REGISTER TRANSFER LEVEL IMPLEMENTATION OF POOLING - BASED FEATURE EXTRACTION FOR FINGER VEIN IDENTIFICATION

By

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LIST OF ABBREVIATIONS

1-NN	First-Nearest Neighbor
BLPOC	Band-Limited Phase-Only Correlation
CPU	Central Processing Unit
DC	Design Compiler
DFT	Discrete Fourier Transform
FIFO	First-In-First-Out
FPGA	Field-Programmable Gate Array
FSM	Finite State Machine
GLS	Gate Level Simulation
GPU	Graphics Processing Unit
HDL	Hardware Description Language
LBP	Local Binary Pattern
LE	Logic Element
MATLAB	Matrix Laboratory
MSB	Most Significant Bit
NCN	Nearest Centroid Neighbor
NIR	Near-Infrared Light
NN	Nearest Neighbor
PCA	Principle Component Analysis
PE	Processing Element

RAM	Random-Access-Memory
ROI	Region-Of-Interest
ROM	Read-Only-Memory
RTL	Register-Transfer Level
SOC	System-On-Chip
SRAM	Static Random-Access-Memory
SVM	Support Vector Machine
TDP	Thermal Design Power
VCS	Verilog Compiler Simulator

IMPLEMENTASI PENGEKSTRAKAN CIRI YANG BERASASKAN PERKONGSIAN DALAM BENTUK REGISTER TRANSFER LEVEL UNTUK PENGENALAN VENA JARI

ABSTRAK

Kebelakangan ini, kaedah pengenalan diri melalui biometrik yang berasaskan vena jari mendapat perhatian di kalangan para penyelidik kerana mempunyai kelebihan seperti: pengenalan diri individu yang unik, kalis usia dan tidak jelas kelihatan (sukar untuk ditiru). Terdapat banyak penambahbaikan telah dilakukan untuk memendekkan masa dan menambahkan ketepatan ke atas kaedah pengenalan tersebut. Teknik pengesktrakan ciri yang berasaskan ciri-ciri global seperti PCA telah digunapakai sebelum ini. Walau bagaimanapun, keputusan kajian tidak menunjukkan yang teknik tersebut adalah teguh kepada masalah. Oleh itu, kaedah pengekstrakan ciri tempatan telah digunapakai untuk mengatasi masalah ini. Dalam kajian ini, kaedah pengestrakan ciri berasaskan perkongsian untuk pengenalan vena jari telah digunapakai. Kaedah yang dicadangkan dilakukan dengan mengekstrak maklumat corak cap vena jari berdasarkan ciri tempatan, dan menggunakan imej tampalan berdasarkan corak vena jari tersebut untuk memperbaiki keteguhan pengenalan. Kaedah ini banyak dipegaruhi oleh kaedah "spatial pyramid pooling" atau kaedah perkumpulan berdasarkan kedudukan, ruang dan saiz corak secara piramid yang digunakan untuk pengklasifikasian imej asas dan dibantu dengan PCA. Dengan saiz imej tampalan empat, empat aras piramid [1x1, 2x2, 3x3, 4x4] dan 38% pengurangan dimensi terhadap ciri-ciri yang telah diekstrak (10 pekali-pekali PCA). kadar ketepatan sistem pengenalan ini meningkat kepada 88.69% iaitu jauh lebih tinggi daripada PCA sebanyak 10.10%. Algoritma yang dicadangkan ini telah diimplementasikan ke FPGA dengan menggunakan Verilog-HDL. Menurut hasil kajian, kaedah ini menunjukkan peningkatan terhadap kecepatan sistem pengenalan berbanding dengan

kaedah menggunakan perisian(software). Masa yang diambil untuk mengekstrak ciri bagi sistem perkakasan(hardware) untuk satu imej ialah 0.134 milisaat. Masa yang ditunjukkan oleh sistem perkakasan adalah 310 kali lebih cepat berbanding sistem perisian.

REGISTER TRANSFER LEVEL IMPLEMENTATION OF POOLING - BASED FEATURE EXTRACTION FOR FINGER VEIN IDENTIFICATION

ABSTRACT

Recently, finger vein biometric identification methods have had more attention among the researchers due to its various advantages such as: uniqueness to individuals, immunity to ages and invisibility to human eye (hard to duplicate). Many improvements methods were utilized to increase the speed and accuracy of the identification. Feature extraction techniques based on global feature extraction such as Principle Component Analysis (PCA) were implemented. However, the results did not show robustness to occlusions and misalignments on the finger vein images. Therefore, local feature extraction techniques were used to overcome these issues. A pooling based feature extraction technique for finger vein identification was implemented in this research. The proposed algorithm extracted the local feature information of the finger vein pattern (patches), and used these patches to improve the robustness of the identification. The algorithm was mainly inspired by spatial pyramid pooling in generic image classification combined with PCA. With patch size = 4, four pyramid levels = [1x1, 2x2, 3x3, 4x4] and ~38 % dimension reduction on the extracted features vector (10 PCA coefficient), the accuracy of the identification was 88.69 % which was higher than PCA by 10.10%. The proposed algorithm was implemented on hardware using Verilog-HDL, and targeting Field Programmable Gate Array (FPGA) applications. The result showed an outstanding speed improvement compared to software implementation. The time consumed by the hardware for extracting the features of one image was 310X time faster than the consumed time for software implementation. With those improvements in accuracy and the speed, the proposed algorithm contributes to the advancement of finger vein biometric system.

CHAPTER 1 INTRODUCTION

1.1 Background

Nowadays, people has started to seek high authentication methodologies to keep their information and belongings safe. It can be easily seen that most of the storing places (e.g.: banks which stores money or multinational companies stores technology, process etc..) are protected with high level of security to allow the rightful individuals to access the rightful information through a proper individual identification process. This identification process systems could be done through conventional security methods such as identification cards or security cameras which is vulnerable and less secured, or could be done through any of the conventional biometric identification system which is more secured. The conventional biometric identification systems are divided into two categories [1], the biometric identification systems that based on behavioral patterns such as voice [2], gait [3], signature [3] and the systems that based in physiological patterns such as face recognition [4] or fingerprint [5]. Those systems somehow have some disadvantages, as those features are visible to the human eyes so they can be copied fraudulently, beside those features are vulnerable and prone to damage such as the fingerprint [6]. Iris recognition is considered as the least user-friendly biometric system as during the capturing process, the brightness of the emitted light tends to cause discomfort for the human eyes. Beside the accuracy is very sensitive to the illumination variance, poses and facial expressions [7].

Recently, the biometric recognition method based on vascular patterns have had the most attention among the researchers and technologies, such as hand-vein [8] and finger-vein [9] as it has excellent advantages that will be summarized shortly. A finger-vein pattern resides inside the human's finger which gives her a big immunity to forge, it also exhibits excellent features advantages such as[6]:

- It is unique to everyone including identical twins.
- It is immune to ages, which means your finger-vein feature doesn't change with time.
- It is invisible to human eyes, so it is secure, can't be replicated or imitated.
- The acquisition of the finger-vein pattern is very user friendly, unlike iris pattern acquisition.
- Every individual has ten available finger, so under bad circumstances happen to one of the fingers, other fingers can be used as a replacement for the authentications.

As have mentioned earlier, the finger-vein is not seen by the naked eye, it requires a special device to detect the vein pattern. A Near-infrared light wavelengths between 700 and 1000 nanometers is usually used to capture the finger-vein pattern. The principle of operation is that the hemoglobin in the vein's blood absorbs the near-infrared light intensively but the light is going through the other tissues of the finger, then the vein pattern in the finger will be captured as a shadow [10]. Figure 1-1 shows how finger-vein is captured

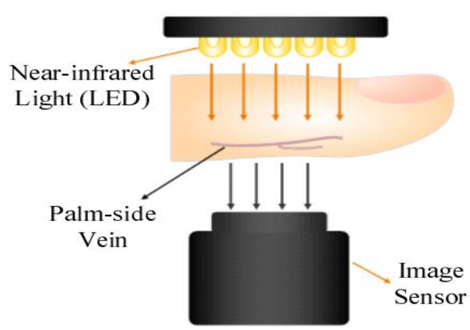

Figure 1-1 Finger vein image acquisition [10]

As mentioned earlier, finger-vein has many advantages over other biometric identification system. Hence, this research focuses on the finger-vein pattern recognition. Furthermore, it proposes an efficient feature extraction method for finger-vein pattern recognition which is inspired by spatial pooling in generic image classification to improve the identification accuracy. This is carried out using MathWorks Matrix Laboratory (MATLAB). In addition, the proposed algorithm was developed in Register Transfer Level (RTL) targeting Field-Programable Gate Array (FPGA) Application.

1.2 Problem Statement

Finger vein recognition uses the unique pattern that extracted from the vein image to identify individuals at a high level of accuracy, However, those images are not always clear, they might show irregular shadings and highly saturated regions. Furthermore, feature extraction based on global feature extraction are not robust to misalignment and occlusions on the images [11]–[14]. Therefore, the identification errors might be increased while extracting the accurate vein pattern [15]. However, feature extraction based on local feature extraction has proven more robust against those problem (e.g. histograms of local binary patterns (LBP) [16] Gabor features [17]–[19] and their fusions [20] have proven to improve the robustness of face recognition systems . This research proposes a finger vein recognition system that extracts local information of finger-vein pattern (patches), and uses this information to increase the robustness of the identification. This research illustrated, along with a linear classifier, features formed by simply pooling local patches over a multi-level pyramid can achieve state-of-the-art performance on face recognition [21].

Another problem that affecting the finger vein identification is the speed of detection, when the feature extraction is implemented and verified on software it requires a long processing time. The pooling based feature extraction is based on dividing each single image into several patches, and those patches are used for pre-processing before detection stage. The sequencing on processing for the software and the lack of parallelism make the feature extraction slow. Various hardware techniques can be used to improve the processing time; this research will cover this area as well.

1.3 Research Objectives

1. To improve the accuracy of finger vein identification by utilizing pooling-based feature extraction method.
2. To implement the proposed feature extraction method on RTL targeting FPGA application.

1.4 Scope of Research

The proposed algorithm in this research was derived from an implementation presented in [21]. However, there were no classification, image acquisition, ROI extraction and image enhancement for the acquired images since they were out of the scope of this research. As such, the accuracy and speed of identification were tested on the FV-USM database [22] .The hardware implementation was carried out to HDL synthesis utilizing FPGA. It was simulated using Intel-ModelSim on a local machine. The speed was measured from the simulation based on a single test sample and the entire dataset.

1.5 Research Contribution

The research contributions targeted the accuracy improvement of finger vein identification by proposing an algorithm and implementing it on software using MATLAB. Next, an RTL architecture was developed and synthesized to utilize FPGA applications by parallelizing the algorithm in hardware.

1.6 Thesis Outline

The remainder of this thesis consists of four chapters. The literature review in Chapter 2 examines existing finger vein feature extraction algorithms; their identification accuracy and drawbacks, and RTL implementations of finger vein feature extraction algorithms; their speed improvements and their limitations. Chapter 3 describes the overall methodology of the research. It describes in detail the steps taken to implement the proposed algorithm, how it works and how is the accuracy compared. Part 2 proposes the RTL architecture of the algorithm, how it works and how is the speed improvements measured. Chapter 4 contains the results of the algorithm supported by explanations on the improvements in accuracy. The simulation of the RTL implementation in ModelSim is also described here. The hardware speed improvement is measured against a computer running a MATLAB-based algorithm. Chapter 5 wraps up this research with a conclusion, as well as providing several future works that can be explored to further improve finger vein identification accuracy and speed.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Biometrics system is referring to the way of identifying or recognizing individuals by using physiological or behavioral human features. Physiological biometrics are those which identify or recognize individuals from biological or physiological features like hand geometry, finger vein, face, fingerprint, iris, etc. [22]. Behavioral biometrics on the other hand, are those which identify or recognize individuals from human behavior or attitude such as signature, hand writing or voice recognition. There have been several kinds of biometric recognition systems such as fingerprint, face, iris. However, these conventional systems have some problems in terms of convenience and performance [23].

Finger vein is a relatively new biometric system; hence it is important to ascertain that finger vein qualifies as a biometric system. So, the criteria of a biometric system were discussed here in this chapter. The advantages and disadvantages of the biometric system was discussed as well. Since finger vein is relatively new, then the identification flow is not generally known and was described in this chapter.

For biometric identification flow, feature extraction algorithms were needed. The pooling-based feature extraction [22] was studied for finger vein identification to improve the accuracy of the identification. Finally, various hardware implementations were reviewed and studied to find the most suitable way to implement the proposed algorithm in hardware.

2.2 Criteria of a Biometrics

There are different types of biometric identification systems each has its own features of interest which are used to identify individuals. The question is which human biological measurement could be qualified to be used as a biometric characteristic? This question has been described in [24]. As any human physiological and/or behavior characteristic can be used as a biometric characteristic if it satisfies the following requirements:

- Distinctiveness: the characteristics should be a unique biological characteristic to individuals. And those characteristics could be divided into two groups:
  - Physiological: features like iris patterns, finger vein, fingerprint, etc.
  - Behavioral: features such as voice, signature, etc.
- Universality: those characteristics should be possessed by all individuals.
- Collectability: those characteristics could be measured quantitatively using any sort of measuring device.
- Performance: those characteristics should be sufficiently invariant.

However, in practical biometric system, there are some other criteria that should be considered [24].

- Circumvention: which indicates the immunity of the system against fraudulent methods.
- Acceptability: which reflect the acceptance and comfortability of the individual to use this this biometric identifier in their daily lives.
- Performance: which indicate the accuracy and the speed of the biometric identification system.

2.3 Biometric Systems Advantages and Disadvantages

Currently, many biometric identification systems are in use due to the increasing demand for high security measures. Hence, some of the advantages of the biometric identification systems were summarize as below[25] :

- Security enhancement: losing identity cards or sharing pin number or password can lead to security issues. However, using biometric system will enhance the security and reduce the risks as it has unique identifiers for individuals and it is almost impossible to be imitated.
- User friendly: individual doesn't have to remember different passwords or carry more identity cards, which make it very convenient to the end users.
- Low cost: industry improvements have led to decrease the cost of biometric systems, making them affordable to many end users. For example, most of the laptops are equipped with fingerprint scanners.

In addition, there are some drawbacks that should be mentioned as well [25].

- Privacy: the information gathered about individuals from the biometric system is valuable and should be kept in a secure storage from attackers same as passwords and PINs, etc.
- Physical harm: it is believed that iris detection device may cause damage to eyes, and for some individuals touching the same device used by others can cause diseases spread. However, biometric systems didn't cause any damages to human beings.
- Fake biometrics: One of the drawbacks of biometric systems is that artificial or simulated samples can be made. To overcome these problems, liveliness detection can be performed which controls if the presented sample is from a live human being or not.

- Stolen credentials: stealing biometric attributes is very difficult. However, there are some cases where individual's parts have been stolen to overcome the system and in such cases the biometric data can't be reset or replaced like the password.

2.4 Finger Vein Based Biometric System

Finger vein is qualified as a biometric system, as it meets the criteria described in section 2.2. These criteria were summarized and discussed regarding the advantages of finger vein as a biometric system. Next, the general flow of the finger vein identification system was described.

- Distinctiveness: Finger vein patterns are unique for individuals including identical twins [26].
- Universality: all human beings have finger veins as it is part of the human body.
- Collectability: NIR (near-infrared light) is used to capture the finger vein pattern.
- Performance: the finger vein patterns are time invariant and doesn't change with age.

2.4.1 Finger Vein Biometric Advantages

Finger vein as a biometric identification system exhibits excellent feature advantages against other biometric system identification system and those advantages are summarized as below[6]:

- It is unique to everyone including identical twins.
- It is immune to ages, which means finger-vein feature doesn't change with time.
- It is invisible to human eyes, so it is secure and can't be replicated or imitated.
- The acquisition of the finger-vein pattern is user friendly compared to iris pattern acquisition.

- Every individual has ten available finger, so under bad circumstances happen to one of the fingers, other fingers can be used as a replacement for authentications.

2.4.2 Finger Vein Biometric Flow

Finger vein identification flow is described in Figure 2-1. Firstly, the finger vein image was captured. Then, the Region-Of-Interest (ROI) was extracted usually through cropping, which contains the finger vein pattern. After that, post-processing operation starts on the ROI to improve the accuracy and the speed of the identification. This operation consists of multiple stages, namely: image resizing, image enhancement and normalization. Once the Finger vein database is created, new finger vein images were collected using the same individuals to avoid discrepancies. Same post-processing operations were performed on the new finger vein images. After collecting all the images, one of the feature extraction methods was implemented to extract the feature row vectors for both the database images and the new finger vein images. Finally, these feature row vectors are sent to a classifier. The classification process seeks to find a match for the new finger vein by comparing the feature row vectors of the new finger vein to the feature row vectors stored in the database. Then, the classifier assign a class for the new finger vein based on the comparison results. Finally, a comparison is carried out between the assigned class by the classifier and the actual class to measure the accuracy of the identification algorithm.

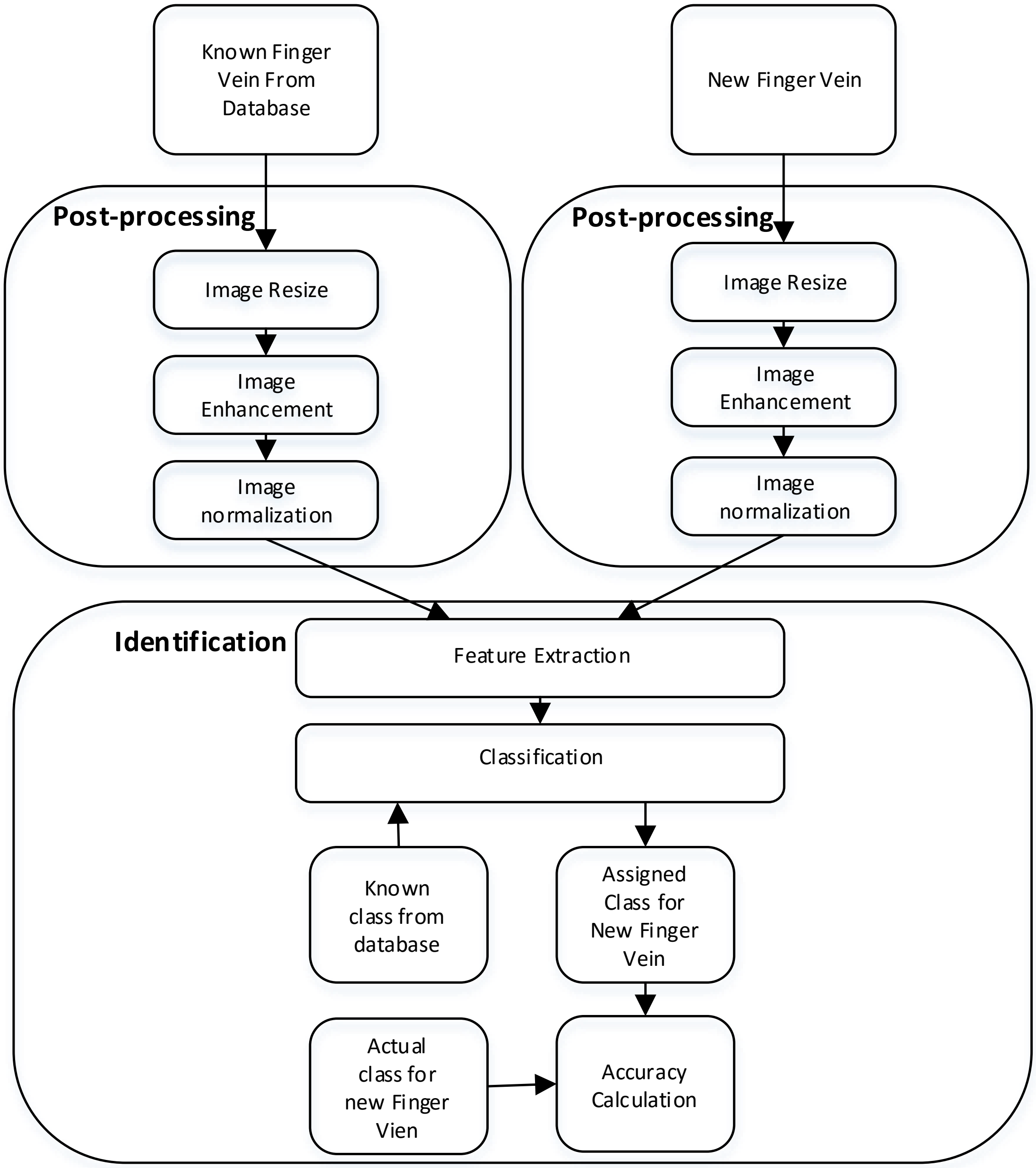

Figure 2-1 Finger vein identification flow (adapted from [7]).

As mentioned earlier, the first step is to acquire the finger vein images. There are many challenges in the finger vein acquisition process. [6] Firstly, the finger vein acquisition device that being used to capture the image, it has a great impact on the quality of the image. During the acquisition process, the distance between the camera and the finger is short, this close distance might cause optical blurring on the captured image. Besides, the lighting of the capturing device is very critical attribute for the system.

Poor lighting might cause the image to be extremely dark or extremely bright. In addition, the position of the finger is also important so it must be guided. If the finger is not guided, the finger could be misaligned thus mismatch may occur which may lead to a lower recognition rate. some other factors might affect the system like the thickness of bones and skin as it is varied for every individual. Therefore, light scattering may happen as the human's skin layer is not consistent[6]. The noise on the captured images need to be eliminated as much as possible. Consequently, to overcome the those issues, the conventional finger vein recognition methods implemented complex image preprocessing algorithms to the system. Figure 2-2 shows various lighting effects in finger-vein samples.

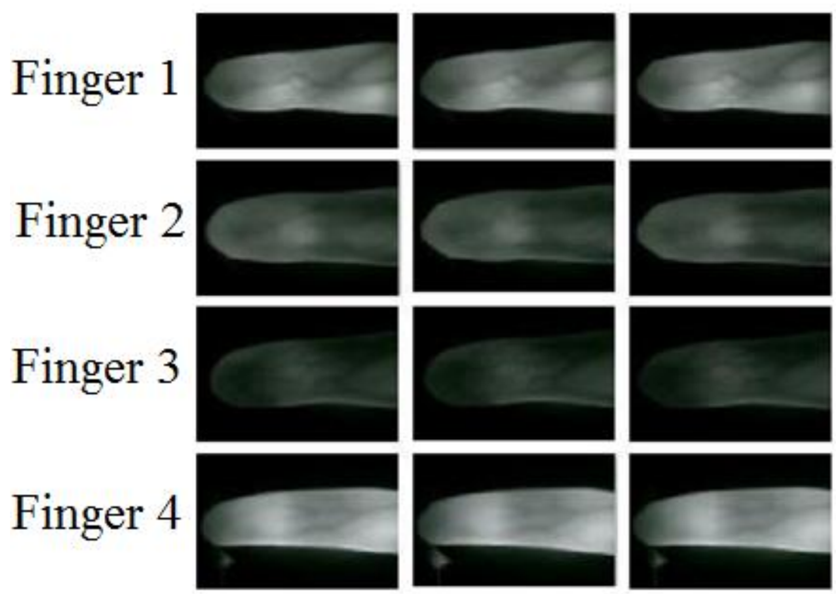

Figure 2-2 Various lighting effects in finger-vein samples [6].

There are no much publicly available finger vein databases. This research utilized a dataset