identification methods but also can be used as a framework to fuse different biometrics to achieve Double Low goal. It has considerable value for high security applications in biometrics field.

Future work will focus on two aspects. One is to fuse more different fingerprint algorithms with the proposed hybrid fusion method to solve the Double Low problem more thoroughly for fingerprint identification. The other is to try the proposed hybrid fusion method with different biometrics for high security applications.

5. ACKNOWLEDGEMENTS

This work was supported in part by Shandong Province Natural Science Foundation under No. Z2008G05, Shandong University Independent Innovation Foundation 2009TS034 and 2009TS035.

6. REFERENCES

[1] A. A. Ross, K. Nandakumar, and A. K. Jain, *Handbook of multibiometrics*, Springer-Verlag, New York, 2006.

[2] Jianjiang Feng, "Combining minutiae descriptors for fingerprint matching," *Pattern Recognition*, vol. 41, issue 1, pp. 342-352, 2008.

[3] D. Maltoni, D. Maio, A. K. Jain, and S. Prabhakar, *Handbook of fingerprint recognition*, Springer-Verlag, New York, 2009.G

[4] A. K. Jain , S. Prabhakar, and S. Chen, "Combining multiple matchers for a high security fingerprint verification system," *Pattern Recognition Letters*, vol. 20, issues 11-13, pp. 1371-1379, 1999.

[5] L. Marcialis, and F. Roli, "High security fingerprint verification by perceptron-based fusion of multiple matchers," *Multiple Classifier Systems*, vol. 3077, pp. 364-373, 2004.

[6] X. D. Jiang, and W. Y. Yau, "Fingerprint minutiae matching based on the local and global structures," *15th International Conference on Pattern Recognition*, vol. 2, pp. 1038-1041, 2000.

[7] J. J. Feng, Z. Y. Ouyang, and A. Cai, "Fingerprint matching using ridges," *Pattern Recognition*, vol. 39, issue 11, pp. 2131 - 2140, 2006.

[8] M. M. Monwar, and M. L. Gavrilova, "Multimodal Biometric System Using Rank-Level Fusion Approach," *IEEE Trans. On Sysgtems*, Man And Cybernetics-Part B: Cybernetics, vol. 39, no. 4, pp. 867 - 878, 2009.