

**LOG-GABOR FILTER BASED FINGER VEIN BIOMETRIC SYSTEM
USING MODIFIED REPEATED LINE TRACKING ALGORITHM**

by

AMIR HAJIAN

**Thesis submitted in fulfilment of the
requirements for the degree of
Master of Science**

July 2018

ACKNOWLEDGEMENT

This dissertation is dedicated to everyone in the field of biometrics and image processing system who embarks the journey of expanding the collection of knowledge and transcendent passion for improving verification system base on finger vein biometric trait.

My uttermost gratitude goes to Associate Prof. Dr. Dzati Athiar Bt Ramli, my thesis advisor and project supervisor, for her invaluable support and guidance that were crucial for the completion of this project. Dr. Dzati has been supportive during the process of brainstorming. Her guidance and immense knowledge throughout all the time of research and writing this thesis are highly appreciated.

My special thanks reach out to Dr. Sepehr Damavandinejadmonfared who had supported me as technical advisor. Besides, I would like to thanks Universiti Sains Malaysia for supporting though the Fundamental Research Grant Scheme (6071266).

Extensive acknowledgment needs to be paid to my family and friends for their endless love and support in any aspect during the completion of this project and thesis.

Last but not least, I would like to express my deepest appreciation to my dearest friend, Dr. Hamid Reza Sadeghpour for his kindness support he has given to me on the difficult task of writing the thesis.

TABLE OF CONTENTS

| | Page |
|---|-------------|
| ACKNOWLEDGEMENT | ii |
| TABLE OF CONTENTS | iii |
| LIST OF TABLES | vii |
| LIST OF FIGURES | ix |
| LIST OF ABBREVIATIONS | xiv |
| LIST OF SYMBOLS | xvi |
| ABSTRAK | xvii |
| ABSTRACT | xviii |
| | |
| CHAPTER ONE: INTRODUCTION | |
| 1.1 Overview of Biometric System | 1 |
| 1.2 Finger Vein Biometric System | 4 |
| 1.3 Problem Statement | 6 |
| 1.4 Objectives | 7 |
| 1.5 Scope of Research | 8 |
| 1.6 Thesis Contribution | 9 |
| 1.7 Thesis Outline | 9 |
| | |
| CHAPTER TWO: LITERATURE REVIEW | |
| 2.1 Introduction | 11 |
| 2.2 Typical Finger Vein Biometric System | 11 |
| 2.3 Data Acquisition of Finger Vein Image | 11 |

| | | |
|-------|---|----|
| 2.4 | Pre-processing Techniques for Finger Vein Image | 15 |
| 2.4.1 | Researches in Finger Vein Pre-processing | 16 |
| 2.4.2 | Contrast Enhancement | 19 |
| 2.4.3 | Sharpness Enhancement | 23 |
| 2.4.4 | Log-Gabor Filter | 25 |
| 2.5 | Feature Extraction of Finger Vein | 28 |
| 2.5.1 | Extraction of Feature Based on Vein Pattern | 30 |
| 2.5.2 | Extraction of Feature Based on Local Binary | 30 |
| 2.5.3 | Extraction of Feature Based on Dimensionality Reduction | 31 |
| 2.6 | Classification Techniques of Finger Vein Pattern | 31 |
| 2.7 | Summary | 37 |

CHAPTER THREE: METHODOLOGY

| | | |
|-------|--|----|
| 3.1 | Introduction | 38 |
| 3.2 | Research Framework | 38 |
| 3.3 | System Requirements | 40 |
| 3.3.1 | Software Requirement | 40 |
| 3.3.2 | Hardware Requirement | 41 |
| 3.4 | Database | 41 |
| 3.4.1 | Database Description | 41 |
| 3.4.2 | Database Management | 43 |
| 3.5 | Pre-processing | 43 |
| 3.5.1 | Region of Interest (ROI) | 44 |
| 3.5.2 | Contrast Limited Adaptive Histogram Equalization (CLAHE) | 46 |

| | | |
|-----------|---|----|
| 3.5.3 | Filtering Enhancement with Modified Un-sharp Mask (MUM) with Log-Gabor Filter | 51 |
| 3.5.4 | Modification Algorithm in Pre-processing Stage | 53 |
| 3.5.5 | Quantitative Evaluation of Enhanced Image | 58 |
| 3.5.5 (a) | Mean Squared Error | 58 |
| 3.5.5 (b) | Peak Signal to Noise Ratio | 58 |
| 3.6 | Feature Extraction | 59 |
| 3.6.1 | Repeated Line Tracking Algorithm | 62 |
| 3.6.2 | Modified Repeated Line Tracking Algorithm | 67 |
| 3.7 | Classification by Support Vector Machine | 70 |
| 3.8 | Performance Evaluation | 71 |
| 3.9 | Summary | 73 |

CHAPTER FOUR: RESULTS AND DISCUSSIONS

| | | |
|-------|---|----|
| 4.1 | Introduction | 74 |
| 4.2 | The Results of Different Steps of Pre-processing Stage | 74 |
| 4.2.1 | The Results of Contrast Limited Adaptive Histogram Equalization (CLAHE) | 74 |
| 4.2.2 | The Designed Log-Gabor Filter | 76 |
| 4.2.3 | Subjective Evaluation of Pre-processed Images | 77 |
| 4.2.4 | The Evaluation of Images Quality in Pre-processing Stage | 82 |
| 4.3 | Modified Repeated Line Tracking Results | 83 |
| 4.3.1 | The Line Tracking Repetition | 83 |
| 4.3.2 | Subjective and Numeric Evaluation of Extracted Pattern of Vein | 84 |
| 4.4 | Performances of Finger Vein Biometric System | 89 |
| 4.4.1 | Performances of Finger Vein Biometric System Based on | 89 |

| | |
|---|-----|
| Different Numbers of Training Data | |
| 4.4.1 (a) Performances of System with Original Image Based on Different Numbers of Training Data | 89 |
| 4.4.1 (b) Performances of System with CLAHE Based on Different Numbers of Training Data | 90 |
| 4.4.1 (c) Performances of System with CLAHE then MUM Based on Different Numbers of Training Data | 91 |
| 4.4.2 Performances of Finger Vein Biometric System Based on Enhancement Techniques | 92 |
| 4.4.2 (a) Performances of Finger Vein Biometric System Based on Enhancement Techniques on One Training Data | 93 |
| 4.4.2 (b) Performances of Finger Vein Biometric System Based on Enhancement Techniques on Two Training Data | 94 |
| 4.4.2 (c) Performances of Finger Vein Biometric System Based on Enhancement Techniques on Three Training Data | 95 |
| 4.5 Comparison with Previous Related studies | 96 |
| 4.6 Summary | 96 |
| | |
| CHAPTER FIVE: CONCLUSION | |
| 5.1 Conclusion | 98 |
| 5.2 Suggestion for Future Work | 99 |
| REFERENCES | 101 |
| LIST OF PUBLICATIONS | |

LIST OF TABLES

| | | Page |
|-----------|---|-------------|
| Table 1.1 | Comparison of different biometric traits | 5 |
| Table 2.1 | Comparison of different finger databases | 14 |
| Table 2.2 | Comparison of different pre-processing methods of finger vein recognition system | 16 |
| Table 2.3 | Comparison of different feature extraction methods of finger vein pattern | 29 |
| Table 2.4 | Comparisons between different pre-processing, feature extraction and corresponding classifier techniques | 36 |
| Table 2.5 | Comparisons between different finger vein recognition techniques of previous table based on number of subjects, samples and accuracy rate | 37 |
| Table 4.1 | The number of white pixels in the extracted vein samples of subject1 | 88 |
| Table 4.2 | The number of white pixels in the extracted vein samples of subject2 | 88 |
| Table 4.3 | The number of white pixels in the extracted vein samples of subject3 | 88 |
| Table 4.4 | EERs of System with original image and based on 1, 2 and 3 training data | 90 |
| Table 4.5 | EERs of system with CLAHE enhance and based on 1, 2 and 3 training data | 91 |
| Table 4.6 | EERs of system with proposed enhancement method (CLAHE then MUM) and based on 1, 2 and 3 training data | 92 |
| Table 4.7 | EERs of system with different enhancement methods with one training data | 93 |

| | | |
|------------|--|----|
| Table 4.8 | EERs of system with different enhancement methods with two training data | 94 |
| Table 4.9 | EERs of system with different enhancement methods with three training data | 96 |
| Table 4.10 | Comparison with previous related studies | 96 |

LIST OF FIGURES

| | | Page |
|-------------|--|-------------|
| Figure 1.1 | Samples of behavioural and physiological biometric modalities | 1 |
| Figure 1.2 | Seven basic criteria of a biometric trait | 3 |
| Figure 1.3 | Block diagram of verification mode of a biometric system | 3 |
| Figure 1.4 | Block diagram of identification mode of a biometric system | 4 |
| Figure 1.5 | Overall research architecture | 9 |
| Figure 2.1 | Block diagram of typical finger vein biometric system | 11 |
| Figure 2.2 | Two common ways of pattern acquisition (Hashimoto, 2006) (a) Transmission IR light, (b) reflection IR light | 12 |
| Figure 2.3 | (a) Scheme of acquisition device with reflection IR light method, (b) practical image device | 13 |
| Figure 2.4 | Samples of captured finger images | 13 |
| Figure 2.5 | Non-ideal finger vein sample from SDUMLA-FA database | 15 |
| Figure 2.6 | Histogram of original image and histogram of image after histogram equalization | 21 |
| Figure 2.7 | Block diagram of classical un-sharp mask filter | 23 |
| Figure 2.8 | Block diagram of modified classical Un-sharp mask with Log- Gabor filter | 24 |
| Figure 2.9 | Transfer function of even –symmetric Gabor filter | 25 |
| Figure 2.10 | Multi-resolution Schemes. (a) Schematic contours of filters in Fourier domain with 5 scales and 8 orientations. (b) The elongation of Log-Gabor wavelets (real parts and imaginary parts in left and right column respectively). (c) and (d) are the real part and imaginary part respectively in spatial domain | 27 |

| | | |
|-------------|---|----|
| Figure 2.11 | Inverse Fourier transform functions of Gabor and Log-Gabor at same frequency with different bandwidths (a, b, c are 1, 2 and 3 octaves respectively) | 28 |
| Figure 2.12 | Hyper-plane margin used to separation negative to positive cases | 33 |
| Figure 3.1 | Overall research framework | 40 |
| Figure 3.2 | Original finger images of both hands from a subject in SDUML-HMT Database (a, b, c are index, middle and ring fingers of left hand respectively and d, e, f are index, middle and ring fingers of right hand respectively) | 42 |
| Figure 3.3 | Data enrolment and data verification in recognition system | 43 |
| Figure 3.4 | Left and right boundaries of image | 44 |
| Figure 3.5 | Masks for detection the ROI. (a): Mask for detecting upper boundary of finger. (b): Mask for detection lower boundary of finger | 45 |
| Figure 3.6 | Boundary Detection of Three Finger Images (The original image, binary image, and edge detected, from left to right respectively) | 46 |
| Figure 3.7 | The organization of tiles in a 272×192 finger image | 47 |
| Figure 3.8 | Clipping and Redistribution According to Clip Limit β . (a) Detecting the exceeded counts. (b) Redistributing extra counts uniformly | 48 |
| Figure 3.9 | The neighbouring structure of IR tile. (a) The IR tile with its bordering regions. (b) Specified pixel and its relation with centers of its four nearest regions | 49 |
| Figure 3.10 | The neighbouring structure of BR tile. (a) The BR tile with its bordering regions. (b) Pixel p in quadrant 2 its relation with | 50 |

| | | |
|-------------|--|----|
| | centers of its four nearest regions | |
| Figure 3.11 | The Neighbouring Structure of CR tile | 50 |
| Figure 3.12 | Product of Low-pass filter to radial Log-Gabor component of filter | 52 |
| Figure 3.13 | The result of MUM algorithm and the result of CLAHE then MUM algorithm | 55 |
| Figure 3.14 | The pre-processing stage of verification system | 55 |
| Figure 3.15 | The block diagram of image modification in the pre-processing stage of system | 56 |
| Figure 3.16 | Cross-sectional profile of vein image | 60 |
| Figure 3.17 | Location of Current Tracking Point on the Cross-sectional profile | 61 |
| Figure 3.18 | The flowchart of RLT algorithm | 63 |
| Figure 3.19 | The flowchart of MRLT method | 68 |
| Figure 3.20 | (a) Finger image, (b) Binary image, and (c) Skeleton image | 68 |
| Figure 4.1 | Original finger image, contrast enhanced by CLAHE and corresponding histograms. (a),(b) and(c) are three samples of finger image | 75 |
| Figure 4.2 | Designed Log-Gabor Filter. (a) and(c) are the even-symmetric component of the filter. (b) and(d) are the odd-symmetric component of the filter. (e) Angular component of the filter. (f) The product of radial and angular components to make Log-Gabor filter | 76 |
| Figure 4.3 | Results of finger image enhancement of three sample image. (a) Original image. (b) Finger images after applying Log-Gabor filter. (c) Results of enhanced finger image by MUM algorithm | 77 |

| | | |
|-------------|---|----|
| Figure 4.4 | The results of different modification of finger vein images | 78 |
| Figure 4.5 | Finger image of subject 1 (index, middle and ring fingers of both hands) Original image, modified by CLAHE and modified by proposed method | 79 |
| Figure 4.6 | Finger image of subject 2 (index, middle and ring fingers of both hands) Original image, modified by CLAHE and modified by proposed method | 80 |
| Figure 4.7 | Finger image of subject 3 (index, middle and ring fingers of both hands) Original image, modified by CLAHE and modified by proposed method | 81 |
| Figure 4.8 | Average of MSE test for all images of database | 82 |
| Figure 4.9 | Average of PSNR test for all images of database | 83 |
| Figure 4.10 | Extracted patterns of finger vein by RLT method with different repetitions . (a) Finger sample; (b) $N = 500$; (c) $N = 1000$; (d) $N = 1500$; (e) $N = 2000$; (f) $N = 2500$; (g) $N = 3000$; (h) $N = 3500$ | 84 |
| Figure 4.11 | Vein pattern extraction of subject 1 (index, middle and ring fingers of both hands) with pre-processed by CLAHE and proposed enhance method | 85 |
| Figure 4.12 | Vein pattern extraction of subject 2 (index, middle and ring fingers of both hands) with pre-processed by CLAHE and proposed enhance method | 86 |
| Figure 4.13 | Vein pattern extraction of subject 3 (index, middle and ring fingers of both hands) with pre-processed by CLAHE and proposed enhance method | 87 |

| | | |
|-------------|--|----|
| Figure 4.14 | Performance of system with extracted pattern of original images | 90 |
| Figure 4.15 | Performance of system with extracted pattern of enhanced image by CLAHE | 91 |
| Figure 4.16 | Performance of system with extracted pattern of enhanced image by proposed method (CLAHE then MUM) | 92 |
| Figure 4.17 | Performances of system with different enhancement method with one training data | 93 |
| Figure 4.18 | Performances of system with different enhancement method with two training data | 94 |
| Figure 4.19 | Performances of system with different enhancement method with three training data | 95 |

LIST OF ABBREVIATIONS

| | |
|--------|--|
| AHE | Adaptive Histogram Equalization |
| BBHE | Brightness Bi-Histogram Equalization |
| BR | Border Region |
| CCD | Charge-Coupled Device |
| CDF | Cumulative Density Function |
| CLAHE | Contrast Limited Adaptive Histogram Equalization |
| CR | Corner Region |
| CTP | Current Tracking Point |
| DNA | Dexoyribo Nucleic Acid |
| DSIHE | Dualistic Sub-image Histogram Equalization |
| EER | Error Equal Rate |
| et al. | (et alia): and others |
| FAR | False Acceptance Rate |
| FIR | Finite Impulse Response |
| FFT | Fast Fourier Transform |
| FRR | False Rejection Rate |
| GAR | Genuine Acceptance Rate |
| HE | Histogram Equalization |
| ID | Identity Document |
| IR | Inner Region |
| KPCA | Kernel Principal Component Analysis |

| | |
|-------|---|
| LBP | Local Binary Pattern |
| LDA | Linear Discriminate Analysis |
| LDP | Local Direction Pattern |
| LED | Light Emitting Diodes |
| LLBP | Local Line Binary Pattern |
| MLP | Multilayer Perception |
| MRLT | Modified Repeated Line Tracking |
| MSE | Mean Square Error |
| MUM | Modified Un-sharp Mask |
| NIR | Near-Infrared Reflectance |
| PBBM | Personalized Best Bit Map |
| PCA | Principal Component Analysis |
| PSNR | Peak Signal Noise Ratio |
| PWM | Personalized Weight Maps |
| RLT | Repeated Line Tracking |
| RMSHE | Recursive Mean-Separate Histogram Equalization |
| ROC | Receiver Operation Characteristic |
| ROI | Region of Interest |
| RSWHE | Recursive Separated and Weighted Histogram Equalization |
| SVM | Support Vector Machine |

LIST OF SYMBOLS

| | |
|-----------------|----------------------------|
| β | Clip limit value |
| σ_ρ | Angular bandwidth |
| σ_θ | Radial bandwidths |
| θ_{pk} | Frequency center of filter |
| D_{lr} | Dimension left to right |
| D_{du} | Dimension down to up |
| N_r | Neighbouring pixel |
| p_{new} | New pixel value |
| p_{old} | Old pixel value |
| R | Maximal signal power |
| T_r | Locus matrix |
| (x_c, y_c) | Current tracking point |

**SISTEM BIOMETRIK URAT JARI BERASASKAN PENURAS LOG-GABOR
MENGUNAKAN ALGORITMA PENJEJAKAN GARIS ULANGAN
TERUBAHSUAI**

ABSTRAK

Prestasi sistem pengecaman vena jari bergantung pada kualiti imej yang ditangkap. Walaupun topeng penyahtajaman lurus klasik mampu mempertingkatkan bahagian gelap dan bayang-bayang imej urat jari, tetapi imej yang dipertingkatkan akan mengalami dua kekurangan. Pertama, kesan halo yang muncul di sekitar kawasan imej yang lebih tajam. Kedua, hingar yang wujud dalam imej juga akan dipertingkatkan. Kajian ini mengubah topeng penyahtajaman lurus klasik dengan menggunakan penapis Log-Gabor. Topeng Penyahtajaman Diperbaiki (MUM) meningkatkan kontras dan ketajaman imej tanpa kelemahan yang disebutkan di atas. Kajian ini memperkenalkan peringkat pra-pemprosesan dalam sistem pengesanan vein jari yang mana, mulanya, kaedah penyamaan Histogram Pengesuaian Had (CLAHE) akan digunakan pada imej masukan dan kemudiannya teknik MUM digunakan untuk meningkatkan ketajaman dan kontras imej urat jari. Hasil daripada ciri yang diekstrak menunjukkan peningkatan yang cemerlang dalam mengenalpasti perincian vena dengan menggunakan kaedah prapemprosesan yang dicadangkan ini. Penjejakan Garis Ulangan Terubahsuai (MRLT) digunakan sebagai kaedah pengekstrakan ciri Manakala Mesin Vektor Sokongan (SVM) digunakan sebagai pengelas. Kadar Kesalahan Seimbang (EER) digunakan sebagai pengiraan prestasi dalam kajian ini. EER yang diperolehi untuk sistem pengesanan dengan menggunakan tiga data latihan ialah 16.66% untuk imej asal, 14.22% untuk imej CLAHE yang dipertingkatkan dan 6.28% untuk imej bagi kaedah yang dicadangkan (CLAHE kemudian MUM).

LOG-GABOR FILTER BASED FINGER VEIN BIOMETRIC SYSTEM USING MODIFIED REPEATED LINE TRACKING ALGORITHM

ABSTRACT

The performance of finger vein recognition system relies on the quality of captured image. Although the classical linear Un-sharp mask can enhance the dark and shadowy parts of finger vein image, but the enhanced image suffers two drawbacks. First, the halo effects that appears around sharper areas of image. Second, the noises which exist in image are over enhanced. This study modifies the classical linear Un-sharp mask with use of Log-Gabor filter. This Modified Un-sharp Mask (MUM) enhances the contrast and sharpness of image without aforementioned drawbacks. This study, introduced a pre-processing stage in the finger vein verification system which first, applies Contrast Limit Adaptive Histogram Equalization (CLAHE) method on input image then use MUM technique in order to enhance the sharpness and contrast of finger vein image. The results of extracted feature show the excellent improvement in detection of vein details by using the proposed pre-processing method. The Modified Repeated Line Tracking (MRLT) is used as feature extraction method and Support Vector Machine (SVM) is used as classifier. The Equal Error Rate (EER) is used as performance evaluation in this study. The EERs for the verification system at three training data is observed to be 16.66% for original image, 14.22% for CLAHE enhanced image and 6.28% for proposed method (CLAHE then MUM).

CHAPTER ONE

INTRODUCTION

1.1 Overview of Biometric System

The biometric technology is defined as the science of identification/verification based on behavioural or physiological characteristic of a human such as handwriting, signature, voice, face, fingerprint, iris, and DNA (RavaleNerkar, 2015; Syazana-Itqan, Syafeeza, & Saad, 2016). Figure 1.1 shows some biometric modalities that are currently used by researchers.

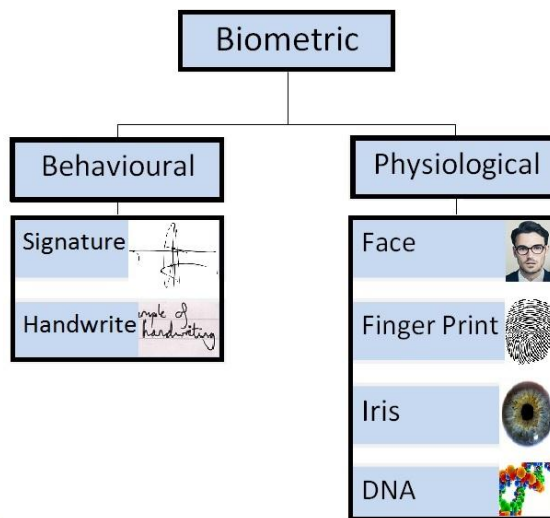


Figure 1.1: Samples of behavioural and physiological biometric modalities.

In recent decades, recognition systems which work based on biometric traits have been widely used and played an important role for individuals' identification/verification in systems and applications (Jain, Ross, & Prabhakar, 2004; Mir, Rubab, & Jhat, 2011). The conventional recognition systems such as pin code, password, and ID card are not reliable and jeopardize the security of the system. This is because the risk of being thieved by scammers is one of the reasons

that is contributed to the unreliability of them (Battacharyya, Ranjan, Alisherov, & Choi, 2009). Furthermore, it is likely being accessed by an unauthorized person which adds cautious to these systems (Connie, Teoh, Goh, & Ngo, 2003). Hence in order to maintain the privacy, security and confidentiality of systems, biometric traits can be a reliable solution.

A biometric trait of human has seven basic criteria such as universality, uniqueness, performance, permanence, acceptability, collectability and circumvention (Schuckers, 2001) that are shown in Figure 1.2.

- Uniqueness: A biometric trait needs to be unique for each person and can has the distinction between individuals.
- Universality: Every person must possess that kind of biometric trait.
- Performance: Considered as accuracy, robustness and process speed of the authentication system.
- Permanence: A biometric trait has to be constant in a certain period of time.
- Acceptability: A biometric trait must be accepted in people's view.
- Collectability: A biometric trait should have the ability to quantitatively measure by the authentication system.
- Circumvention: Considered as how easily the biometric trait which is provided by a person, can lead to failure.

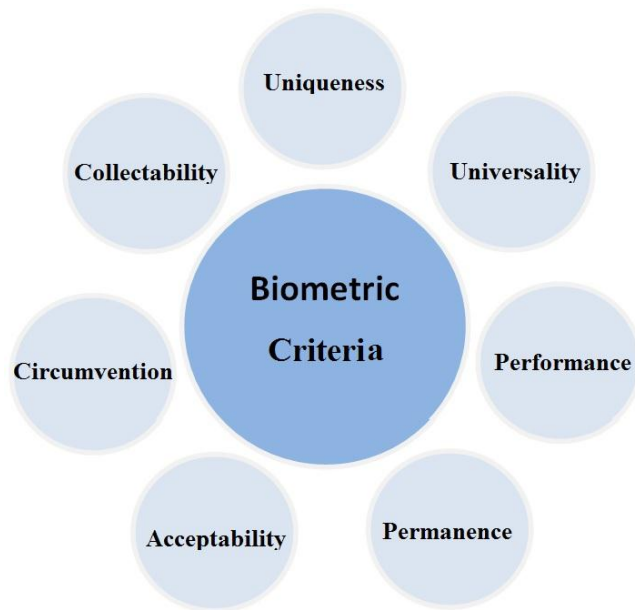


Figure 1.2: Seven basic criteria of a biometric trait

A biometric recognition system is essentially a pattern recognition system which senses a biometric trait, extraction a feature and compares it with stored template of system. In reality, the typical biometric recognition system operates in two modes of verification or identification that are shown in Figure1.3 and Figure 1.4 respectively.

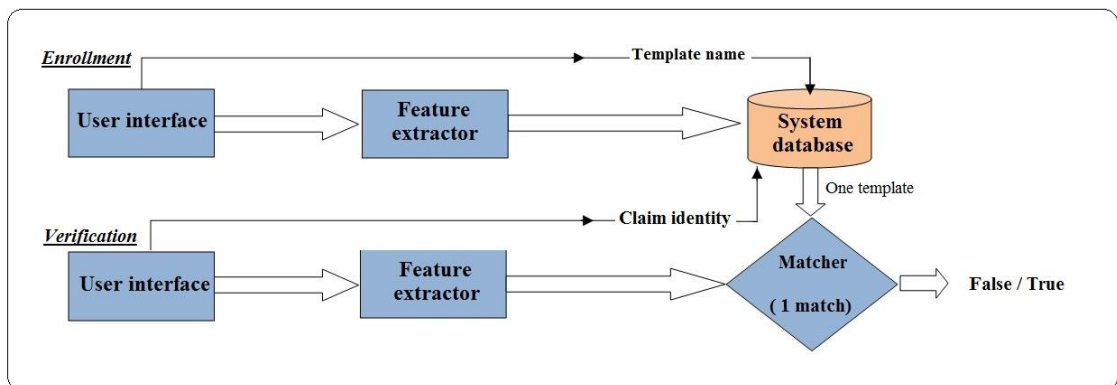


Figure 1.3: Block diagram of verification mode of a biometric system

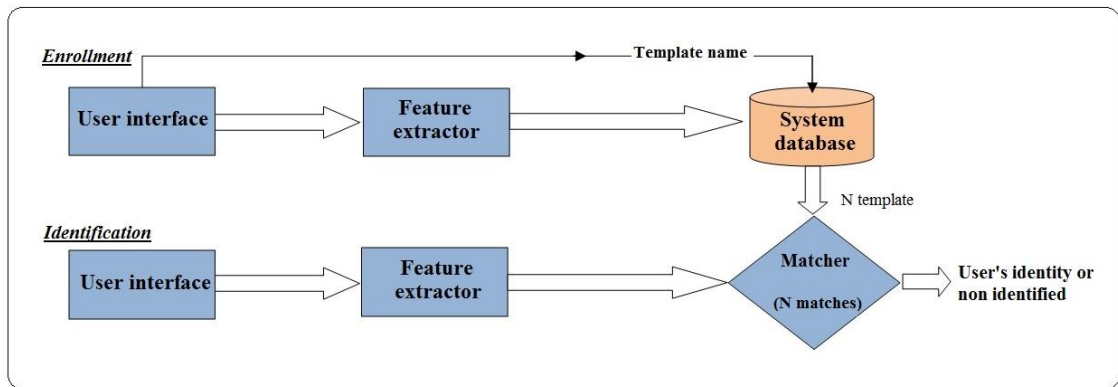


Figure 1.4: Block diagram of identification mode of a biometric system

The duty of enrolment stage is for collecting the information of users from their biometric traits and save the information in the database of the system. The identification or verification phase (recognition is the general term of both) is for extracting the feature of a biometric trait from an examination image, then compare it with the reference database of the system (Mu, 2013).

Identification and verification blocks work differently in the database comparison. The system output of identification is an identity and it is described as a one-to-many comparison. In other words, the system attempts to answer the question “ Who is the person?”. While in the verification mode, the identity of the user is authenticated and it is described as a one-to-one comparison. In other words, the system tries to answer the question “ Is this person who they say they are?” (Kornelije & Miroslav, 2007) .

1.2 Finger Vein Biometric System

Among different biometric modalities such as the face, voice, iris, fingerprint and so on, finger vein trait has more advantages. Table 1.1 shows the comparison among different biometric modalities in terms of advantage, disadvantage, security level and cost of the system (Syazana-Itqan et al., 2016).

Table 1.1 *Comparisons of Different Biometric Traits*

| Biometric Trait | Main Advantage | Disadvantage | Security Level | Sensor | Cost |
|------------------------|------------------------|---------------------------|-----------------------|---------------|-------------|
| Voice | Natural and Convenient | Noise | Normal | Non-contact | Low |
| Face | Remote Capture | Lighting Conditions | Normal | Non-contact | Low |
| Fingerprint | Widely Applied | Skin | Good | Contact | Low |
| Iris | High Precision | Glasses | Excellent | Non-contact | High |
| Finger Vein | High-Security Level | Quality of Captured Image | Excellent | Non-contact | Low |

As it is shown in Table 1.1, the finger vein biometric method has the highest security compared to other methods. Besides, it has low cost and the minimum disadvantage. Some other advantages of the finger vein biometric method are presented as follows:

- Finger vein sample can only capture from living body, therefore it is impossible to steal it from a dead person (Yang, Yang, Yin, & Zhou, 2014).
- Every person generally has ten fingers; hence if an unforeseen incident happens to any of the fingers, other fingers are available for replacement in authentication process (Xuebing , Jiangwei , & Xuezhang 2010; Yang , Shi , & Yang, 2011).
- As vein is located underneath of human’s skin, it is invisible to eyes, so the risk of steal or forgery is lower than other biometric traits.
- As finger vein acquisition process is contactless, ensuring hygiene and convenience for users.

Since the finger vein modality has many advantages such as the highest security and user convenience compared other biometric modalities, this study develops a

recognition system based on finger vein modality and tries to improve the extracted feature of finger in order to get higher accuracy rate.

1.3 Problem Statement

In order to have a recognition system with higher accuracy and lower identification error rate, the pattern of finger vascular has to be extracted precisely from the captured image. The captured finger image by a charge-coupled device (CCD) camera is not clear and it contains noise and irregular shadows since it was produced by different thickness of finger muscles and bones. Therefore, precise extraction of finger vein pattern becomes a challenge (Perez Vega , Travieso , & Alonso 2014).

Since the illumination of a digital image often need to be corrected, many scholars worked on the improvement of capturing devices in order to tune the environmental illumination as the out-coming images of the devices are either too dark or too bright (Ton & Veldhuis 2013; Yin , Liu , & Sun 2011; Yu, Shan, Sook, Zhihui, & Dong, 2013). Besides, many researchers introduced various methods of feature extraction in order to improve the precious of the extracted pattern (Kumar & Zhou 2012; Liu , Xie , Yan , Li , & Lu 2013; Miura & Nagasaka, 2004; Miura, Nagasaka, & Miyatake, 2007; Qin, Yu, & Qin, 2011; Song et al., 2011). Yet, there is still more works to do to achieve more accurate extracted pattern of finger vein.

Scholars have proposed various image enhancement methods based on different concepts of feature extraction techniques. Since the extraction method of the current study is based on Modified Repeated Line Tracking (MRLT) method which operates according to cross-sectional profile of the finger image, hence the modifications of sharpness and contrast of finger image leads to better performance of vein detection