UNIVERSITI PUTRA MALAYSIA

FINGERPRINT IMAGE COMPRESSION USING WAVELET TRANSFORM

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By

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Thesis submitted to School of Graduate Studies, Universiti Putra Malaysia, in Partial Fulfillment of the Requirement for the Degree of Master of Science

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DEDICATION

In the name of God

I dedicate this thesis to my parents

And my wife

My brothers, sisters and my friends.

Abstract of thesis presented to the Senate of the Universiti Putra Malaysia In partial fulfillment of the requirement for the Degree of Master of Science

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Chairman: Abdul Rahman Ramli, Ph.D.

Faculty : Engineering

The fingerprint is considered to be the most reliable kind of personal identification because it cannot be forgotten, misplaced, or stolen. Fingerprint authorization is potentially the most affordable and convenient method of verifying a person's identity.

Storage of fingerprint image databases needs allocation of huge secondary storage devices. To reduce the increasing demand on storage space, efficient data compression techniques are needed. In addition to that, the exchange of fingerprint images between the governmental agencies could be done fast. The compression algorithm must also preserve original information in the original image.

Digital image compression based on the ideas of subband decomposition or discrete wavelet transform (DWT) has received much attention in recent years. In

fact, wavelet refers to a set of basic function, which is recursively defined form, a set of scaling coefficients and scaling function. Discrete Wavelet Transform (DWT) represents images as a sum of wavelet function on different resolution level. Essential for wavelet transform can be composed of any function that satisfies requirements of multi-resolution analysis. It means that there exists a large selection of wavelet families depending on choice of wavelet function.

The objective of this study is to evaluate a variety of wavelet filters using Wavelet toolbox for selecting the best wavelet filters to be used in compress and decompress of selected fingerprint images. Therefore a two-dimensional wavelet decomposition, quantization and reconstruction using several families of filter banks were applied to a set of fingerprint images.

The results show that no specific wavelet filter performs uniformly except for Biorthogonal and Symlets, and that is using the matching technique. The result shows that at a threshold value equal of 160 and decomposition level 3 with a wavelet filter sym4, there is no difference between the original and reconstructed image.

This study concludes that using wavelet filters sym4 and bior3.7 can achieve compression ratio 27:1 with PSNR 20.36 dB and 17:1 with PSNR 21.88 dB respectively. These values indicate that using these filters, the quality of the reconstructed fingerprint still exist.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi syarat untuh ijazah Master Sains

PEMAMPATAN IMEJ CAP JARI MENGGUNAKAN PENJELMAAN WAVELET

Oleh

ABDALLA MUSBAH HANASHI

Jun 2003

Pengerusi: Abdul Rahman Ramli, Ph.D

Fakulti : Kejuruteraan

Cap jari adalah kaedah pengenalan diri yang paling boleh dipercayai kerana ialah tidak boleh dilupakan, tersalah letak atau dicuri. Pengesahan menggunakan cap jari juga merupakan cara pengesahan yang paling murah dan mudah untuk mengenalpasti seseorang.

Penyimpanan imej cap jari di dalam pengkalan data memerlukan perkakasan penyimpan yang mempunyai ruang penyimpanan yang besar. Justeru itu, pengurangan ruang penyimpanan menggunakan teknik mampatan data yang sesuai amat diperlukan. Tambahan pula, penghantaran imej cap jari di antara organisasi boleh dipercepatkan dengan saiz imej cap jari yang lebih kecil. Algoritma mampatan mesti memastikan maklumat asal di dalam imej asal masih dikekalkan.

Mampatan imej digital yang berdasarkan kaedah penguraian sub-jalur atau pemindahan wavelet terputus (DWT) telah mendapat banyak perhatian sejak kebelakanagan ini. Wavelet adalah merujuk kepada suatu kumpulan asas fungsi yang telah didefinasi di dalam bentuk berulang, pengkali berskala dan fungsi berskala. DWT mewakili imej-imej sebagai penjumlahan wavelet pada peringkat resolusi yang berbeza. Asas DWT adalah terdiri daripada sebarang fungsi yang memenuhi keperluan analisis pelbagai resolusi. Bergantung kepada fungsi wavelet, terdapat banyak pilihan diantara keluarga wavelet.

Objektif tesis ini adalah berkenaan penilaian pelbagai penapis-penapis wavelet menggunakan peralatan perisian (*toolbox*) wavelet untuk memilih penapis-penapis wavelet yang terbaik untuk digunakan di dalam mampatan dan penyahmampatan imej-imej cap jari yang dipilih. Pemecahan dua-dimensi anak isyarat iaitu menggunakan kaedah kuanta (*quantization*) dan pembinaan semula (*reconstruction*) dijalankan ke atas cap-cap jari dengan menggunakan beberapa keluarga penapis-penapis.

Keputusan menunjukkan tiada penapis wavelet isyarat yang mempunyai keupayaan yang lebih tinggi daripada yang lain kecuali di dalam kes biorthogonal dan symlets. Keputusan dengan menggunakan teknik pemadanan pada nilai ambang 160 menunjukkan tiada perbezaan di antara imej-imej asal dan imej-imej yang dibina semula untuk pemecahan peringkat ke tiga dan penapis anak isyarat sym4.

Tesis ini menyimpulkan bahawa dengan menggunakan penapis-penapis sym4 dan bior3.7 masing-masing boleh memperolehi nisbah mampatan 27:1 dengan PSNR

20.36 dan 17:1 dan PSNR 21.88. Nilai-nilai ini menunjukkan kualiti imej-imej asal cap jari yang dibina semula masih wujud.

ACKNOWLEDGEMENTS

بسم الله الرحمن الرحيم

أن من يستحق الشكر حقا هو الله سبحانه وتعالى علي عظيم فضله وتوفيقه لي في إتمام هذا البحث المتواضع فله الحمد والشكر سبحانه وتعالى. كذلك شكر وتقدير ومحبه عظيمة الى ابي وأمي الأعزاء لدعائهما لي بالتوفيق ال سنوات العمر الماضية لما وصلت الى هذه الدرجة. ولا يفوتني أن طوال فترة دراستي.

First of all, I would like to express my utmost thanks and gratitude to Almighty Allah S.W.T for giving me the ability to finish this thesis successfully.

As I am nearing my graduation, I am having a mixed feeling of accomplishment excitement about the future, and gratitude to every one who has contributed generously to the realization of this work. My special thanks goes to my supervisor, Dr. Abdul Rahman Bin Ramli, for his continuous support and for providing the research materials.

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LIST OF ABBREVIATIONS

FBI	:	Federal Bureau Investigation
NIST	:	National Institute of Standard and Technology
HVS	:	The human Visual System
DCT	:	Discrete Cosine Transform
DFT	:	Discrete Fourier Transform
WT	:	Wavelet Transform
AFIS	:	Automated Fingerprint Identification System
WSQ	:	Wavelet Scalar Quantization
RLC	:	Run-length coding
MSE	:	Mean-Square Error
RMSE	:	Root-mean-square error
PSNR	:	Peak Signal-to-Noise ratio
DWT	:	Discrete Wavelet Transform
WVQ		Wavelet Vector Quantization

CHAPTER I

INTRODUCTION

1.1 Introduction

With the continuing growth of modern communication technology, demand for image compression and storage is increasing rapidly. Advance in computer technology for mass storage and digital processing have emphasized the need for implementing advanced image compression technique to improve the efficiency of image compression.

The objective of image compression is to represent an image with as few bits as possible while preserving the level of quality and intelligibility required for the given application. There are many applications, which involves image compression, such as broadcast television, computer communication etc.

The Federal Bureau Investigation (FBI) identification division collected 25 millions fingerprint cards in 1992 (Jang, 1997). Each fingerprint card required 9.8 MB of storage (39 square inches scanning size with 500 DPI resolutions and 8 bpp) according to the image capture standard established by the National Institute of Standard and Technology (NIST). Thus, 25 million fingerprint cards required 245,000 GB of storage. To reduce the storage requirements, the captured data must be compressed. The minutia and their relation in fingerprint are the key feature for identification. That means any reconstructed image must preserve these feature.

The Human Visual System (HVS) indicate that a transform coding based on generalized entropy reduction can reach the goal of the best-reconstructed quality with the highest compression ratio. There are many transform coding techniques. In this thesis we use wavelet coding, because every function in wavelet basis is dilated and translated version of one mother wavelet that allows local transformation to be carried out more successfully than other technique such as Discrete Cosine Transform (DCT), and Discrete Fourier Transform (DFT) for image compression.

1.2 Objective of Thesis

The aim of this thesis is to study and investigate the effect of wavelet transform (WT) in the application of fingerprint image compression.

The tasks of this thesis are:

1. Applying different wavelet filters namely: Daubechies, Coiflets, Biorthogonal and Symlets to select the best one for fingerprint images.
2. The best wavelet filter will be applied to compress and decompress fingerprint images.
3. Evaluate compressed images using Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) and Matching Technique.

1.3 Organization of Thesis

The thesis is to study the suitability of wavelet transform (WT) in the application of fingerprint image compression techniques, using MATLAB codes as platform.

This thesis is divided into five chapters. Each chapter has a specific approach. The chapters are classified into introduction, literature review, methodology, result and discussion and the last is conclusion and future work.

Chapter II introduces the historical overview of fingerprint. The fundamental and principles of fingerprint, review of fingerprint compression and fingerprint characteristics. Image representation, the fidelity criteria normally used in determining the quality of a decompressed image and the several of image compression techniques are discussed here.

Chapter III discusses the fingerprint image compression technique. First stage is preprocessing, which describe the fingerprint image enhancement, selecting the type of wavelet filters and perform the discrete wavelet transform and compression are explained in detail.

Chapter IV discusses the result of compression technique and discussion of the result, Finally, Chapter V is concerned with the concluding remarks (conclusion) and proposal for future work (recommendations).

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

If we studied our own body, we will realize that our palm and the inner skin of our foot, will be different from the rest of the skin, because of the this characteristic, people are getting interested to find it's advantages and usefulness. When a person touches something, they will leave a thin layer of sweat on the surface of the thing. Sweat is produced from the continuous burning process in our body, which consists mostly of water (H_2O) and some mixture of salt (NaC1) and fat. After a while the water from the sweat will evaporate, leaving the salt and fat behind. The layer that is left produces fingerprint (Saferstein, 1981).

Fingerprint pattern is different for each person in the world even for a twin. Every person's fingerprint is unique and is a feature that stays with the person throughout his/her life. It also never changes since is person born until the person is dead. It will change only if burned or cut.

The fingerprint is the most reliable kind of personal identification because it cannot be forgotten, misplaced, or stolen. Fingerprint authorization is potentially the most affordable and convenient method of verifying a person's identity. The uniqueness of a fingerprint can be determined by the pattern of ridges and valleys as well as the minutiae points (Zeena, 2001).

2.2 Fingerprint: A Historical Overview

There are two definite periods in the history of fingerprinting. The first period began when human beings became aware of fingerprints and uses them as a mean of individual signature. The second period is much more recent and began with the development of fingerprint coding and filing systems and techniques of searching for the question of who was the first person to recognize fingerprints as a valuable recognizing characteristic will probably remain unanswered. The Chinese and Babylonians (Iraqis) used fingerprints on business contracts. Evidence existed that the Chinese used the fingerprints to sign legal documents as far back as three thousand years ago. The early Egyptians and Chinese were known to have used the fingerprints to identify criminals and to record business transactions. However, whether this use was performed for ceremonial custom or as a mean of personal identity remains a point of conjecture lost to history. In any case, the examples of fingerprint techniques in ancient history are ambiguous, and the few that do exist certainly did not contribute to the development of fingerprinting techniques as known today (Sharath, 2000).

Fingerprints are one of the most mature biometric technologies and are considered legitimate proofs of evidence in courts of law all over the world. Fingerprints are, therefore, used in forensic divisions worldwide for criminal investigations (Sharath, 2000). More recently, an increasing number of civilian and commercial applications are either using or actively considering using fingerprint-based identification because of a better understanding of fingerprints as well as demonstrated matching performance than any other existing biometric technology.

2.3 The Fundamental Principles of Fingerprint

Three fundamental facts made the fingerprints a superlative method for personal identification and accepted by courts:

- A fingerprint is an individual characteristic; no two fingerprints have yet been found to possess identical ridge characteristics. Early fingerprint experts consistently referred to Galton's calculation (the probability that two fingerprint are alike is about 1 in 1.9×10^{15}) showing the possible existence of 64 billion different fingerprints to support this contention. Later, researchers questioned the validity of Galton's calculation. However, no matter what mathematical model one refers to, the conclusions are always the same: the probability for the existence of two identical fingerprint patterns in the world's population is extremely small (Sharath, 2000). Not only this principle is supported by theoretical calculations, but also just as importantly, it is verified by the millions upon millions of individuals who have had their prints classified over the past 70 years, not two have ever been found to be identical (Jain, 2000).

- A fingerprint will remain unchanged during an individual's lifetime. The skin is composed of layers of cells. Those nearest the surface make up the outer portion of the skin known as the epidermis. The inner skin is known as the dermis. Looking at across section of the skin, a boundary of cells separating the epidermis and dermis is noted. It is the shape of this boundary, which is made up of dermal papilla that determines the form and pattern of the ridges on the surface of the skin once the dermal papillae developed in the human fetus, the ridge patterns will remain unchanged throughout life except to enlarge during growth.

- Fingerprints have general ridge patterns that permit them to be systematically classified.

Fingerprints are divided into three major classes on the basis of their general patterns: loop, whorl, and arch. Sixty to sixty five percent of the population has loops, thirty to thirty five percent have whorls, and about five percent have arches (Sharath, 2000).

The sub classes are:

Arch: It is the simplest and the least distinctive pattern. The ridges in this pattern flow from one side rise to form a wave in the center and exit smoothly on the opposite side with no angles of 90 degrees or less. Also, no ridges that recurve and go out the same side from which they entered, and no up thrusting ridges that do not follow the general flow of the ridges. Figure 2.1 shows a typical arch pattern.

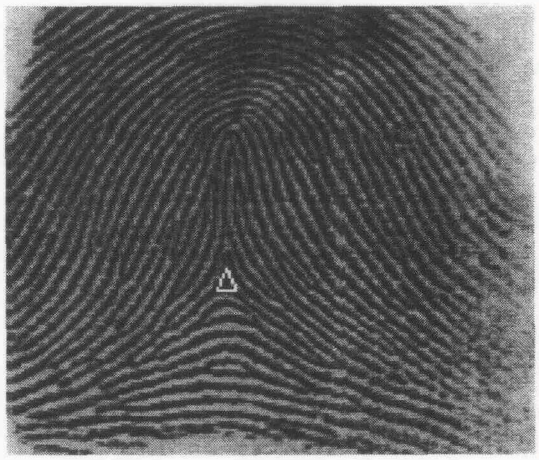


Figure 2.1: Arch fingerprint pattern

Loop: It is a pattern in which one or more of the ridges enter on the side towards the thumb or the little finger, recurve, and then exit on the same side. Figure 2.2 shows a loop fingerprint pattern.

Figure 2.2: Loop fingerprint pattern

Whorl: It is a pattern in which one or more ridges form a complete revolution around the center. Figure 2.3 shows a simple whorl pattern.

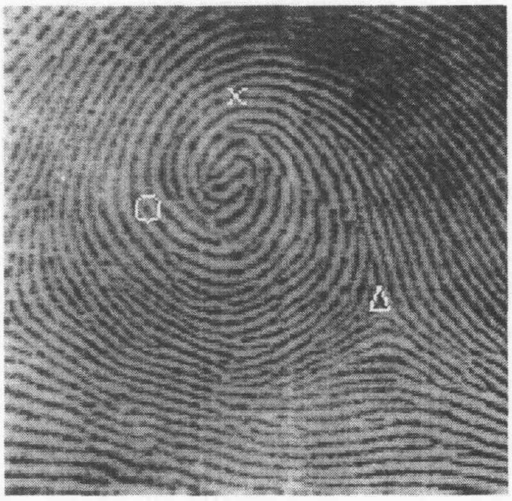
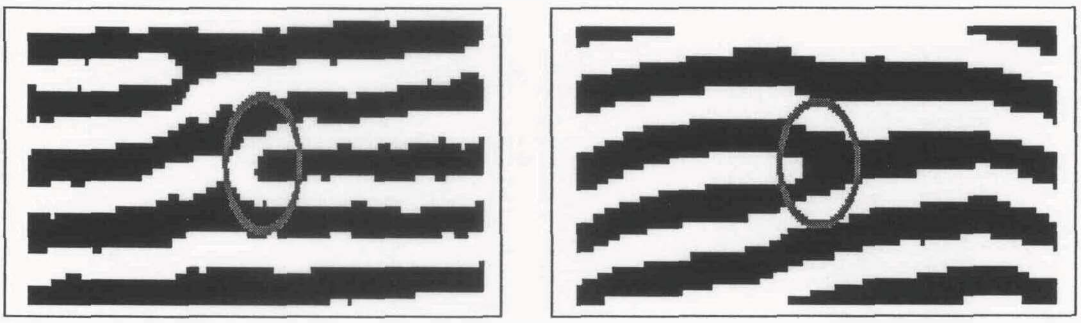


Figure 2.3: Whorl fingerprint pattern

2.4 Fingerprint Representation

Fingerprint representations are of two types: local and global. Major representations of the local information in fingerprints are based on the entire image, finger ridges, pores on the ridges, or salient features derived from the ridges. Representations predominantly based on ridge endings or bifurcations (collectively known as minutiae (see Figure2.4)) are the most common, primarily due to the following reasons: (i) minutiae capture much of the individual information, (ii) minutiae-based representations are storage efficient, and (iii) minutiae detection is relatively robust to various sources of fingerprint degradation. Typically, minutiae-based representations rely on locations of the minutiae and the directions of ridges at the minutiae location. Fingerprint classification identifies the typical global representations of fingerprints. Some global representations include information about locations of critical points (e.g., core and delta) in a fingerprint (Sharath, 2000).



Ridge Ending **Ridge Bifurcation**

Figure 2.4: Ridge ending and ridge bifurcation.