IMPROVED METHODS FOR FINGER VEIN IDENTIFICATION USING COMPOSITE MEDIAN-WIENER FILTER AND HIERARCHICAL CENTROID FEATURES EXTRACTION

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Specially dedicated to:

My wife - Olayinka and children - Toyosi, Toromo & Todimu

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"Education is indispensable! He who miss it, are like fishes in a water well, he is ignorant."

ABSTRACT

Finger vein identification is a potential new area in biometric systems. Finger vein patterns contain highly discriminative characteristics, which are difficult to be forged because they reside underneath the skin of the finger and require a specific device to capture them. Research have been carried out in this field but there is still an unresolved issue related to low-quality data due to data capturing and processing. Low-quality data have caused errors in the feature extraction process and reduced identification performance rate in finger vein identification. To address this issue, a new image enhancement and feature extraction methods were developed to improve finger vein identification. The image enhancement, Composite Median-Wiener (CMW) filter would improve image quality and preserve the edges of the finger vein image. Next, the feature extraction method, Hierarchical Centroid Feature Method (HCM) was fused with statistical pixel-based distribution feature method at the feature-level fusion to improve the performance of finger vein identification. These methods were evaluated on public SDUMLA-HMT and FV-USM finger vein databases. Each database was divided into training and testing sets. The average result of the experiments conducted was taken to ensure the accuracy of the measurements. The k-Nearest Neighbor classifier with city block distance to match the features was implemented. Both these methods produced accuracy as high as 97.64% for identification rate and 1.11% of equal error rate (EER) for measures verification rate. These showed that the accuracy of the proposed finger vein identification method is higher than the one reported in the literature. As a conclusion, the results have proven that the CMW filter and HCM have significantly improved the accuracy of finger vein identification.

ABSTRAK

Pengecaman vena jari merupakan bidang baru yang berpotensi dalam sistem biometrik. Corak vena jari mengandungi ciri-ciri yang sangat diskriminatif, yang sukar untuk dipalsukan kerana ianya berada di bawah kulit jari dan memerlukan peranti khusus untuk mengesannya. Penyelidikan telah dijalankan dalam bidang ini namun terdapat isu yang masih tidak diselesaikan berkaitan dengan kualiti data yang rendah yang disebabkan oleh pengesanan dan pemprosesan data. Data yang berkualiti rendah menyebabkan ralat dalam proses pengekstrakan ciri dan mengurangkan kadar prestasi pengecaman dalam pengenalpastian vena jari. Bagi menangani isu ini, kaedah peningkatan imej dan pengekstrakan ciri telah dibangunkan untuk meningkatkan pengenalpastian vena jari. Peningkatan imej, penapis Komposit Median-Wiener (CMW) akan menambah baik kualiti imej dan mengekalkan tepi imej vena jari. Seterusnya, kaedah pengekstrakan ciri, Kaedah Ciri Sentroid Berhierarki (HCM) digabungkan dengan kaedah ciri pengagihan berdasarkan piksel statistik pada gabungan tahap ciri untuk meningkatkan prestasi pengecaman vena jari. Kaedah-kaedah ini dinilai pada pangkalan data awam vena jari SDUMLA-HMT dan FV-USM. Setiap pangkalan data dibahagikan kepada set latihan dan set ujian. Hasil purata kajian yang dilakukan diambil untuk memastikan ketepatan pengukuran. Pengkelas Tetangga k-Terdekat dengan jarak *city block* telah dilaksanakan untuk menyesuaikan ciri-ciri. Kedua-dua kaedah ini menghasilkan ketepatan setinggi 97.64% bagi kadar pengecaman dan 1.11% kadar kesamaan ralat (EER) bagi mengukur kadar pengesahan. Ini menunjukkan bahawa kaedah ketepatan pengecaman jari yang dicadangkan lebih tinggi daripada yang dilaporkan dalam kajian lepas. Sebagai kesimpulan, keputusan membuktikan bahawa penapis CMW dan Kaedah HCM telah meningkatkan dengan nyata ketepatan pengecaman vena jari.

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LIST OF ABBREVIATIONS

BIS	-	Biometric Identification Systems
BLPOC	-	Band-Limited Phase-Only Correlation
BVS	-	Biometric Verification Systems
CCD	-	Centroid Contour Distance
CCD	-	Charged Coupled Device
CF	-	Composite Filter
CFM	-	Combine Feature Method
CLAHE	-	Contrast Limited Adaptive Histogram Equalization
CMC	-	Cumulative Match Curve
CMW	-	Composite Median Wiener
COG	-	Center of Gravity
CSS	-	Curvature Scale Space
DFT	-	Discrete Fourier Transform
DNA	-	Deoxyribo-Nucleic Acid
DoG-HE	-	Difference of Gaussian-Histogram Equalization
DWPT	-	Discrete Wavelet Packet Transform
DWT	-	Discrete Wavelet Transform
EER	-	Equal Error Rate
FAR	-	False Accepted Rate
FRR	-	False Rejection Rate
FVIS	-	Finger Vein Identification Scheme
HCGR	-	Histogram of Competitive Gabor Responses
HCM	-	Hierarchical Centroid Method
HD	-	Hamming Distance
KECA	-	Kernel Entropy Component Analysis
KNN	-	k-Nearest Neighbor

LBP	-	Local Binary Pattern
LDA	-	Linear Discriminant Analysis
LDC	-	Local Directional Code
LDC	-	Local Directional Code
LED	-	Light-Emitting Diode
LLBP	-	Local Line Binary Pattern
LPP	-	Local Projection Pattern
MDA	-	Multilinear Discriminant Analysis
MSE	-	Mean Square Error
NHB	-	Number of Horizontal Bars
NIR	-	Near Infra-Red
NOHF	-	Number of Horizontal Features
NOVF	-	Number of Vertical Features
NSDFB	-	Non-Subsampled Directional Filter bank
NVB	-	Number of Vertical Bars
PBBM	-	Personalized Best Bit Maps
PCA	-	Principal Component Analysis
PDM	-	Pixel Distribution Method
PSNR	-	Peak Signal-to-Noise Ratio
PWM	-	Personalized Weight Maps
ROC	-	Receiver Operating Characteristic
ROI	-	Region of Interest
RWF	-	Rotated Wavelet Filter
SVD	-	Singular Value Decomposition
SVM	-	Support Vector Machine
WCCD	-	Width-Centroid Contour Distance
WKNCN	-	Weighted K-Nearest Centroid Neighbor

CHAPTER 1

INTRODUCTION

1.1 Introduction

Biometric via physiological attributes (fingerprint, dorsal vein, finger vein, and facial) or behavioural characters (signature, speech, and handwriting), refers to science of validating and authenticating the identity of a person for automatic recognition (Ross *et al.*, 2006; Xueyan and Shuxu, 2008; Syazana-Itqan *et al.*, 2016). Law enforcement agencies were the first to adopt biometric systems in the 1970s to investigate criminals through fingerprint recognition (Jain and Kumar, 2010; Jain and Ross, 2015). However, the current biometric technologies advancement, in parallel with the growth of threats in information security, the biometric application systems have proliferated into the physical and logical access control domains (Ahmad *et al.*, 2012; Smith *et al.*, 2018). This kind of system gains attraction because the cost of biometric capture machines is low (Rhodes *et al.*, 2003; Market, 2008; Zhang, 2013).

Currently, biometric application technologies are applied in forensics, most especially in the identification of criminal and prison security. Similarly, biometrics has the capability to remain extensively approved for the very wide scope of national purposes such as voter and driver registration, national identification, customs and immigration systems, physical access control, and banking security. These technologies have been made possible by explosive advances in computing power and have been made necessary by the near general interconnection of computers around the world (Saini and Kapoor, 2016). Figure 1.1 shows typical existing biometric features.

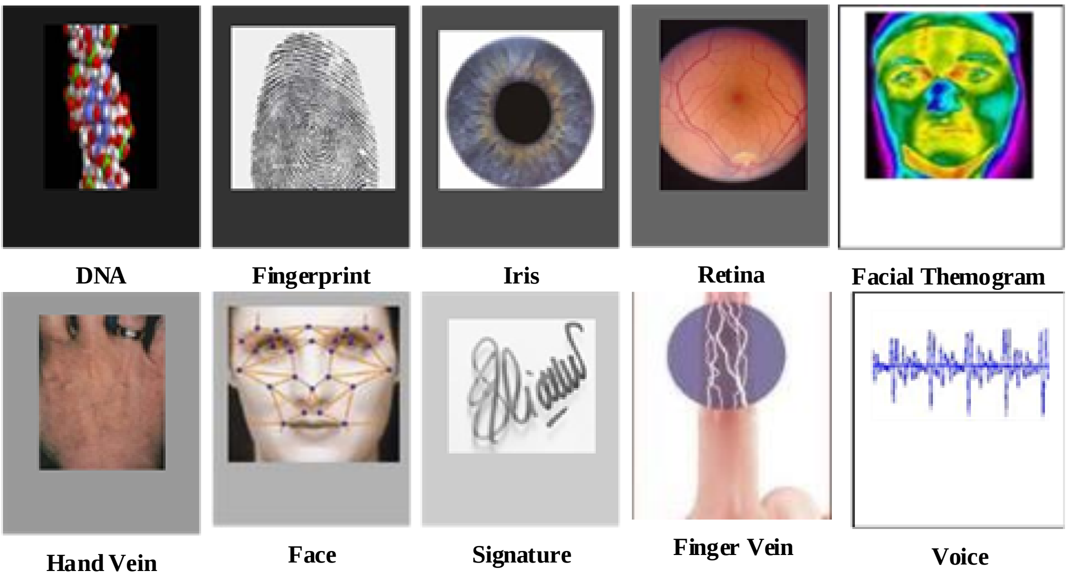


Figure 1.1 A typical biometric features (Source: Researcher Intuition)

However, every biometrics authentication systems have its own shortcomings based on the qualities, capturing device, database, and feature of that quality (Lin, 2000; Singh *et al.*, 2012; Du, 2013; Farokhi *et al.*, 2014). To solve the inadequacies of existing based biometric systems, research into finger vein identification comes to the limelight. The beginning of finger vein can be traced back to the year of 2000 when a Japanese medical researcher introduced biometric finger vein trait for identification systems (Kono, 2000). Since then, finger vein has attracted a lot of researchers' attention in other countries worldwide to develop finger vein identification systems because of its merits (Tagkalakis *et al.*, 2017). Finger vein is the vein patterns or the networks of blood tissue under the skin of a finger. The vein that contains deoxygenated blood absorb the Near Infra-Red (NIR) light thus appearing darker than the surrounding background in the vein map (Xie *et al.*, 2015). Despite that, finger vein can only be obtained in a living person, it is so unique for every individual, including identical twins (Yang *et al.*, 2011; Syazana-Itqan *et al.*, 2016). Hence, vein patterns are obscured and are not easily be replicated (Yang *et al.*, 2014). Figure 1.2 shows the various application area of finger vein identification biometric system.

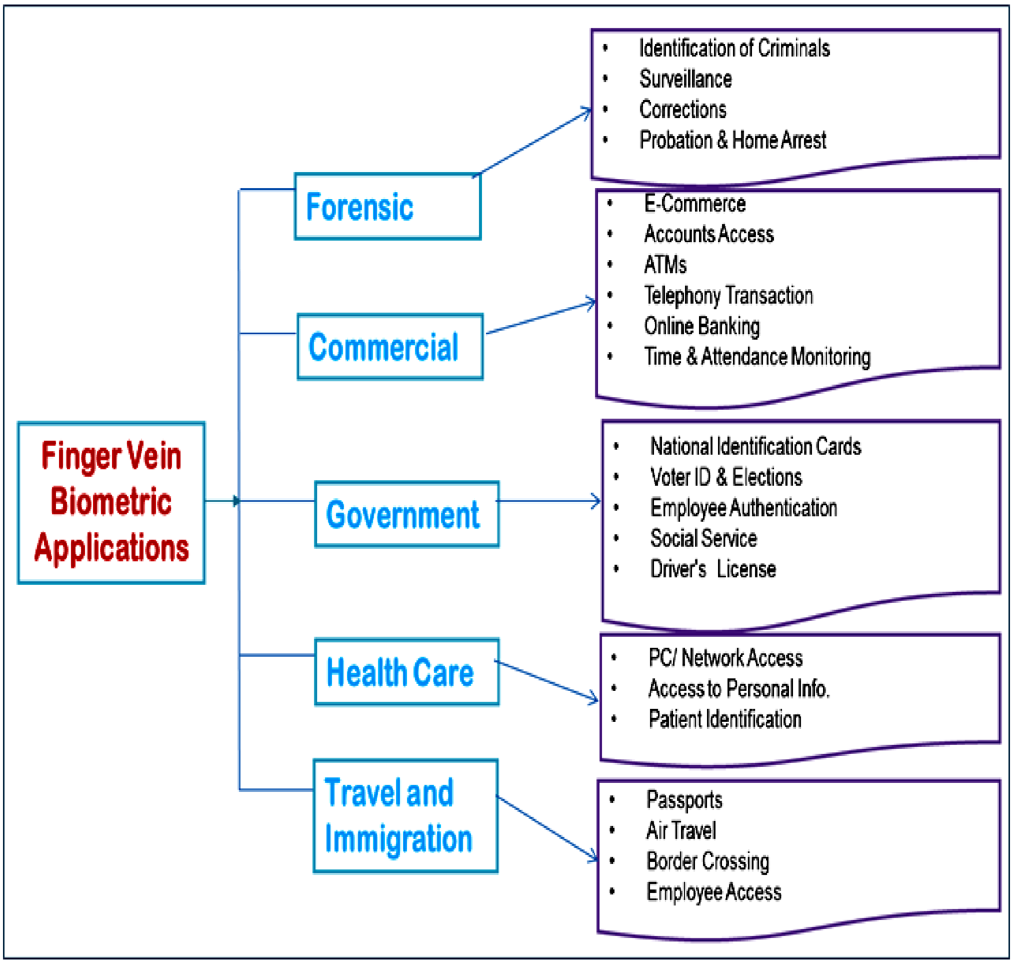


Figure 1.2 Application area of the finger-vein identification biometric system (Source: Author Intuition)

Due to the increasing level of fraud and security threats, the requirement for more secure personal identification technologies is becoming apparent. The conventional identification contains two types of methods, namely contents-based such as password and code, and possessing-based such as smart card and license. However, with the growth in technologies, limitations on these conventional identification methods begin to appear (Baoguiqiu and Xiaosheng, 2001; Sun and Qiu, 2001). Both code and password are always being forgotten or stolen. Though passwords are still widely used, their lack of proper implementation has seen password gaining immense criticism (Bonneau and Preibusch, 2010; Center, 2010). In case of certificate key and a smart card, their possibility of being stolen, forged, and lost is high. Hence, identification technology that is based on bio features arises to address the inadequacies of conventional identification. Human-inbuilt biology characteristics like face, vein, and Deoxyribo-Nucleic Acid (DNA), and humanconduct characteristics like voice, sign, and gait are used to discover a person identity such as in optics, biosensor, and inoculation of the computer. Thus, this discovery becomes better in terms of accuracy, suitability, time, privacy, safety, and trustworthiness compared to the uses of certificate key, code, and card.

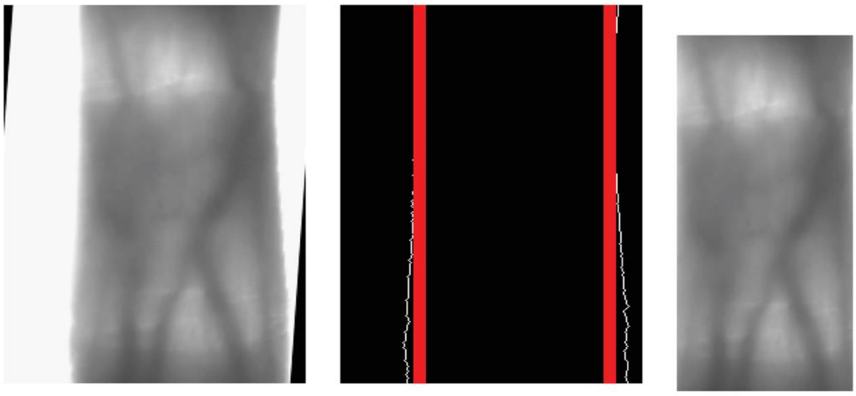
Fingerprint biometric appears to be popular in a human identification system. However, its privacy cannot be granted as it can be spoofed and forged. In identification and information security application, the vein technology offers many merits in biometrics such as generality and distinctiveness. As human age increases, the vein pattern does not change, which means it is static in nature. In addition, sickness, surgery, and epidermis do not change the body vein pattern to causing conflict over two people personal identification. Finger vein biometric trait is increasingly being used nowadays because it overcomes the problem of creating complex passwords and the user has one less thing to remember, their biometric trait (vein) is always with them (Sharma *et al.*, 2014b).

1.2 Problem Background

Despite extensive researches in the finger vein identification system, there are still several aspects of this area that still crave for lots of research studies. The system includes various phases of operation such as: image acquisition, enhancement, feature extraction, and matching.

Research shows that image enhancement and feature extraction are the most known challenging processes in finger vein image processing (Yang and Shi, 2012) and even in finger vein identification system (Podgantwar and Raut, 2013). In previous years, image enhancement and its feature extraction image methods have been created and enhanced to conquer the challenges of images. Enhancement and feature extraction of finger vein refers to the removal of the unwanted object, increasing the contrast between ridges identify and obtain information that represents the individual through the vein.

Enhancement of finger vein images is the procedure of extracting Region of Interest (ROI), and improving the image quality, out of a reduced input image quality (Wang and Tang, 2017). ROI refers to a discrete section of the image that detects some specific objects extracted from the image (Maragos, 2005; Rosdi *et al.*, 2011; Yang *et al.*, 2013). The extracted ROI example from a finger vein image is displayed in Figure 1.3. The object within the rectangle illustrates the ROI.



(a) (b) (c)

Figure 1.3 Extracted ROI of finger vein image (Yang *et al.*, 2013); **(**a) Original image. (b) Finger image edge using internal lines. (c) ROI of a vein image

Working with finger vein images have anonymities such as noise, blurred, and low contrast at some vein tissues. Noise is an unwanted information added to an original finger vein image, which reduces the image quality (Yang *et al.*, 2013; Qin *et al.*, 2018). Noise in finger vein images has several origins. The photoelectronic during finger vein capturing caused the Gaussian noise due to the thermal motion of the electron. Likewise, unstable network caused impulse noise known as Salt-and-pepper noise during transmission of the image (Gupta and Kaushik, 2014). When an image is corrupted by several feature noises simultaneously such as a combination of Gaussian and impulse noise on an image, it is known as mixed noise, which is common in finger vein image (Ahamed and Rajamani, 2009; Shi and Yang, 2012; Yan, 2013; Gupta and Gupta, 2015).

Feature extraction process in finger vein is performed to find a subset of features to ensure either the maximum effectiveness of identification or the efficiency of the process (by minimizing the number of features) or both. Many features can be extracted from the image properties. These features can be categorized into five sets: image characteristics-based features, statistical calculation-based features, a region of pixels-based features, the boundary of segmented region-based features, and image textures-based features (Ezhilmaran and Joseph, 2015). Nevertheless, the type of features depends mainly on the state of images employed in the identification. Finger vein images are in various states of low image contrast, an uneven-illumination, scale variation, hair and skin texture, which occurred as a result of noise. It is worth noting that feature extraction for finger vein using the methods referred to in this paragraph still need more image enhancement to improve the accuracy level performance of finger vein identification scheme. In this context, scheme is the method of attaining finger vein images to identify individuals accurately.

1.3 Problem Statement

Despite several previous works on finger vein identification system, issues on finger vein image enhancement and feature extraction are still challenging the system. Efforts and research to improve the contrast level and denoise the mixed noise in image enhancement and feature extraction have not been adequately investigated. Therefore, the finger vein image enhancement and feature extraction problems to be solved in this study can be described as follows:

Having a dataset of finger vein images corrupted by many characteristics of noises simultaneously with Gaussian noise and Impulse noise form mixed noise (Rodríguez *et al.,* 2012; Filipović and Jukić, 2014). The challenges are to increase the contrast level, divide the image into regions using neighborhood contrast intensity in order to get an exact localization of the region and employ different methods to filter the pixels in regions from noise. Based on this challenge, several issues are required to answer for a possible solution. It is discovered that many existing image enhancement methods are limited to increasing the contrast level and filtering (Shi *et al.*, 2012). Also, it has been studied that a satisfactory filtering cannot be obtained using a single filter method (Arora and Jangera, 2017; Lin, 2018).

Hence, the main challenge is the development of an improved image enhancement method to be used in removing the mixed noise.

The next issue is related to the feature extraction methods, which are the fundamental components of finger vein identification systems. Various methods to extract the local and global features from finger vein images have been developed for a finger vein identification system. Extraction of local features are mainly using minutiae points, repeated line tracking and maximum curvature method, which were found very difficult to produce enough information about finger vein images (Shrikhande and Fadewar, 2016). Also, some methods extract local and global features with complexity, which makes them so impractical for real-life applications (Gupta and Gupta, 2015). Comparing with single extraction type of feature, the fusion of many features of extraction can improve the performance of finger vein identification system (Asaari *et al.*, 2014). Therefore, it was found that the areas for a combination of multiple features in the feature extraction stage for finger vein identification system need to be explored more (Subramaniam and Radhakrishnan, 2017).

Besides the features extraction, the combination of classifier and metric distance employed has a significant effect on similarity matching between the query and the data images, which affect the performance of the system (Rosdi, 2016).

1.4 Research Questions

Consequently, the primary research question is:

"*How effective is the improved scheme of finger vein images could accurately identify individuals with the improved methods of image enhancement and feature extraction?*"

To address the above main question, the following secondary research questions need to be addressed and answered carefully:

i. How can noisy finger vein images be enhanced to ensure better performance of finger vein identification?

ii. What representations or features extracted from the finger vein image are most appropriate to reflect the uniqueness of the person?

iii. Are optimized features extracted from the finger vein be efficient for identification and verification tasks?

1.5 Research Goal

The goal of this research is to improve scheme of finger vein identification for human identification with better accuracy.

1.6 Research Objectives

The objectives of this research study are:

i. To propose an image enhancement method that removes the mixed noise and improve the contrast in the finger vein images.

ii. To enhance the feature extraction method based on texture and structural features that could improve the similarity matching between the query and data images in order to improve the accuracy of the identification scheme for the noisy finger vein images.

iii. To optimize finger vein identification (FVI) based on the supervised learning algorithm (SLA).

1.7 Research Scope

The scopes of this research are bound by the following limitation:

The research used the quantitative method only, which is limited to two public databases of finger vein images, namely:

a. SDUMLA-HMT finger vein image database, which was created at Wuhan University. The database contains 106*6*6, which is 3816 finger vein samples collected from 106 subjects and all images were saved with "bmp" format of 320 × 240 pixels' size, and hence 0.85G bytes is the total size of this finger vein database.

b. FV-USM finger vein image dataset, which was created by Universiti Sains Malaysia. It was collected from 123 participants, which consist of 83 males and 40 females from staff and students. The 5904 total images from 492 finger classes were obtained. The captured finger images have spatial and depth resolution of 640 × 480 and 256 gray levels, separately.

1.8 Organization of the Thesis

The proposed research is presented through this thesis and it organized by seven chapters, which can be outlined as the follows:

Chapter 1 presents the general introduction of biometric and finger vein, the research background and problem research. The chapter additionally addresses some research impacts in this field precisely focusing on finger vein image enhancement and feature extraction method. Also, research questions, goal, objectives, scope, and organisation of the thesis were present.

Chapter 2 presents an overview of the literature regarding finger vein and acquisition devices. This chapter also reviews several types of image enhancement, feature extraction methods, and related finger vein identification work.

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