FingRF: A Generalized Fingerprints Research Framework

Ali Ismail Awad[1] and Kensuke Baba[2]

[1] Graduate School of Information Science and Electrical Engineering, Kyushu University, Japan
[2] Research and Development Division, Kyushu University Library, Japan
{awad,baba}@soc.ait.kyushu-u.ac.jp

Abstract. Biometrics is an emerging technology for consistent automatic identification and authentication applications. Fingerprint is the dominant trait between different biometrics like iris, retina, and face. Many fingerprint-based algorithms have been individually developed to investigate, build, or enhance different AFIS components such as fingerprint acquisition, pre-processing, features extraction, and matching. The common shortage of these contributions is the missing of complete platform to ensemble all system components to study the impact of developing one component on the others. This paper introduces FingRF as ongoing fingerprint research framework that links all fingerprint system components with some other supporting tools for performance evaluation. FingRF aims to provide a facility for conducting fingerprint research in a reliable environment. Moreover, it can be extended to include both off-line and on-line operational modes. The prototype version of FingRF is targeted to work as a stable research environment, and hence, it may be extended further for other biometrics technologies.

Keywords: Biometrics, Fingerprints, Performance Evaluation, Matlab®.

1 Introduction

Personal identification and authentication have become a crucial need for wide variety of applications such as Electronic Commerce, Remote Banking, and Accessing Heath Care Archives in an electronically connected era. Biometrics uses physiological characteristics such as fingerprint and iris, or behavioral characteristics like voice and gait to determine person identity. It is an emerging technology for accepting or denying the claimed identity. Biometrics overcomes many problems of using traditional techniques such as ID-cards, passwords, or a combination of both for better security. Fingerprint is defined as the ridges and furrows patterns drawn on the tip of the human finger. Due to the full understanding of biological properties, characteristics, and formation of human fingerprint, it has been used extensively for civilian and forensic identification purposes for centuries [1]. It is considered as one of the dominant traits between different biometrics, and it is widely used for personal identification according to

V.V. Das, E. Ariwa, and S.B. Rahayu (Eds.): SPIT 2011, LNICST 62, pp. 1–6, 2012.

its easier accessibility, uniqueness, reliability, and lowcost. Automatic Fingerprint Identification System (AFIS) has six common components or phases, as shown in Fig. 1, these phases are expressed as: acquisition, pre-processing, features extraction, classification, storage in database, and fingerprint matching. Through the last decades, many algorithms have been developed for each system component explained in Fig.1. Different fingerprint sensor technologies are used for capturing small or coarse details of fingerprint images such as capacitive sensors, solid-state-sensors, and thermal sensors [2]. Fingerprint enhancement is the most important step in the pre-processing phase, and it is varying from using spatial domain filtering [3], frequency domain filtering [4], Gabor filters [5], to using wavelet coefficients [6]. Fingerprint classification is the problem of assigning fingerprint image into labeled classes to reduce the total search time inside the large database. Fingerprint classification is still a hot research area, therefore, many classification approaches found in the literature. They can be classified into rule-based [7], Neural Networks [8, 9], Gabor filter [10], and frequency domain [11]. Finally many standard databases are available for research purposes such as NIST-4 [12] and FVC2004 [13].

However, the conducted researches in AFIS have increased the reliability, accuracy, and have overcame many problems to enhance the AFIS system performance, a complete and ensemble research framework was totally missing. Therefore, there was no suitable environment for measuring the overall system performance. Wherefore, some conducted researches have been evaluated individually. As an example, the classification algorithm proposed in [14] is used to classify fingerprints database into five sub-sets to speed up the total matching time. The classification method was consuming (4.8 seconds) for Adaboost learning phase, and (1.6 seconds) for real time classification process. Although, the algorithm achieved high classification accuracy, but the classification time is considered very high comparing to the acquisition time (0.04 to 0.26 seconds) [15], and enhancement time (0.1 seconds). Therefore, an ensemble research framework becomes indispensable requirement for measuring the overall system performance with different algorithms.This paper presents FingRF as ongoing research framework for broadly investigating the overall AFIS system performance in different phases with different algorithms. The contributions of this work are three-folds: Firstly, the conceptual design and the implementations of each module in the AFIS, shown in Fig.1. Secondly, FingRF is going to provide a useful set of tools for performance evaluation and data visualization to accurately measure different algorithms performance on both individual and broad scales. Thirdly, the proposed framework will be used not only for fingerprint, but also it can be extended further to include other biometrics traits. The reminder part of this paper is organized as follows: Section 2 explains the conceptual design of the proposed framework from software engineering point of view. Section 3 explains some system implementations, and it also shows some output results from the implemented prototype version. Finally, conclusions and future work are reported in Section 4.

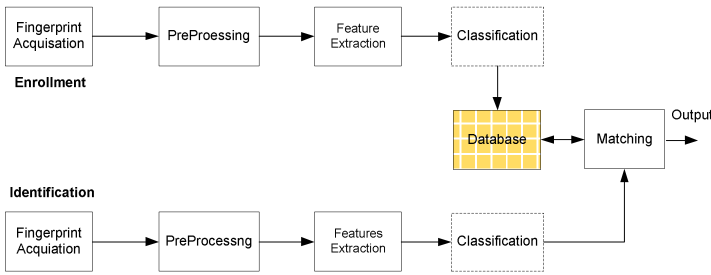

Fig. 1. Common AFIS system components from acquisition to matching

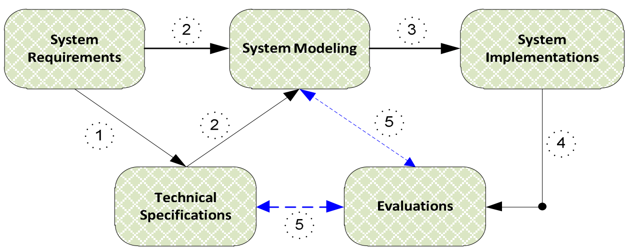

Fig. 2. Conceptual system design from software engineering point of view

2 Conceptual System Design

From software engineering point of view, the conceptual framework design follows five sequential phases including system requirements, technical specification, modeling and design, system implementations, and system evaluations. Fig. 2 shows a block diagram of the conceptual system design phases. A system requirement is a very early stage in the system design. By working on that stage, we have extrapolated that the prototype version of the FingRF should achieve the following requirements:

1. Can be extended for adding different biometrics systems like face
2. Includes common tools for the system performance evaluation
3. Represents all phases of AFIS from acquisition to matching
4. Possibility to add/remove algorithms in the same structure
5. Platform independent as Windows, Linux, and MAC
6. Works on off -line/on-line operational modes.

The above requirements have been translated into technical specifications, and they have also been reflected on the system modeling phase. In order to achieve the above requirements, we have divided every system component into small individual modules which can be easy modified, updated, or replaced without impacting the system architecture. Fig. 3 shows the overall architecture of the proposed framework. Fingerprint acquisition depends on using an Application Programming Interface (API) for reading fingerprint images from different sensors and exports them into the main application via PC connection. The evaluation tool of this stage measures the quality of the captured images, the capturing speed, and reports any capturing failure.

According to Fig.1, AFIS has different types of errors in each system phase. For example, in capturing phase many errors may be generated from the sensor or the user behavior [2]. There are some other parameters to measure the efficiency and the accuracy of the whole AFIS. These parameters are explained as [16]: Genuine Acceptance Rate (GAR) which is the number of samples that have been correctly accepted, False Acceptance Rate (FAR) as the number of samples that have been incorrectly accepted and it should be rejected, False Rejection Rate (FRR) which is the number of falsely rejected samples but it should be accepted, and Equal Error Rate (ERR) is the system point where FAR is equal to FRR. It is worth mentioning that the above parameters are highly related, and they can be tuned to achieve the targeted system performance. Data visualization is a set of tools that automatically reads the output of the performance measurement tools, and show it in an appreciated formats and graphs.

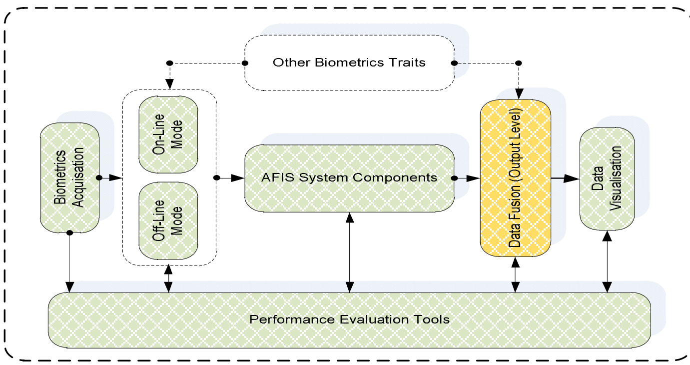

Fig. 3. A global structure of the ongoing FingRF research framework

3 Implementations and Results

The implementation process is going through each module shown in Fig. 3. It is worth mentioning that the other biometric system in the grey block may be included in the future extension of the framework.Singular points (core and delta) are one the most important global characteristics of a fingerprint. Core point is defined as thetopmost point of the innermost curving ridge, and the delta point is the center of triangular regions where three different direction flows meet. Singular points detection is an essential concept of fingerprint recognition and classification. Singular point detection process is sensitive to different conditionssuch as noise, sensor type, and also fingerprints status like dryness and wetness levels. Driven from the former definitions, complex filters [17] is a proposed method to extract regions with high orientation changes using first order complex filter.Complex filter with Gaussian window has been applied on the complex directional image to extract the symmetry singular points from fingerprint images.The main steps of the complex filter implementations are: orientation field estimation, complex filter construction and the convolution between both complex filter and directional image. In order to speed up the total consumed time, convolution process has been performed in frequency domain with great investment of the separable Gaussian window. Some implementations of the complex filter have been expressed in [18]. Fig. 4 shows sample results of the prototype implementation of the singular point detection module. Fig. 4 points out seven different graphs including: main widow, input image, spatial domain representation of the complex filter, shifted frequency domain representation, absolute filter response, the localized singular point, and the otal consumed time.

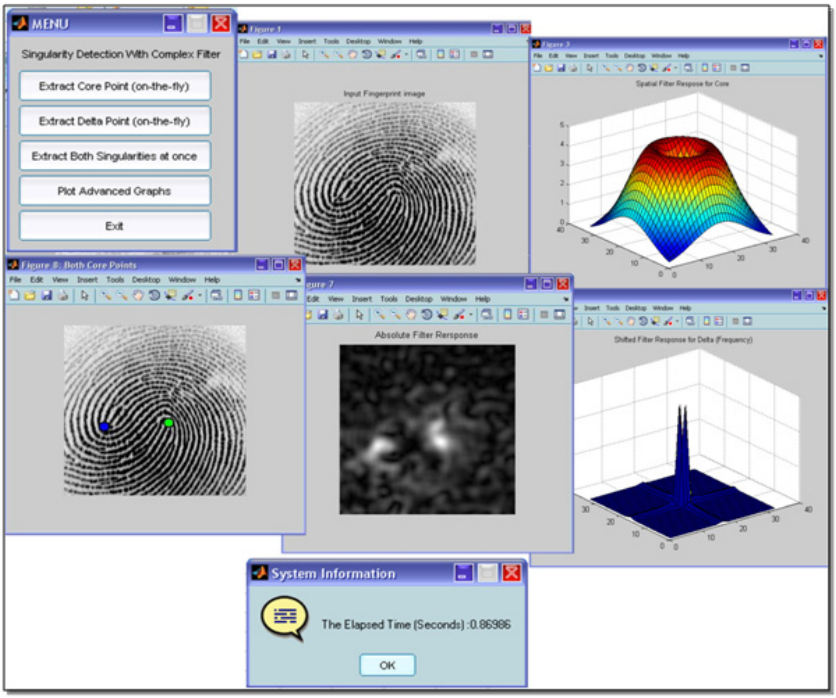

Fig. 4. Screenshots from running singular points detection module

4 Conclusions and Future Work

In order to fairly evaluate and compare different methods or algorithms in the fingerprint research area, we need to conduct the evaluation process in a unique environment. This paper introduced the design of FingRF as ongoing fingerprint research framework for creating a unique environment for the purpose of testing and evaluation of different research algorithms in AFIS. The contributions of this work are three-folds: firstly, the design of overall architecture of the framework, and the conceptual design of each individual component; secondly, in details implementations of the prototype version of framework and producing acceptable results; thirdly, the possibility to extend the FingRF to include different biometrics traits. Moreover, FingRF can be further developed to use Parallel Processing and Graphical Processing Unit (GPU) facilities that are available in the commodity personal computers to increase the research framework reliability and efficiency.

References

1. Yager, N., Amin, A.: Fingerprint classification: a review. Pattern Analysis & Applications 7, 77–93 (2004)
2. Maltoni, D., Maio, D., Jain, A.K., Prabhakar, S.: Handbook of fingerprint recognition. Springer (2009)
3. Khan, M.A.U., Khan, M.K., Khan, M.A.: Fingerprint image enhancement using decimation-free directional filter bank. Asian Network for Scientific Information, Information Technology Journal 4, 16–20 (2005)
4. Chikkerur, S., Cartwright, A.N., Govindaraju, V.: Fingerprint enhancement using STFT analysis. Pattern Recognition 40, 198–211 (2007)
5. Yang, J., Liu, L., Jiang, T., Fan, Y.: A modified Gabor filter design method for fingerprint image enhancement. Pattern Recognition Letters 24, 1805–1817 (2003)
6. Awad, A.I., Abd Allah, M.M., Ali, M.M.: Fingerprint image enhancement algorithm based on wavelet filters. In: Proceedings of the Al Azhar Engineering Ninth International Conference, pp. 100–113. Al Azhar University, Cairo (2007)
7. Klimanee, C., Nguyen, D.T.: Classification of fingerprints using singular points and their principal axes. In: Proceedings of the IEEE International Conference on Image Processing (ICIP 2004), pp. 849–852. IEEE, Singapore (2004)
8. Yao, Y., Marcialis, G.L., Pontil, M., Frasconi, P., Roli, F.: Combining flat and structured representations for fingerprint classification with recursive neural networks and support vector machines. Pattern Recognition 36, 397–406 (2003)
9. Wang, W., Li, J., Chen, W.: Fingerprint classification using improved directional field and fuzzy wavelet neural networks. In: Proceedings of the IEEE Sixth World Congress on Intelligent Control and Automation, pp. 9961–9964. IEEE, Dalian (2006)
10. Jain, A.K., Prabhakar, S., Hong, L.: A multichannel approach to fingerprint classification. IEEE Transactions on Pattern Analysis and Machine Intelligence 21, 348–359 (1999)
11. Awad, A.I., Baba, K.: Toward an efficient fingerprint classification. In: Albert, M. (ed.) Biometrics - Unique and Diverse Applications in Nature, Science, and Technology. InTech (2011)
12. Watson, C.I., Wilson, C.L.: NIST special database 4, fingerprint database (1992)
13. Maio, D., Maltoni, D., Cappelli, R., Wayman, J.L., Jain, A.K.: FVC2004: Third Fingerprint Verification Competition. In: Zhang, D., Jain, A.K. (eds.) ICBA 2004. LNCS, vol. 3072, pp. 1–7. Springer, Heidelberg (2004)
14. Liu, M.: Fingerprint classification based on Adaboost learning from singularity features. Pattern Recognition 43, 1062–1070 (2010)
15. SecuGen: Biometric Solution, `http://www.secugen.com/products/sensor_usb.html`
16. Jain, A.K., Bolle, R., Pankanti, S.: Biometrics personal identification in networked society. Springer (2005)
17. Nilsson, K., Bigun, J.: Localization of corresponding points in fingerprints by complex filtering. Pattern Recognition Letters 24, 2135–2144 (2003)
18. Awad, A.I., Baba, K.: Fingerprint Singularity Detection: A Comparative Study. In: Mohamad Zain, J., Wan Mohd, W.M.B., El-Qawasmeh, E. (eds.) ICSECS 2011, Part I. CCIS, vol. 179, pp. 122–132. Springer, Heidelberg (2011)