FINGERPRINT CLASSIFICATION: A BI-RESOLUTION APPROACH TO SINGULAR POINT EXTRACTION

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To my beloved dad and mum, and all people who have influenced my life.

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ABSTRACT

Fingerprint has been used as a biometric feature for security reasons for a long time. Studies have shown that fingerprint is unique to each and every person, even between two identical twins. Nevertheless, each fingerprint structure has a noticeable pattern, which is easily spotted by the naked eye. This flow-like pattern can be classified into five main categories: Arch, Tented Arch, Left Loop, Right Loop and Whorl. They can be used to classify fingerprints and improve the performance of fingerprint recognition. Various fingerprint classification scheme using singular points have been known in literature. Extracting singular points have been found to be an error prone process, depending on the quality of the fingerprint image. This thesis presents a singular point extraction method using two layers of information, without pre-processing of the image. The directional image is computed with Gaussian smoothed squared gradients pixel wise directly from the greyscale image. Two resolutions of the directional image are taken. The coarser level is used to estimate the position of singular points. The algorithm will only search for singular points in the finer level in a particular region if and only if there is a hit. Since the fingerprint is not segmented *a priori*, the algorithm makes use of the strength of the directional image as region of interest. The algorithm is tested with the NIST 4 fingerprint database. The result of this algorithm is very promising.

ABSTRAK

Cap jari telah lama digunapakai sebagai butiran (fitur) biometrik bagi tujuan keselamatan. Cap jari adalah unik bagi setiap orang, mahupun bagi kembar seiras. Walau bagaimanapun, setiap cap jari mempunyai corak yang tertentu dan senang dicamkan oleh mata kasar. Corak cap jari yang beralur-alur ini boleh diklasifikasi kepada 5 kategori yang utama: *Arch*, *Tented Arch*, *Left Loop*, *Right Loop* dan *Whorl*. Pengkategorian ini boleh digunakan untuk mengkelaskan cap jari dan memperbaiki hasil pengecaman cap jari. Daripada kajian literasi, diketahui pelbagai skema pengelasan cap jari yang menggunakan titik singular telah dibangunkan. Ketepatan pengekstrakan titik singular telah didapati bergantung kepada kualiti imej cap jari. Tesis ini mempersembahkan satu cara pengekstrakan titik singular dengan menggunakan 2 lapisan maklumat, tanpa melalui proses pra-pemprosesan imej. Imej berarah dihitung dengan piksel kecerunan kuasa dua licinan Gaussan daripada imej berskala kelabu. Dua resolusi bagi imej berarah telah digunakan. Imej resolusi rendah telah digunakan untuk menganggarkan kedudukan bagi titik singular. Algoritma akan mencari titik singular pada resolusi tinggi dalam lingkungan kawasan yang berkenaan sahaja. Oleh sebab cap jari tidak disegmentasi pada awal proses, algoritma ini akan mengeksploitasikan keseluruhan imej berarah sebagai kawasan sasaran. Algoritma ini telah diuji dengan pangkalan data cap jari NIST. Hasil daripada algoritma ini adalah memberangsangkan.

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CHAPTER 1

INTRODUCTION

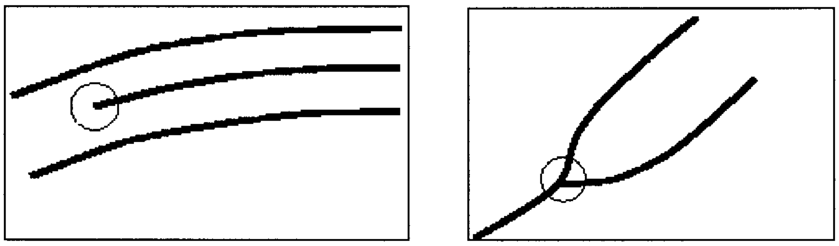
1.1 Overview

Fingerprints are graphical flow-like ridges on human fingers. Their formations depend on the initial conditions of the embryonic mesoderm from which they develop. Alobaidi (1998) pointed out that the dermal papillae determine the form and pattern of ridges on the skin surface. Once developed in human foetus, this ridge pattern remains unchanged except to enlarge as a person grows.

Due to fingerprints uniqueness and invariance to one's age, it has been long used as a mean of verification of people. Moreover, it is one of biometric techniques. Biometric is a technology that identifies a person based on his physiological or behavioural characteristics (Jain *et al.*, 1997). It relies on "something that you are" to register an identity for a particular person. Therefore, it can differentiate between an authorized person and fraudulent impostor.

Besides fingerprint, according to Jain *et al.* (1997), there are currently nine different biometric techniques that are widely used or being researched. The techniques include face, hand geometry, hand vein, iris, retinal pattern, signature, voiceprint, and facial thermograms. Although each of them satisfies the biometric requirements and some has been used in practical systems, not many are acceptable as the undisputable evidence of identity. For example, despite the fact that extensive studies have been conducted on automatic face recognition and that a number of face recognition systems are available, it has not yet been proven that face can be used to verify identity reliably, and a biometric system that relies only on face can achieve acceptable identification accuracy in a practical environment. So far, only automated fingerprint identification technique is a mature and legally accepted biometric technique. Although signatures are also legally acceptable, they rank a distant second to fingerprints due to issues involved with accuracy, forgery, and behavioural variability.

Fingerprint matching techniques can be divided into two, which is fine-level matching and coarse-level matching (Karu and Jain, 1996). Fingerprint recognition systems in the market usually use minutiae matching to identify a fingerprint image. The similarity between two fingerprints is determined by comparing the two sets of minutiae points. Minutiae are the local features extracted from a fingerprint image. The minutiae points used in identification are the ending points of a ridge, and the bifurcation points (which is where a ridge forks into two or more branches). See Figure 1.1.



(a) (b)

Figure 1.1 Minutiae. (a) Ridge ending. (b) Ridge bifurcation.

Fingerprint classification is a coarse-level matching of a fingerprint. Fingerprints are categorized according to the flow-like ridges, which form a special pattern in the central region of a fingerprint. Meltem Ballan *et al.* (1997) classify the fingerprints into Wirbel and Lasso class. However, most literatures (Candela *et al.* 1995, Capelli *et al.*, 1999, Cho *et al.*, 2000, Jain *et al.*, 1997a, Jain *et al.*, 1997b, Jain *et al.*, 1999, Kamijo, 1993) use the subclasses of the two general classes as the basic representation. The fingerprint classes are arch, tented arch, whorl, left loop and right loop. Twin loop is the sixth class of fingerprints. As twin loop has many of the same features as whorl class, therefore twin loop is merged into the whorl class. Some literatures (Jain *et al.*, 1997a, Jain *et al.*, 1997b, Jain *et al.*, 1999) have also merged the arch and tented arch into one class. The classification results from reducing the class problem into four classes has been encouraging, and shown an increase in accuracy and reduction of errors. Nevertheless, the reduction of classes beats the purpose of fingerprint classification.

While fingerprint classification cannot identify a fingerprint uniquely, it is helpful in determining when two fingerprints do not match (Karu and Jain, 1996). This is the indexing quality of fingerprint classification. For example, by partitioning a fingerprint database into the five major classes, a left loop image would then have to be matched with other left loop images only. Not only does it reduce comparisons of fingerprints, it also improves the overall efficiency of a fingerprint identification system.

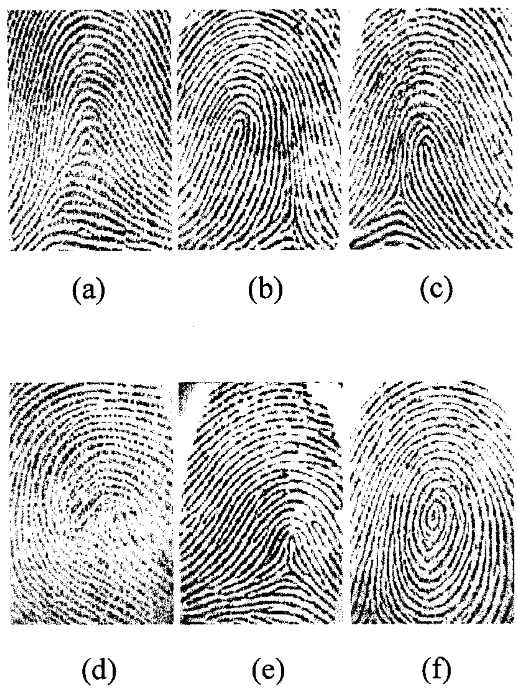


Figure 1.2 Fingerprint classes as recognised by the PCASYS classifier. (a) Arch, (b) Left Loop, (c) Right Loop, (d) Scar, (e) Tented Arch, and (f) Whorl.

1.2 Problem Background

Fingerprint identification is widely used today in many types of applications, such as security, authentication. The growing number of fingerprints in a fingerprint database would lead to retrieval inefficiency in the end. Thus, a method to solve this problem is to differentiate the fingerprints according to their macro-features, which is commonly recognized as fingerprint patterns. This is where fingerprint classification comes into picture. The most common method of fingerprint classification is the singular points detection technique.

Many fingerprint classification schemes have to go through some pre-processing steps, such as fingerprint image enhancement, binarization and thinning. Unless some optimization is done, any one of the process is time consuming. Furthermore, some features will be destroyed during thinning.

This has led us to belief in using an algorithm that could generate a directional image from a grey-scale fingerprint image directly, bypassing the thinning process, and image enhancement stage too.

Extracting singular points is an error prone process. It heavily depends on the quality of the directional image. A noisy directional image will generate a lot of spurious singular points and render the classifier fail.

1.3 Problem Statement

This study looks into the generation of directional image directly from a fingerprint greyscale image without any sort of pre-processing, e.g. thinning, image enhancement and binarization. This study will also look into methods of singular point extraction.

1.4 Objective

The purpose of this study is to find an efficient method of generating accurate directional image estimation and extracting singular points for fingerprint classification.

1.5 Scope

This thesis focused on firstly at estimating the directional image of a fingerprint directly from a greyscale image. No pre-processing of greyscale image was done. Nevertheless, directional image enhancement techniques would be studied.

Next was the study on singular point extraction. The extraction would be based upon the result of the first phase of study.

At the end, this thesis would derive an efficient singular points extractor. It would be based on the results of previous studies. An experiment would be run to compare the results of the proposed algorithm and two methods in literature, which was the conventional and multi-resolution method. The dataset would consist of 50 fingerprints from the NIST Special Database 4, with 10 from each class. The classes include Arch, Tented Arch, Left Loop, Right Loop, and Whorl.

1.6 Theoretical Framework

The framework of this research was graphically summarized in Figure 1.3. The processes in a singular point fingerprint classification system consisted of

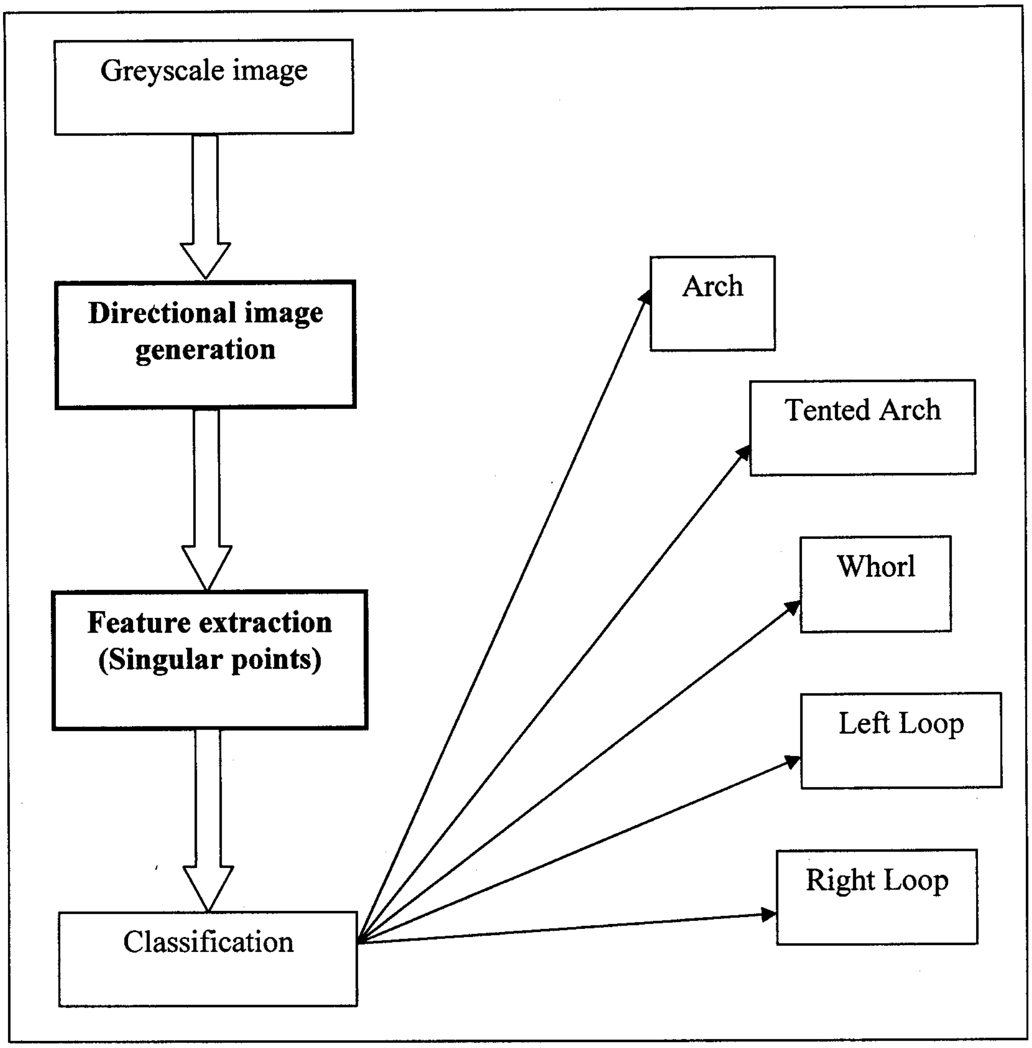


Figure 1.3 Theoretical framework of fingerprint classification.

generating a directional image from an input greyscale image. Then features were extracted from the directional image. The features here refer to singular points. The singular points would be used as the feature vector for classification into the five classes shown in figure. The bold-shaded boxes in the figure were the focus of this research.

1.7 Thesis Outline

This thesis was organized as follows. In Chapter 2 we gave a brief introduction to fingerprint classification. In Chapter 3 and 4, the generation of directional image and extraction of singular points were described. Chapter 5 described the proposed method, namely the bi-directional approach. The next chapter described the experiments carried out and the results were discussed. We then concluded this thesis in Chapter 7.

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