CHALLENGES AND POTENTIAL RESEARCH IN FINGERPRINT IMAGE RECOGNITION

Saparudin
Image Processing, Computer Vision, and
Pattern Recognition Laboratory,
Faculty of Computer Science,
Universitas Sriwijaya
E-mail: saparudinmasyarif@gmail.com

Abstract - The issues about security of the system and the device are still to be a potential topics in computer technology and networking. The fingerprint image as a kind of human biometric features has been used for over a century and the most widely used for personal recognition in civil, forensic, and commercial areas. In this paper is discussed the latest in trend in fingerprint recognition is viewed from the category of fingerprint images, namely; patent, impressed, and latent. The survey of various research articles indicated that opportunities in the fingerprint identification, particularly the problems in fingerprint image enhancement are topic that potential for researched.

Keywords: fingerprint recognition, latent fingerprint, fingerprint enhancement

1. INTRODUCTION

The end of last year, there were several important milestones for the adoption of fingerprint technology. Smartphone industries launched their new devices, all coming fingerprint readers with touch sensor. The smartphones become more advanced, the requirements of small hardware components become even greater. Touch sensors will continue to decrease in size, which poses large technological challenges on especially fingerprint software to ensure a great user experience with high security. E-commerce industries produced payments services with secure identity verification through fingerprint technology. The e commerce continues to grow, fingerprint technology will become an important technology to protect consumers from fraud, hacking and identify theft. Mobile payment services using fingerprint authentication will continue to spread quickly. Until now, The bureau of investigation in various country, such as the police, have been using fingerprint technology for identify criminals. Since 1969, Federal Bureau of Investigation (FBI) developed a system to automate its fingerprint identification process. The FBI contracted the National Institute of Standards and Technology (NIST) to study the process of automating fingerprint classification, searching, and matching.

Fingerprint identification is one of the most well-known and publicized biometrics. Because of their uniqueness and consistency over time, fingerprints have been used for identification for over a century, more recently becoming automated (i.e. a biometric) due to advancements in computing capabilities. Fingerprint identification is popular because of the inherent ease in acquisition, the numerous sources (ten fingers) available for collection, and their established use and collections by law enforcement and immigration.

An important research challenge is the measurement of quality of a fingerprint image. The automatic Fingerprint Identification System (AFIS) are affected by quality of input data. Therefore, it is important to quantitatively evaluate the quality of a fingerprint image that is indicative of its ability to function as a biometric. The quality of a fingerprint image is susceptible to irregularities during capture or storage, it may also have low quality by its very nature. For instance, as shown in Figure 1, an input fingerprint image may possess a widerange of quality. Various efforts to improve the poor quality fingerprint image, be it increased accuracy of input devices and methods of enhancement is still done by researchers. Here is presented a survey of various recent research that are grouped by category of fingerprint image, namely; patent , impressed, and latent. Patent prints are those fingerprints that are easily spotted without the use of magnesium powders, ultra violet lights or chemicals that might assist in the visualisation of such a print.

Patent prints are often found perhaps in blood, ink, oil or on surfaces such as glass, wooden doorframes or paper. Impressed prints are those that have been made in soft material or tissue by pressing down with the finger or hand. These prints can be photographed or in certain circumstances moulds made if they are very fragile. Latent prints are prints that are not visible to the naked eye but do exist.

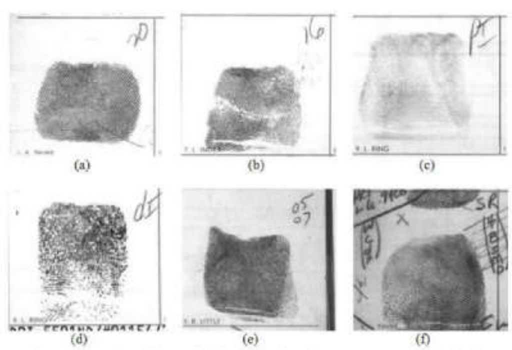

Figure 1. Quality of fingerprint image: (a) Good, (b) Broken/cut, (c) Low contrast, (d) Dry, (e) Wet, and (f) Stain.

ISBN: 979-587-573-6

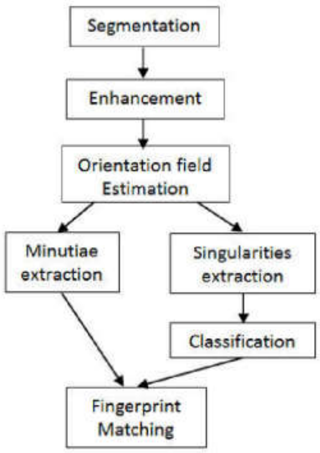

Figure 2. Fingerprint matching process

2. FINGERPRINT AS A BIOMETRICS IDENTIFIER

Biometric is automatic recognition of a person based on physiological measurements and behavioural traits [5]. Physiological characteristics are related to the shape of the body (i.e. DNA, fingeprint, face, ear, palm print, iris, and retina). Behavioral characteristics are related to the pattern of behavior of a person (i.e. typing rhythm, gait, odour, signature and voice). Biometric data are separate and distinct from personal information.

Biometric templates cannot be reverse-engineered to recreate personal information and they cannot be stolen and used to access personal information. Fingerprint as a kind of human biometric features has been used for over a century and the most widely used for personal recognition in civil, forensic, and commercial areas because of its uniqueness, immutability, reliability, and low cost. The uniqueness of fingerprint has been studied and it is well established that the probability of two fingerprints matching is vanishingly small [7][8]. The immutability of fingerprint is persistent with age and can not be easily disguised [9].

Generally, a fingerprint recognition system works in two modes: verification or identification, depend on the application and the requirement. In the verification mode, the user inputs fingerprint and claims identity information, then the system verify whether the query fingerprint is consistent with the claimed identity. In the identification mode, the user only inputs fingerprint and the system needs to identify the potential corresponding fingerprints from the database without the claimed identity information. Fingerprint identification needs to search the entire database to find the potential corresponding ones to the query fingerprint. The huge amount of data of the large fingerprint databases seriously compromises the efficiency of the identification task, although the fastest matching algorithms take only a few milliseconds per matching.

To perform fingerprint identification, both matching accuracy and processing time are critical performance issues. A critical step in automatic fingerprint matching is to automatically and reliably extract minutiae from the fingerprint images [11]. The two most prominent local ridge characteristics, called minutiae, namely; ridge ending and ridge bifurcation. A ridge ending is defined as the point where a ridge ends abruptly. A ridge bifurcation is defined as the point where a ridge forks or diverges into branch ridges. However, the performance of a minutiae extraction algorithm relies heavily on the quality of the input fingerprint images.

An automatic fingerprint identification system (AFIS) require the fingerprint classification stage before the matching stage, it is very difficult to design an automatic system able to perform such classification with high accuracy [10]. Fingerprint classification significantly reduces the processing time to search and retrieve in a large-scale fingerprint database [12]. When a class of a query fingerprint is known, matching the fingerprint only requires the comparison to be done within the class similar to the query fingerprint. Maltoni et al. described that most of the existing fingerprint classification approaches are based on global features, such as ridges orientation and singularities [6]. Bazen and Gerez explained that to encourage more suitable performance of fingerprint classification, algorithms for accurate orientation fields' estimation and singular points detection are required [13]. The ridges orientation contains information about local average directions of fingerprint. It describes the local directions of the ridges structures. It is useful for extraction of singular points. Singular points can be viewed as points where the orientation fields are discontinuous [14]. However, The performance of orientation image and singular points features are influenced directly by accurate segmentation of fingerprint images [15][16]. Since the performance of both features also relies heavily on the quality of the fingerprint image, it is necessary to employ fingerprint noise removal and enhancement to improve the clarity and continuity of the ridges structure. Figure 2 shown step by step process of the fingerprint matching.

III. LIVE-SCAN OR INK FINGERPRINT IMAGE

Fingerprints acquired from a scanning procedure using either ink or life scanner normally contain inheritance handicaps or defects such as noise, handwritten annotation, scars, bruises, wet, dry and low contrast [17][18]. Hence, to reflect a real life environment, the fingerprints should be taken in their raw forms which contain the above handicaps, and also are free of cropping and realignment. Failure to do that will result in unreliable findings and disputable. It is utmost important to use reliable dataset with an appropriate sample size in order to test and evaluate true performance of a identification technique.

The datasets that are often used to test and evaluate of fingerprint is the NIST database. As an example, Prior to 1993, most researchers used NIST Database 4 fingerprints for development and testing of fingerprint classification systems [19]. However, this database contains only 2000 fingerprints pairs, and uniformly distributed in five classes. Worse still, the fingerprints have undergone two important pre-processes viz. cropping and realignment. Hence, the database is considered unsuitable for the above classification task.

Later, in 1993, NIST released a new version of fingerprints database well suited for development and testing of fingerprints classification systems. This upgrade version is called NIST Special Database 14, Mated Fingerprint Cards Pairs 2, and version 2, hereinafter named DB14 in its short form [20]. The dataset is considered as de facto standard fingerprints database that is used for developing and testing of automated fingerprint classification systems [20][21]. The DB14 is made up of 54,000 8-bit grey-scale fingerprint images obtained by rolled method of fingerprint acquisitions scanned from 27,000 fingers. Moreover, the fingerprints are classified manually by human expert using National Crime Information Centre (NCIC) classes assigned by FBI. Valid classes include: Arch (A), Tented-arch (T), Left-loop (L), Right loop (R), Whorl (W) and scar. The distribution of classes in the dataset, and it reveals that Left-loop, Right loop and Whorl combined constitutes exactly 93.29% of the fingerprints, which reflects natural distribution of the population fingerprint classes. Apart from that, there are 21 fingerprints which have defective ridges structure and could not be classified even by human experts, and are classified as scar type. An example of such print is given in Figure 3.

Furthermore, there is about 6.63% of the total 27 000 fingerprints in DB14 is categorised as ambiguous print [21] whose exclusive membership cannot be positively determined by human experts. Normally, this type of print carries multiple patterns of ridges structure that belong to two or more different classes. As a result, it may lead to misclassification. For instance, fingerprint as shown in Figure 4, which is manually labelled as “co/09” by the human expert. The fingerprint is classified as a Whorl, but the right delta is near the core making it similar to the Right-loop so it was given another code which is a “09” reference. In other words, the fingerprint has dual classes i.e. Whorl and Right-loop.

Besides, there is about 9.53% of the fingerprints is of low quality caused by dry, wet, cuts, bruises, and low contrast as reported by [21]. Worse still, almost all prints in the DB14 contain extraneous objects like handwritten annotations and other artefacts common to inked fingerprints. The unavoidable annotation is resulted from the labelling process performed by the human experts who are tasked to manually classify the fingerprint.

Fingerprint image enhancement is a process to change low quality fingerprint image to high quality fingerprint image. Excellent quality of fingerprint image has high different contrast between ridges and valley, continuity of the ridges structures, and flow of ridges and valleys in a locally constant direction. In such situations, the ridges structure can be easily detected and singular points can be precisely located in the image. However, in practice, due to skin conditions (e.g. wet, dry, cuts, and bruises), low contrast, noisy, broken, or smudgy, causing spurious, and others, a significant percentage of fingerprint images with low quality cannot be correctly detected.

Normalization is used to determine the new intensity value of each pixel in a fingerprint image so that it has a pre-specified mean and variance. Due to imperfections in the fingerprint image capturing process such as non-uniform ink intensity or non-uniform contact with the fingerprint capture device, a fingerprint image may exhibit distorted levels of variation in grey-level values along the ridges and valleys. Normalization is also used to standardize the intensity values in an image by adjusting the range of grey-scale values so that it lies within a desired range of values. Normalization removes the effects of sensor noise and finger pressure difference. Most researchers used normalization among other [22][23] which facilitates the subsequent image enhancement steps to develop fingerprint enhancement algorithm. Normalization process is effective as initial processing steps in a more sophisticated fingerprint enhancement algorithm [6]. Since the mean and variance can change in different regions of a fingerprint image, the above global technique can be implemented in a local mode.

Gaussian noises appear in the image caused by factors such as poor illumination and high temperature of sensor. Gaussian filter is a linear smoothing used to smooth the fingerprint image and removes the noises. This filter is similar to mean filter, but it uses a different kernel that represents the shape of Gaussian hump. The goal of Gaussian Filter is to use this distribution as a point spread function that can be performed by convolution mask. In literatures, Gaussian filter is widely used to enhance fingerprint image. For example, Zhang and Yan used Gaussian filter to smooth gradient [24]. Wang and Wang used Gaussian filter for fingerprint enhancement in the singular point area [22]. The Gaussian filter kernel of size 3□3 for smoothing orientation image is used in [23][25].

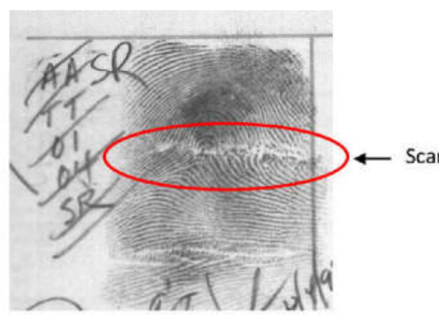

Figure 3 Scar fingerprint

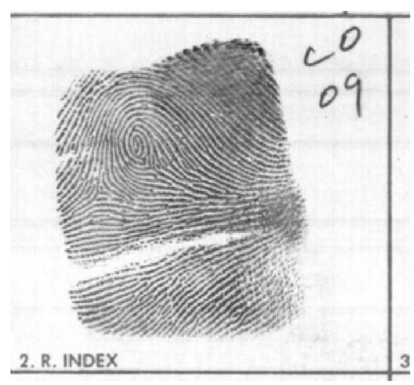

Figure 4. Fingerprint with a cross-referenced classification or ambiguous fingerprint

ISBN: 979-587-573-6

Figure 5 Latent Fingerprint with matching tenprint [28]

Directional filter is one of the enhancement techniques which recognizable in multi-resolution enhancement method [6]. The multi-resolution analysis has been proposed to remove noise from fingerprint image by decomposing the image into dissimilar frequency band (or sub-images). This allows compensating for different noise component at different scales: in particular, at higher levels (low and intermediate frequency bands) the rough ridge flow is cleaned and gaps are closed, whereas at the lower levels (higher frequencies) the finer details are preserved.

Wu, Shi, and Govindaraju proposed fingerprint enhancement method based on integration of anisotropic filter and Directional Median Filter (DMF). The fingerprint images are first convolved with anisotropic filter, and then are filtered by DMF. Eight DMF templates, with suitably pre-selected windows size W , adopt different flow-like topological shapes, following their respective orientations and then select more relative points to enhance ridge-flow continuity. This method is effectively reduces Gaussian-distributed noises and impulse noises along the direction of ridge. However, this algorithm may fail when image regions are contaminated with heavy noises and orientation field in these regions can hardly be estimated [26].

Wang, Hu, and Han proposed an enhanced gradient based method for estimation of fingerprint orientation fields using weighted averaging scheme that exploits the salient features of fingerprint ridge patterns. The basic idea is to conduct redundant estimation over four overlapping neighbourhoods for each target block [27].

IV. LATENT FINGERPRINT IMAGE

Identifying latent fingerprints is of vital importance for law enforcement agencies to apprehend criminals and terrorists. Compared to live-scan and inked fingerprints, the image quality of latent fingerprints is much lower, with complex image background, unclear ridge structure, and even overlapping patterns. Conventional fingerprint recognition algorithm, which can satisfactorily process most live-scan and inked fingerprints, do not provide acceptible result for most latents.

The mayority of the database used for the test and the experiment in latent fingerprint recognition is NIST special database 27 (NIST DB27). This database contains 258 cases in ditribution with each case containing an image of latent and its matching tenprint mate [28. Figure 5 shows a good quality latent on the left and its matching tenprint on the right. Quality of latent image separated into three categories of good, bad, ugly for each cases as 88, 85, 85, repectively [28].

However, the accuracy of identification reported in the state-of-the-art literature is low due to the distortion in latent fingerprint images. They are usually of poor quality with unclear ridge structure and various overlapping patterns. Although significant advances have been achieved on developing automated latent fingerprint identification system, it is still challenging to achieve reliable feature extraction and identification for latent fingerprints due to the poor image quality, complex background noise and overlapping structured noise in latent images Accordingly, manual markup of various features (e.g., region of interest, singular points and minutiae) is typically necessary to extract reliable features from latents. To reduce this markup cost and to improve the consistency in feature markup, fully automatic and highly accurate latent matching algorithms are needed.

Feng, Zhou, and Jain proposed a fingerprint orientation field estimation algorithm based on prior knowledge of fingerprint structure. It is inspired by spelling correction techniques in natural language processing. They represent prior knowledge of fingerprints using a dictionary of reference orientation patches. which is constructed using a set of true orientation fields, and the compatibility constraint between neighboring orientation patches. Orientation field estimation for latents is posed as an energy minimization problem, which is solved by loopy belief propagation. Experimental results on the challenging NIST SD27 latent fingerprint database and an overlapped latent fingerprint database demonstrate the advantages of the proposed orientation field estimation algorithm over conventional algorithms [1]. Perez et al. described a new algorithm based on the use of clustering which is independent of the minutiae descriptors. The proposed technique improves the robustness of identification in the presence of large non-linear deformation which is associated with latent fingerprint images. The new algorithm finds multiple overlapping clusters of matching minutiae pairs which are merged together to find matching minutiae. Several experiments performed using latent fingerprint databases show that proposed algorithm achieves higher accuracy than those presented in state-of-the-art literature. Moreover, the results show that the proposed algorithm is successful in dealing with the large distortion associated with latent fingerprints formed under the worst conditions [2].

Liu, Chen, and Wang proposed a latent fingerprint enhancement algorithm by combining the total variation model and multiscale patch-based sparse representation. First, the total variation model is applied to decompose the latent fingerprint into cartoon and texture components. The cartoon component with most of the nonfingerprint patterns is removed as the structured noise, whereas the texture component consisting of the weak latent fingerprint is enhanced in the next stage. Second, they proposed a multiscale patch-based sparse representation method for the enhancement of the texture component. Dictionaries are constructed with a set of Gabor elementary functions to capture the characteristics of fingerprint ridge structure, and multiscale patch-based sparse representation is iteratively applied to reconstruct high-quality fingerprint image. The proposed algorithm cannot only remove the overlapping structured noises, but also restore and enhance the corrupted ridge structures. In addition, they presented an automatic method to segment the foreground of latent image with the sparse coefficients and orientation coherence. Experimental results and comparisons on NIST SD27 latent fingerprint database [3].

In [4] A dictionary-based approach is proposed for automatic latent segmentation and enhancement towards the goal of achieving "lights-out" latent identification systems. Given a latent fingerprint image, a total variation decomposition model with L1 fidelity regularization is used to remove piecewise-smooth background noise. The texture component image obtained from the decomposition of latent image is divided into overlapping patches. Ridge structure dictionary, which is learnt from a set of high quality ridge patches, is then used to restore ridge structure in these latent patches. The ridge quality of a patch, which is used for latent segmentation, is defined as the structural similarity between the patch and its reconstruction. Orientation and frequency fields, which are used for latent enhancement, are then extracted from the reconstructed patch. To balance robustness and accuracy, a coarse to fine strategy is proposed. Experimental results on two latent fingerprint databases, i.e. NIST SD27 and WVU DB show the proposed algorithm outperforms the state-of theart segmentation and enhancement algorithms and boosts the performance of a state-of-the-art commercial latent matcher.

V. **CONCLUSION**

That has carried out a survey of the articles of research on fingerprint recognition. Conventional fingerprint recognition algorithm, which can satisfactorily process most live-scan and inked fingerprints, do not provide acceptible result for most latents. Quality of fingerprint image is an important challenge for the biometrics research community. The quality of the fingerprint greatly affect in matching process.

REFERENCES

[1] J. Feng, J. Zhou, and A.K. Jain, "Orientation Field Estimation for Latent Fingerprint Enhancement," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 35, no. 4, pp. 925-940, April 2013.

[2] M.A.M. Perez, A.M. Moreno, M.A.F. Ballester, M.G. Borroto, O.L. Gonzalez, and L.A. Robles, "Latent Fingerprint Identification using Deformable Minutiae Clustering," Neurocomputing, In Press, Accepted Manuscript, 4 November 2015.

[3] M. Liu, X. Chen, and X. Wang, "Latent Fingerprint Enhancement via Multi-Scale Patch Based Sparse Representation," IEEE Transactions on Information Forensics and Security, vol. 10, issue 1, pp. 6-15, 2015.

[4] K. Cao, E. Liu, and A.K. Jain,"Segmentation and Enhancement of Latent Fingerprints: A Coarse to Fine Ridge Structure Dictionary,"IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 36, issue 9, pp. 1847-1859, 2014.

[5] A.K. Jain, L. Hong, and S. Pankanti, "Biometric Identification," Communications of the ACM, vol. 43, no. 2, pp. 91–98, 2000.

[6] D. Maltoni , D. Maio, A.K. Jain, and S. Prabhakar. Handbook of Fingerprint Recognition. Second edition, SpringerVerlag London Limited, 2009.

[7] A.K. Jain, S. Prabhakar, L. Hong, and S. Pankanti,"Filterbank-based Fingerprint Matching," IEEE Transactions on Image Processing, vol. 9, pp. 846-859, 2000.

[8] S. Pankanti, S. Prabhakar, and A.K. Jain,"On the Individuality of Fingerprints," IEEE Transaction Pattern Analysis and Machine Intelligence, vol. 24, no. 8, pp. 1010–1025, 2002.

[9] N. Yager and A. Amin,"Fingerprint Classification: a Review," Pattern Analysis Application, vol. 7, pp. 77 93, 2004.

[10] K. Karu and A.K. Jain,"Fingerprint Classification," Pattern Recognition, vol. 29, no. 3, pp. 389-404, 1996.

[11] L. Hong, Y. Wan, and A.K. Jain,"Fingerprint Image Enhancement: Algorithm and Performance Evaluation," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 20, no. 8, pp. 777-789, 1998.

[12] R. Cappelli, A. Lumini, D. Maio, and D. Maltoni,"Fingerprint Classification by Directional Image Partitioning," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 21, no. 5, pp. 402-421, 1999.

[13] A.M. Bazen and S.H. Gerez, "Systematic Methods for the Computation of the Directional Fields and Singular Points of Fingerprints," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 24, no. 7, pp. 905 919, 2002.

[14] J. Zhou and J. Gu, "A Model-Based Method for the Computation of Fingerprints' Orientation Field," IEEE Transactions on Image Processing, vol. 13, no. 6, 2004.

[15] A.M. Bazen and S.H. Gerez, "Segmentation of Fingerprint Images," ProRISC 2001 Workshop on Circuits, Systems and Signal Processing, Veldhoven, the Netherlands, 2001.

[16] X. Chen, J. Tian, J. Cheng, and X. Yang, "Segmentation of Fingerprint Images using Linear Classifier," EURASIP Journal on Applied Signal Processing, vol. 2004, no. 4, pp. 480-494, 2004.

[17] S. Saparudin, G. Sulong, "Fingerprint Enhancement Algorithm Based-on Gradient Magnitude for the Estimation of Orientation Fields," Comengapp (Computer Engineering and Application Journal), vol. 4, no. 2, 2015.

[18] S. Saparudin, G. Sulong, "Segmentation of Fingerprint Image Based on Gradient Magnitude and Coherence. IJECE (International Journal of Electrical and Computer Engineering), vol. 5, no. 5, Oktober 2015.

[19] C.I. Watson and C.L. Wilson. NIST Special Database 4 Fingerprint Database. U.S. National Institute of Standards and Technology, 1992.

[20] C.I. Watson. NIST Special Database 14 Mated Fingerprint Cards Pairs 2 version 2. U.S. National Institute of Standards and Technology, 1993.

[21] R. Cappelli and D. Maltoni,"On the Spatial Distribution of Fingerprint Singularities," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 31, no. 4, 2009.

[22] S. Wang and Y. Wang, "Fingerprint Enhancement in the Singular Point Area,"IEEE Signal Processing Letters, vol. 11, no. 1, 2004.

[23] S. Chikkerur, A.N. Charwright, and V. Govindaraju,”Fingerprint Enhancement using STFT Analysis,” Pattern Recognition, vol. 40, pp.198-211, 2007.

[24] Q. Zhang and H. Yan,”Fingerprint Orientation Field Interpolation based on The Constrained Delaunay Triangulation,” International Journal of Information and Systems Sciences, vol. 3, no 3, pp. 438-452, 2007.

[25] K. Mao, Z. Zhu, and H. Jiang,”A Fast Fingerprint Image Enhancement Method,” IEEE Proc. 3rd Int. Joint Conf. on Computational Science and Optimization, pp. 222-226, 2010

[26] C. Wu, Z. Shi, and V. Govindaraju,”Fingerprint Image Enhancement Method using Directional Median Filter,” Proc. SPIE Conf. on Biometric Technology for Human Identification, 2004.

[27] Y. Wang, J. Hu, F. Han,”Enhanced Gradient-based Algorithm for the Estimation of Fingerprint Orientation Fields,” Applied Mathematics and Computation, 185(2): pp. 823-833, 2007.

[28] M.D. Garris and R.M. McCabe. NIST Special Database 27 Fingerprint Minutiae from Latent and Matching Tenprint Images. National Institute of Standard and technology, 2000.