INVESTIGATION AND DEVELOPMENT OF FLATTENING ALGORITHMS FOR CURVED LATENT FINGERPRINT IMAGES

By

CHONG BEI WEI

A Dissertation submitted for partial fulfilment of the requirement for the degree of Master of Science (Electronic Systems Design Engineering)

August 2015

Acknowledgement

First of all, I would like to express my sincere gratitude and appreciation to my supervisor, Dr. Khoo Bee Ee, who helps and guides me a lot during the period of the research. She has always been patient, caring, motivating, observant and professional in the process of supervising my research. Without her constant support, sacrifice and understanding, it is impossible for me to get to learn some extra knowledge, technical skills and overcome problem faced.

Besides, I would like to thank Mr. Low Wei Zeng for his selfless help in making this research success. I am grateful for the cooperation and help offered by all the staffs includes all the lecturers and technicians. Last but not least, I would like to thank my family and friends for encouraging, supporting and helping me in completing my project.

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List of Abbreviations and Nomenclature

Abbreviation	Meaning
AFIS	Automated Fingerprint Identification System
CSM	Cylindrical Surface Model
DSLR	Digital Single-lens Reflex Camera
ELFT	Evaluation of Latent Fingerprint Technologies
FpMV	Fingerprint Minutiae Viewer
FRS	Friction Ridge Subcommittee
GCS	General Cylinder Surface
MINDTCT	Minutiae Detection
NBIS	NIST Biometric Image Software
NIST	National Institute of Standards and Technology
OCR	Optical Character Recognition
OSAC	Organization of Scientific Area Committees
RANSAC	Random Sample Consensus
ROI	Region of Interest
SIFT	Scale-invariant Feature Transform
SIVV	Spectral Image Verification and Validation analysis
SL	Structured Light

PENYIASATAN DAN PEMBANGUNAN ALGORITMA UNTUK MERATAKAN LENGKUNGAN BAGI IMEJ CAP JEJARI PENDAM

ABSTRAK

Cap jejari sering digunakan untuk pengesahan identiti disebabkan keunikan dan ciri-cirinya yang kekal sepanjang hidup. Akan tetapi, cap jejari sering dikesan atas permukaan yang tidak rata ataupun imej yang kontranya tidak mencukupi, cap jejari yang diperolehi adalah tidak tepat dan memberi kesan kepada keputusan perbandingan cap jejari amat sukar. Disebabkan itu, cap jejari yang diperolehi perlu diproses sebelum perbandingan dilakukan. Untuk meningkatkan ketepatan perbandingan, ralat yang disebabkan permukaan tidak rata perlu diperbetulkan. Tujuan penyelidikan ini adalah untuk membangunkan algoritma yang boleh meleperkan imej cap jejari terpendam yang diperoleh daripada permukaan berbentuk silinder. Proses peleperan memerlukan pengekstrakan sempadan ataupun rangka imej tersebut. Sempadan cap jejari boleh diperolehi dengan meggunakan algoritma yang ditetapkan, ataupun dilukiskan oleh penguna sendiri. Koordinat imej asal perlu ditukarkan daripada sistem koordinat silinder kepada sistem koordinat imej. Dengan mengggunakan ciri-ciri imej lengkungan yang berbentuk segi empat, algoritma direka berdasarkan penghampiran kepada bentuk parabola and elips. Eksperimen yang dilakukan telah membuktikan bahawa algoritma yang mengunakan penghampiran berdasarkan bentuk elips dapat meningkatkan kualiti and menambahkan ketepatan perbandingan cap jejari terpendam. Walau bagaimanapun, hasil pengukuran garis melintang menunjukkan bahawa pembetulan bentuk secara mendatar adalah tidak cukup berkesan. Secara ringkas, kedua-dua algoritma yang direka berupaya untuk meratakan lengkugan yang ada pada imej cap jari terpendam dengan andaian imej yang perlu diproses merupakan silinder

menegak dan sempadan untuk silinder dapat diekstrak secara berkesan. Algoritma yang direka berdasarkan penghampiran bentuk elips memberikan keputusan yang lebih baik berbanding dengan penghampiran menggunakan bentuk parabola.

INVESTIGATION AND DEVELOPMENT OF FLATTENING ALGORITHMS FOR CURVED LATENT FINGERPRINT IMAGES

ABSTRACT

Fingerprint had been used to identify a person due to its uniqueness and unchangeable throughout life. However, latent fingerprint acquisition normally being performed on uneven or noisy surface with poor contrast, causing fingerprint minutiae point extracted appear to be inaccurate and affect the result of fingerprint matching. Thus, latent fingerprint required image to be pre-process and enhance before latent search. In order to increase latent matching accuracy, geometry rectification is needed to correct distortion in fingerprint images due to uneven surfaces. This research will investigate and develop flattening algorithm that can be adapted to latent fingerprint images on cylindrical surface. The boundary of an image is required to detect the curvature of an image that need to be flattened. Boundary of interested area can be acquired using a predefined algorithm or define by user using interactive drawing. The flattening algorithm required mapping from cylindrical coordinate to image coordinate. Since curved image appears to be rectangular shape, parabolic approximation and ellipse approximation are being used to design algorithms for flattening. Experimental results prove that algorithm that applies ellipse equation to flatten fingerprint images able to increase the quality of the minutiae. However, measurement results for horizontal axes shows that the distortion in horizontal axis is not being well taken care of. In summary, both algorithms developed able to flatten curved latent fingerprint images with the assumption that image that needs to be flattened is vertical cylindrical shape and boundary of cylinder must be detectable. Algorithm that applies ellipse approximation provides better performance as compared with the algorithm that developed based on parabolic approximation.

CHAPTER 1

INTRODUCTION

1.1 Overview

The study had been done over the years of using physical characteristics such as voice, fingerprints, DNA, facial appearance and many more to identify an individual. A database of fingerprints from the known criminals was created by the FBI since the year 1962 (Seow, Yeoh, Lai, & Abu, 2002).

Fingerprint had been used to identify a person due to its uniqueness and unchangeable throughout life. It has been used not only for forensic purposes, but for access control and internet authentication as well (Wu, Xie, Seo, & Lee, 2008). Using of a fingerprint on electronic devices such as laptop and smartphone getting more and more popular. Despite security purposes, fingerprint appears to be the most persuasive fact or evidence that is needed for person identification in crime scenes.

The creation of the FBI’s Identification Division in the year 1924 was aimed to provide a central repository criminal identification of data for law enforcement agencies throughout the United States. Hundreds and thousands of new fingerprint records were added to their collection. Searching within a huge database required more time. For that reason, a new automatic approach was needed in extracting fingerprint images, process these images to produce template which summarize character information and search for probable candidate matches automatically (Cole, 2009). Thus, automated fingerprint identification system (AFIS) was developed with the goal to use emerging electronic digital computers to assist or replace labor-intensive processes of characterizing searching and matching used for personal identification (Komarinski, 2005).

Nowadays, automated fingerprint identification system (AFIS) had become a necessary tool in law enforcement agencies (Komarinski, 2005). Wide deployment of AFIS has improved accuracy and fingerprint identification significantly (Jain & Feng, 2011). There are two types of fingerprint searching in forensic AFIS, which are ten-print fingerprint search and latent search. In ten-print fingerprint search, rolled or plain fingerprint is searched to match with the database of known person. Latent search, on the other hand, use a latent fingerprint to do matching with the database of known person to apprehend suspects in forensics.

Automated system having the difficulties in classifying and reliably locate minutiae of fingerprints. Hence, latent fingerprint examiners are needed to analyze and manually mark up each fingerprint as a preparation of fingerprint matching. The manual identification process of extraction and verification stages by latent examiners is common referred as ACE-V procedure which consist of analysis, comparison, evaluation and verification (Ashbaugh, 1999).

To further improve automatic latent feature extraction and matching, National Institute of Standards and Technology (NIST) has been conducting Evaluation of Latent Fingerprint Technologies (ELFT) (Yoon, Feng, & Jain, 2010). However, latent identification systems still cannot offer accuracy at a satisfactory level. Therefore, latent fingerprint image preprocessing needs to be improved to further increase accuracy in fingerprint matching. Research effort in latent fingerprint identification should focus on reducing manual input rather than completely eliminating manual input due to the reason that latent matching accuracy still the primary concern (Yoon et al., 2010). In order to increase latent matching accuracy, geometry rectification is needed to correct distortion in fingerprint images due to uneven surfaces, so this thesis will focus on developing flattening algorithm that able to reduce distortion of fingerprint images on curved surfaces.

1.2 Problem statement

A lot of studies or research had been done on image pre-processing of latent fingerprint, especially on image enhancement. Most of the images involved are on a planar surface and there are not many studies on processing latent fingerprint which involve geometry transformation. However, in the real world, latent fingerprint acquisition normally being performed on uneven or noise surface which cause minutiae become undetectable and affect the result of fingerprint matching. There is a need to flatten and enhance fingerprint images before it can be used for matching personal identification purposes. Thus, this research will focus on the investigation and development of flattening algorithm for fingerprint image collected from cylindrical surfaces.

1.3 Objectives

The aim of this project is to investigate and develop flattening algorithms for curved latent fingerprint images.

The objectives of this project are:

1. To investigate flattening algorithm to flatten fingerprint image.
2. To analyze and evaluate performances of various models of flattening on fingerprint images.

1.4 Scope of Research

This research will focus on developing the flattening algorithm for camera captured fingerprint images with fingerprint lies on a vertical cylindrical surface. Single image is being used and assuming that images taken are in parallel projection.

1.5 Thesis Outline

There are five chapters covered in this thesis. Chapter 1 introduces latent fingerprints. Besides, the aims and objectives of this thesis are introduced.

Chapter 2 is the literature review where the latent fingerprint, image processing, geometry rectification, minutiae detection and Mathematica are discussed.

Chapter 3 discuss the methodology on how to design and implement the flattening algorithm for a curved latent fingerprint. This chapter describes workflow and details in doing the research.

Chapter 4 is the part for results and discussions. In this chapter, the results of image flattened and number of minutiae detected are shown and discussed.

Chapter 5 is the last parts which consist of conclusions and suggestions. The conclusion is included to conclude the overall results of this project. Further recommendation able to enhance and improve this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter is a summary and explanation of the evolution and current state of knowledge on latent fingerprint pre-processing and image flattening found in academic books and journal articles. In this chapter, characteristics of a latent fingerprint are being discussed. Besides, the evolution of fingerprint matching is included. Methods used for flattening are being reviewed along with their advantages and disadvantages to provide a good starting point for this research. On the other hand, the platform tool that will be used for this research will be included as well.

2.2 Latent Fingerprint

According to Friction Ridge Subcommittee (FRS) of Organization of Scientific Area Committees (OSAC), a fingerprint is an impression of the friction ridges of all or any part of the finger. Due to its uniqueness, latent fingerprint plays a very important role in forensic to investigate crime scenes (Gische, Langenburg, & Maceo, 2011). Traditionally, matching of two fingerprints involves comparing the discrete features of finger's friction skin, called minutiae. The minutiae of a fingerprint consist of ridge ending and ridge bifurcation. Ridge ending is the point where a ridge ends, whereas ridge bifurcation point to where a ridge split into branch ridges (Hong, Wan, & Jain, 1998). Figure 2.1 shows an example of minutiae.

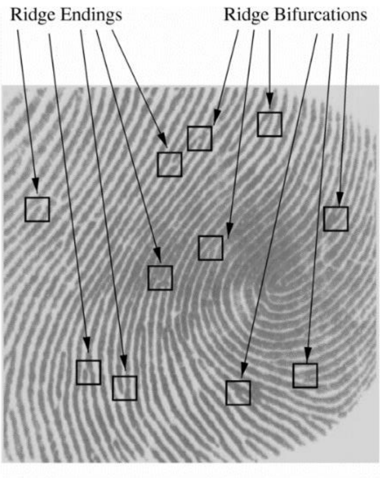


Figure 2.1: Minutiae overlaid on a fingerprint image (Hong et al., 1998)

Three types of fingerprint impressions are shown in Figure 2.2 (Paulino, Feng, & Jain, 2013; J. Zhang, Lai, & Kuo, 2012). Rolled fingerprint images obtained through rolling finger “nail to nail” to capture ridge details of fingerprint whereas plain fingerprint obtained by pressing down fingerprint in flat without rolling. A latent fingerprint, on the other hand, are fingerprint lifted from the surfaces of objects that are inadvertently touched or handled by a person typically at crime scenes. Latent fingerprint which appears to be left unintentionally required complicated dusting or chemical processing to acquire fingerprint minutiae extract point for person identification purposes (Champod, Lennard, Margot, & Stoilovic, 2004). Moreover, latent fingerprints on background with diverse combinations of colors and texture will mask the minutiae extract point. Therefore, generally a latent fingerprint will have poorer quality. If a ten-print fingerprint image consists of 100 or more minutiae, there may be only a dozen of minutiae on a latent fingerprint.

Figure 2.2: Three types of fingerprint impressions (a) Rolled; (b) plain; (c) latent (Paulino et al., 2013)

2.3 Latent Fingerprint Image Preprocessing

In practice, images collected may be in poor quality due to several reasons, including contrast, background, and other reason. Thus, image preprocessing is needed to produce good quality images that is able to extract feature points of fingerprint for matching purposes. The common transformation being used include color management, contrast adjustment, edge enhancement, background suppression, and noise filtration.

Preprocessing of fingerprint images proposed by Jia and Cao (2012) include image segmentation, image enhancement, binarization, and thinning. The fingerprint segmentation algorithm is based on the fingerprint direction information. This segmentation algorithm can remove most of the unwanted background information of fingerprint image by making the direction of the histogram in accordance to the ridge line and valley line to have a peak. Whereas for image enhancement, Jia and Cao (2012) use Gabor filtering method. Gabor filtering can be combine with spatial and frequency domain effectively due to its orientation and frequency selection characteristic. The next step is image binarization that turns a fingerprint image to a binary image with two gray levels. The block-binarized method is being performed. The last part is image thinning. Thinning can reduce the amount of data and improve recognition accuracy. As the thickness of fingerprint ridge does not affect the characteristic of a fingerprint, thinning will not cause losing of data.

Gabor filter able to connect broken ridges and separate joined ridges only with proper parameters being used. The incorrect parameter will result in true ridges may be weakened and spurious ridges become straight after filtering and consequently causing the reliability issue. Hence Yoon et al. (2010) proposed to focus on the estimation of orientation field in latent images for image enhancement. Ridge orientation is given the priority during image enhancement as compared with frequency due to the reason that ridge frequency values is smaller for adult fingerprint and estimation of ridge frequency normally performed after knowing the ridge orientation (Hong et al., 1998). Orientation field estimation can be done by using a gradient-based method for initial estimation and followed by regularization.

The other proposed preprocessing sequence for latent fingerprint image is using an extension of the Spectral Image Verification and Validation analysis (SIVV) (Guan, Dienstfrey, & Theofanos, 2013). SIVV originally designed for validation and verification of ten-print fingerprint images (Libert, Grantham, & Orandi, 2009). In order to make it applicable on latent fingerprint, Region of Interest (ROI) focuses only on local region, which contains fingerprint signal in the spatial domain and peak location constraint focus on a small window that may contain the ridge in the frequency domain.

2.4 Geometric Image transformation

Geometric image transformation generally did not change the content of an image, but deform the pixel grid and map this deformed grid to the destination image (Bradski, 2000). Geometric transformation often are called rubber-sheet transformation. It is like image print on a sheet of rubber and followed by a twist or tweak according to a predefined set of rules (Gonzalez & Woods, 2008). According to Gonzalez and Woods (2008), spatial transformation and gray-level interpolation are two basic operations in geometric transformation as shown in Figure 2.3. Spatial transformation involves the rearrangement of a pixel, whereas gray-level interpolation taking care the alignment of a gray level to pixels.

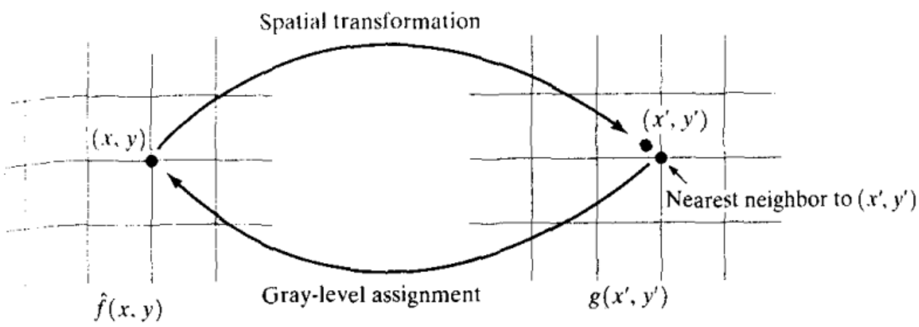


Figure 2.3: Gray-level interpolation based on the nearest neighbor concept (Gonzalez & Woods, 2008).

2.5 Geometry Rectification of Image

Latent fingerprint images that captured through a camera can generate a digitized image to extract the minutiae for person identification. Retrieving fingerprint information from camera captured images bring advantages due to its flexibility in carry and picture can take from any point of view. However, a camera captured image will have image distortion, which is caused by the position of the camera in relation to the subject (Zhang & Sun, 2013). Unwanted distortion will result in misleading data, thus distortion needs to be rectified.

Over years, a lot of research has been done on developing algorithms for geometry distortion rectification. Document images appear to be one of the common images that apply image rectification. This is due to the existence of bookbinding which cause page cannot be flattened properly. As a result, document layout analysis and Optical character recognition (OCR) task becomes inaccurate and more processing jobs need to be done to get a quality image.

The main challenge in geometry correction is how to recover its 3D shape. One of the solutions proposed is using a 3D scanner to obtain parameter needed. Brown and Seales (2001) come out with a 3D acquisition that able to restore and register shape and texture of manual script for different lighting condition. The structured light (SL) approach was used to obtain point accurately between devices, whereas projector sweep line across a document in vertical or horizontal direction. At the same time, the camera observes document using striping approach (Brown & Seales, 2001). Mass-spring particle system was being used to deform a complex shape to a plane subject.

Due to the relatively slow in computation and additional processing needed for alignment, Brown and Pisula (2005) improve the speed of processing by using conformal mapping to address the flattening problem. A conformal map is a 2D parameterization of a 3D surface with angle preserved locally (Abbena, Salamon, & Gray, 2006). Arbitrarily distorted documents can be restored to within a single pixel of their true planar format by using conformal parameterization. This method has the disadvantages of having missing intensity information due to the projection and shading artifacts are not addressed.

Brown and Pisula (2005) further improve the algorithm to target non-text based materials which required solving both geometrical distortion and shading artifacts (Brown, Sun, Yang, Yun, & Seales, 2007). The original images that exhibit geometric and illumination distortion along with images with fixes applied are shown in Figure 2.4. With changes in image intensity, illumination edges caused by the distorted surface can be removed in order to modify gradient fields and reduce shading artifacts. Figure 2.5 showed the overall document restoration process. The combination of two processes improves the visual appearance of the content printed on distorted documents but cannot deal with smooth shading changes or those caused shadows. On the other hand, a high-resolution image is needed for processing. 3D scanning system as shown in Figure 2.6, which consists of two digital video cameras, a high-resolution digital camera, and a laser light source are needed in order to acquire a high-resolution image.

The other way to estimate the 3D shape is using multiple images collected from a different viewing angle. Figure 2.7 showed Tsoi and Brown's work on combining multiple views of a document to produce images with rectified geometry and illumination (Tsoi & Brown, 2007). In their research, they target on documents that can be modeled as ruled surface. The overall process is inclusive of rectangular rectification, illumination correction, geometric rectification and lastly histogram matching and multi-view compositing. There are a few assumptions that have been made, which include images taken are at the same distance away from the document and perspective distortion is not significant.

Figure 2.4: (a) Original image exhibiting geometric and illumination distortion. (b) Geometry corrected. (c) Geometry and illumination corrected (Brown et al., 2007).

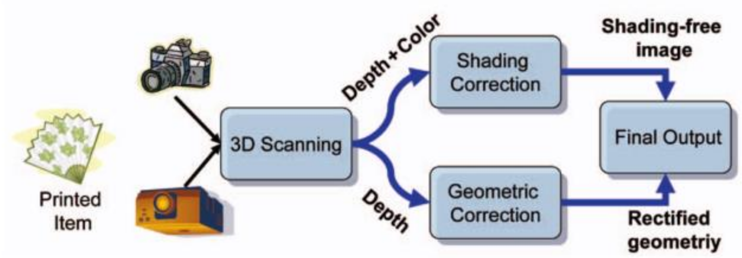


Figure 2.5: A system diagram of the overall document restoration process (Brown et al., 2007).

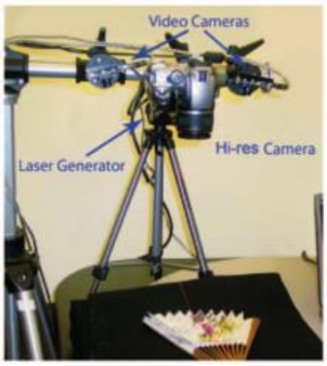


Figure 2.6: 3D scanning system (Brown et al., 2007).

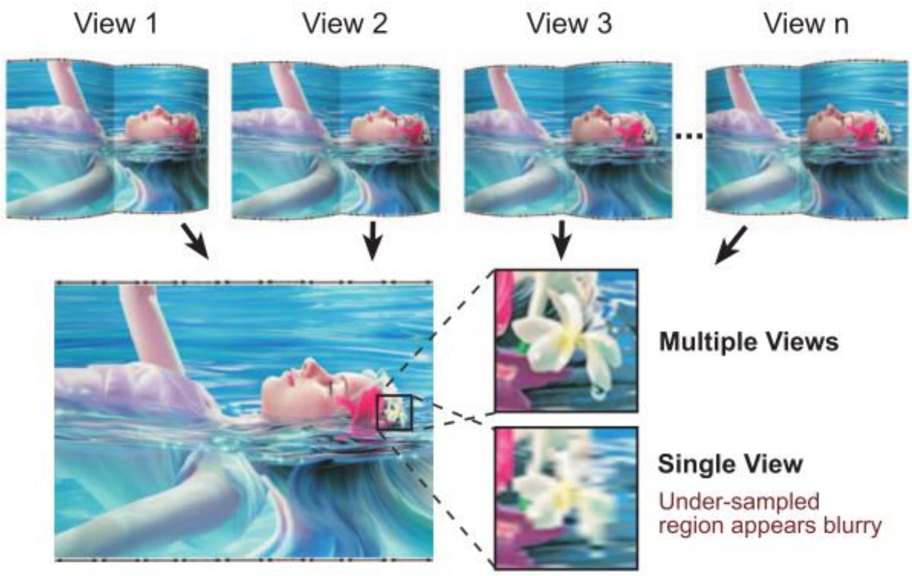


Figure 2.7: Multiple views of a document are composited to produce an output with rectified geometry and illumination (Tsoi & Brown, 2007).

With two images from different angle, the 3-D shape can be estimated by using document dewarping algorithm (Koo, Kim, & Cho, 2009). Stitching both geometric corrected images will result in better images. The document dewarping algorithm consists of three parts, there are two view structure reconstruction, 3-D projection analysis and random sample consensus (RANSAC) based curve fitting. Text lines and boundaries are not needed for this method, giving more flexibility for images. But the shading correction is not included.

A similar method was being used for automated label detection to reduce labor cost at the same time ensure product quality (Lin, Liao, He, & Shi, 2013). Images are first rectified using adverse cylinder projection, then combined using an image mosaicing algorithm based on Scale-invariant feature transform (SIFT). SIFT required sufficient number of feature points to obtain an accurate estimation for 3D images and often fail to deal with large distortion and blur image.

Another way to deal with geometric distortion is recovering two 3D document images using two structured beams illuminating on the page surface (Meng, Wang, Qu, Xiang, & Pan, 2014). Figure 2.8 provides the overview on the document restoration process. Two curves interpolate into the developable surface and flattened into a planar surface using the system of differential equation. Global dewarping transformation obtained apply onto the image to solve the geometry distortion. The developable surface appears to be lower computational complexity as compared with 3D range data.

As most of the method proposed did not take care of shading artifact, Tsoi and Brown (2004) come out with the idea of using the boundary to solve geometry and shading correction. In their works, they use Coon patch blending with four boundary curves to parameterize models and use the boundary interpolation framework to estimate intrinsic illumination. A new image with shading correction is generated.

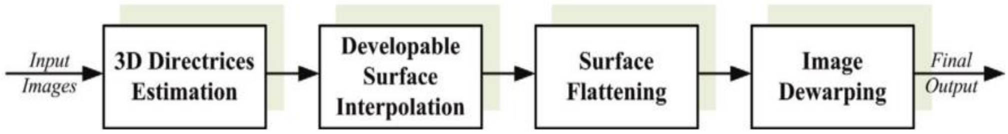


Figure 2.8: An overview of the proposed document restoration process (Meng et al., 2014).

In order to rectify geometry on an image of document, Zhang and Tan (2001) proposed a restoration system that reduce noise, on the other hand, adjust the location and orientation of warped word in document images that scanned. They further improve their ideas in terms of cost and resolution independent by introducing a simpler connected component and regression technique (Zhang & Tan, 2003).

Another solution to solve the warping issue on document image is using analytically accurate Cylindrical Surface Model (CSM) to rectify the bound document image warping (Cao, Ding, & Liu, 2003). The result of implementing this module is words in a different location of document image getting same orientations and length. CSM significantly improves character segmentation and reduce recognition error for OCR at the same time. However, this rectification subject to the constraint that the generatrix of the cylinder and image plane are in parallel condition.

Cao et al.'s work was further extended by allowing document to be captured in arbitrary view angle and position, which is using a novel metric rectification method that able to restore document image captured using the uncalibrated camera (Meng, Pan, Xiang, Duan, & Zheng, 2012). Figure 2.9 showed the flow chart on the proposed method. That method can be used to restore distortion due to page curl, perspective, and their coupling simultaneously. The shape of a page in this method is modeled by using General Cylinder Surface (GCS) and followed by the building of isometric mesh. Distortion removal was done using mesh-based image warping. The method proposed by Meng et al. (2012) having the flexibility for document image to be captured at an arbitrary view angle and position, but limit by the requirement to have at least two horizontal lines.

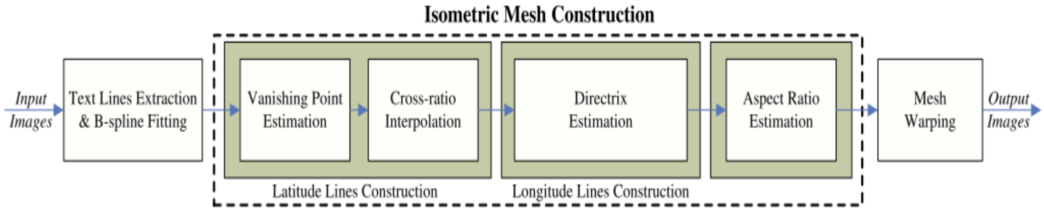


Figure 2.9: The flowchart of the proposed method by Gaofeng et al (Meng et al., 2012).

Despite all the complicated algorithms being used for geometry rectification, Nikie ((http://mathematica.stackexchange.com/users/242/nikie), 2012) proposed a simple way to flatten the image of a label on a food jar. In his proposed idea, he used the second order polynomial equation to flatten label image. The idea that he proposed bound to a few assumptions which are label has to be brighter than the background, the label is a rectangular shape, the jar is vertical and lastly the jar is the cylindrical shape.

2.6 Mathematica 9.0 (Wolfram Research, 2012)

Wolfram Research was founded by Stephen Wolfram in 1987 to pursue long-term vision development in science, technology and tools to make computation an ever more potent force for now and future. Wolfram language, as the center of revolution of Wolfram Research, defines unique convergence for computation and knowledge.

Mathematica was first released in 1988 as original and longstanding flagship of Wolfram Research. It represents a unique blend of major research breakthrough outstanding user-oriented design, and world-class software engineering.

2.7 MINDTCT - Minutiae Detection / Fingerprint Minutiae Viewer (FpMV)

Fingerprint Minutiae Viewer (FpMV) is a software developed by the National Institute of Standards and Technology (NIST) ("Fingerprint Minutiae Viewer (FpMV)," 2014). This software equipped with MINDTCT application from NIST Biometric Image Software (NBIS) and is able to view a fingerprint image with minutiae points overlaid on top of the fingerprint. Figure 2.10 shows the GUI of FpMV. The user can define the quality to eliminate false minutiae by controlling the quality of minutiae in FPMV.

MINDTCT are used by FBI’s universal Latent Workstation to locate and records ridge ending and bifurcation of fingerprint image automatically (Ko, 2007). The algorithm of MINDTCT (“HO39”) was inspired by Home Office’s Automatic Fingerprint Recognition system. That algorithm was set to optimally process image scanned at 19.69 pixels per millimeter (ppmm) (500 pixels per inch) and quantized to 256 levels of gray. Figure 2.11 shows minutiae detection flow of MINDTCT.

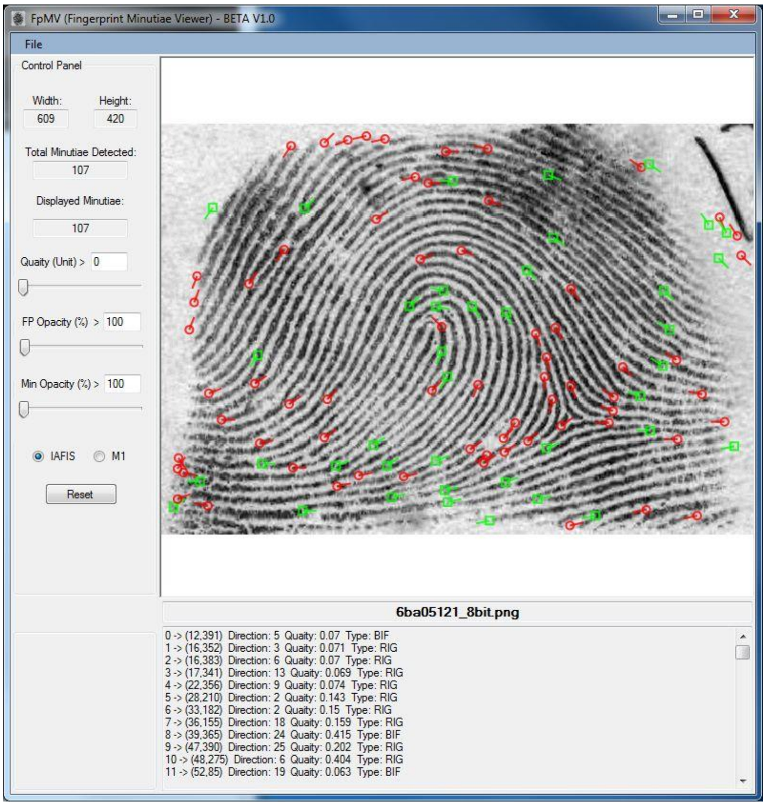


Figure 2.10: Fingerprint Minutiae Viewer(FpMV)("Fingerprint Minutiae Viewer (FpMV)," 2014)

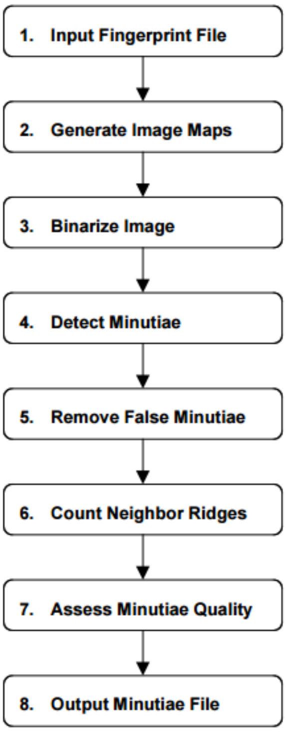


Figure 2.11: Minutiae detection process (Ko, 2007)

2.8 Summary

In summary, latent fingerprint preprocessing involves image enhancement that required manual operation by latent fingerprint expert due to the uncertainty of the images. There is not much research being done on latent fingerprint process which involve geometry rectification. Most of the flattening algorithm reviewed are applied to document image or label. Those proposed algorithms required more than one image or 3D scanner to acquired parameter needed for flattening. For flattening using a single image, approximation mapping using second order polynomial equation is a good and convenient idea. In this method, the rest of the parameters needed can be acquired through optimization. Thus, this research will further improve flattening algorithm that applies second order polynomial to make it adaptable to curved latent fingerprint images.

CHAPTER 3

METHODOLOGY

3.1 Overview

In this chapter, the design procedure on how to develop flattening algorithms for curved latent fingerprint images are discussed. The research was done before starting on this topic to verify the need for this project and come out with a suitable problem statement and objectives. A well planned procedural steps help to make sure the research meets the end goal and can be completed on time. The first part of this chapter will further discuss this process, start from literature review until the end of this research.

The main goal of this research is to develop algorithms that can be applied to flatten curved fingerprint images, so the second part will focus on flattening algorithm development. Due to the oval shape of the fingerprint, images that need to process must come with the geometric shape so that flattening can take place. In this research, conic equation is being used to develop algorithms for flattening. The detail will be discussed further.

The last part of this chapter will focus on image quality and measurement to detect the relative error for horizontal distortion. The reason of using FpMV to detect minutiae and how to get the relative error for horizontal distortion are being discussed.

3.2 Design Planning

Flow chart in Figure 3.1 shows the design procedure for this research. From the flow chart in Figure 3.1, the whole project starts with literature review or previous research study. Studying related research regarding project will provide a clearer idea of latent fingerprint processing nowadays. This project uses Wolfram Mathematica 9 as the computation platform to develop algorithms for curved image flattening. Mathematica equipped with powerful mathematical and algorithmic capabilities and provides built-in support for both programmatic and interactive image processing.

After having enough information regarding the project, the upcoming stage is to develop algorithm for fingerprint image flattening. In this research, fingerprint images with detectable border are required to detect the curvature of a geometry that need to be flattened. This is due to the fingerprint that appear in oval shape do not provide sufficient information needed for flattening purposes. The development of algorithm consists of two parts, which are fingerprint image pre-processing to get the mask that cover the geometry that need to rectify and flattening algorithm development for image flattening. Mask creation method will be discussed in first part of this chapter. The next step is to develop algorithm that is suitable for curved image flattening. This will be discussed in the second part on this chapter. The following step is to flatten the images by applying the algorithm developed.

The last part of the project is measures the quality of image flatten. The quality of fingerprint images is decided by the number of minutiae detected and measure the distance by using image with equally spaced dots on it. The investigation is done towards bad quality images.

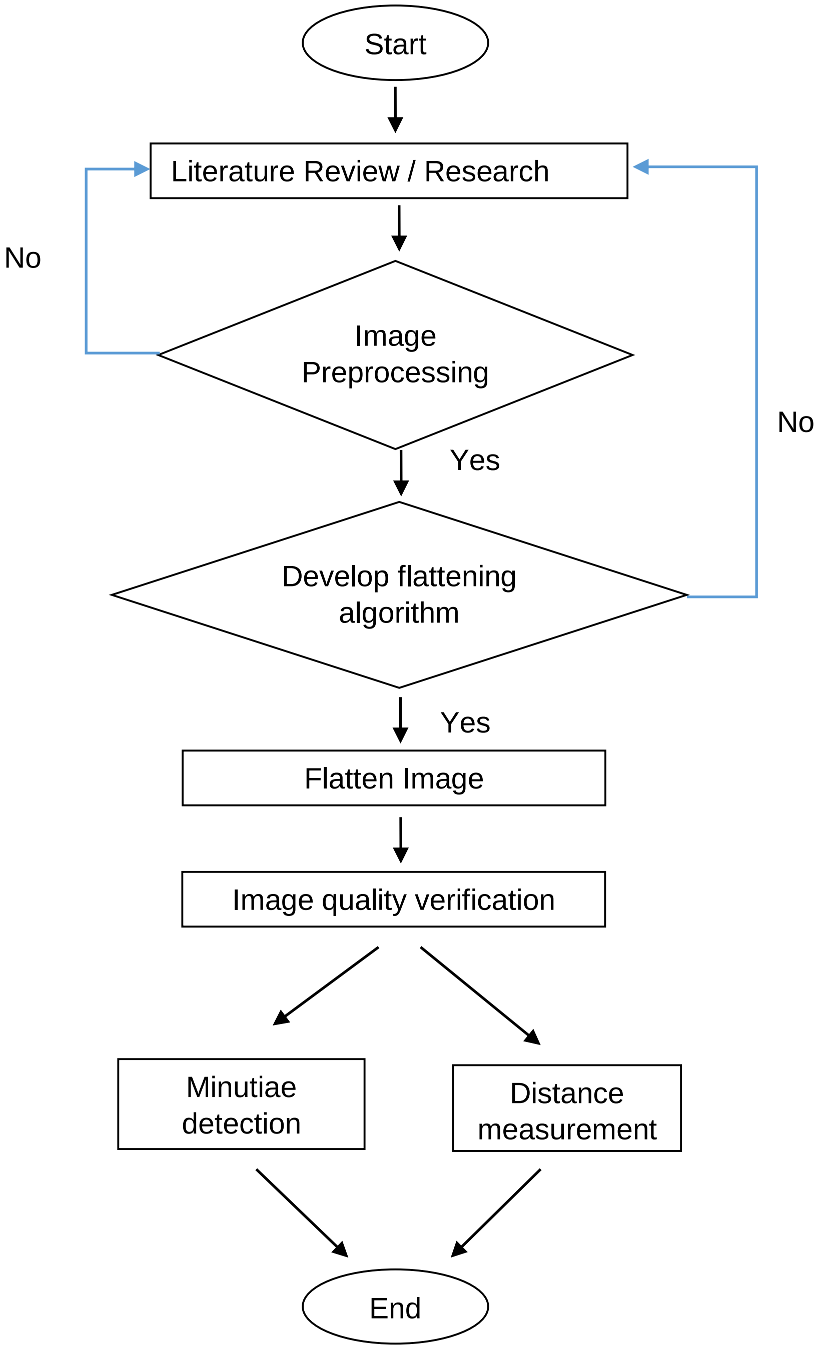


Figure 3.1: Flow Chart of flattening algorithm development

3.3 Fingerprint Image Pre-processing

The reason to pre-process image is to narrow down image size, to reduce evaluation time and to get the mask that cover the region of interest, so that the curve of the geometry can be used for flattening later. Thus, the images captured is being cropped to a smaller region.

There are two ways to extract the edge of ROI, which are process image in an automated way using a list of predefined steps or create a mask interactively using built-in features of Mathematica.

3.3.1 Automated Mask Creation

Figure 4.1 shows the predefine steps to create mask for ROI. In order to get the edge of the region of interest, the image captured is being cropped to a smaller area. The user defines the edge of ROI for left-hand side and right-hand side. This is to make sure that the correct edge is being used. Besides, this step removes the limitation for image without left or right edge. Unwanted left and the right area will be colored to black.

The next step is using the Gaussian filter to smoothen the image and followed by the edge detection feature. Edge detect will find the edge of the image, but some of the border line will still remain separated. In order to joint those border lines together to form the closed shape, dilation is performed and thinning comes next to change it back to the thin border. There still some unwanted branches remain on the image, thus, pruning is applied to remove the unwanted parasitic branches. The last step is to fill up the region for the closed shape with white color.

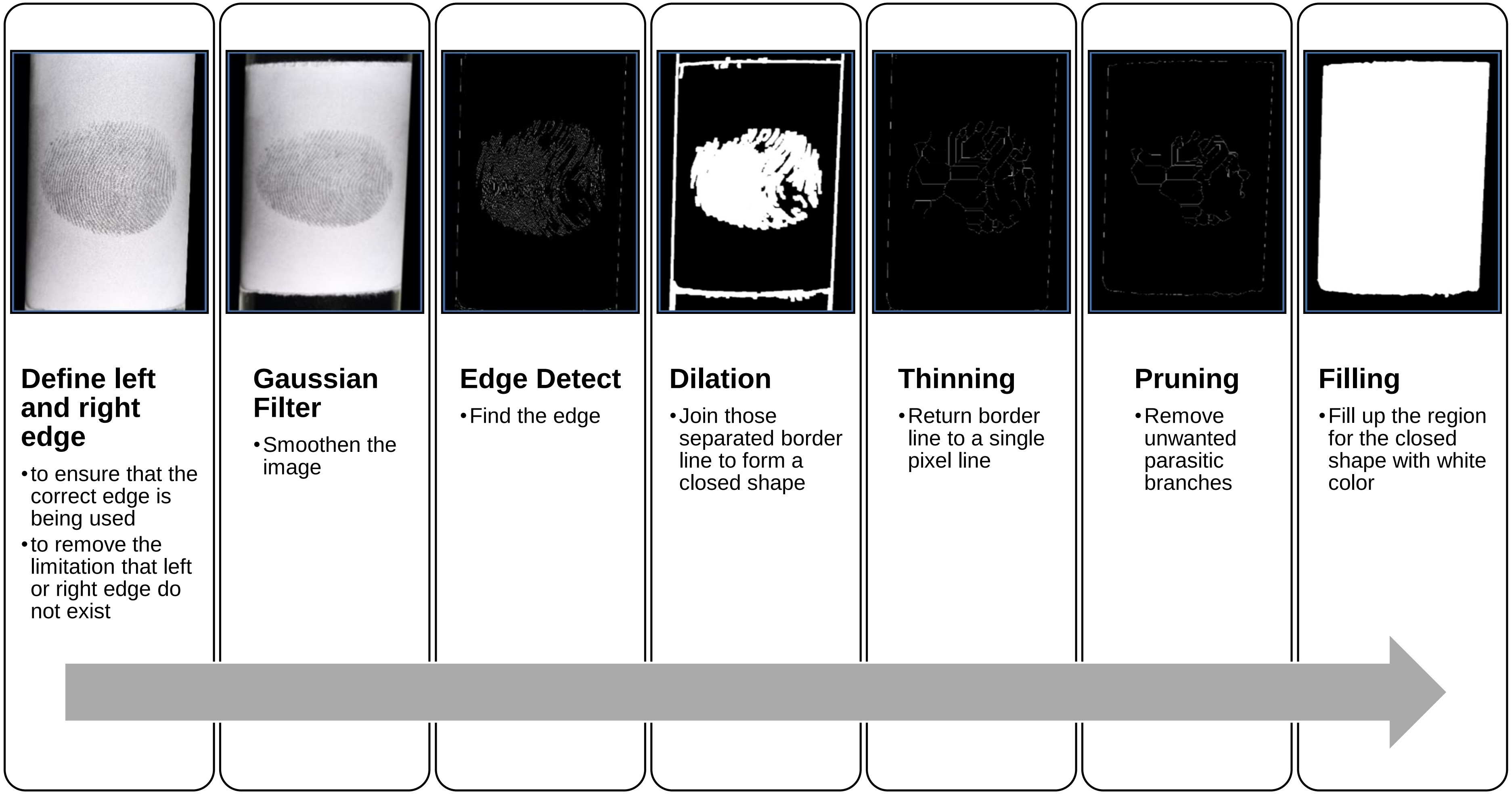
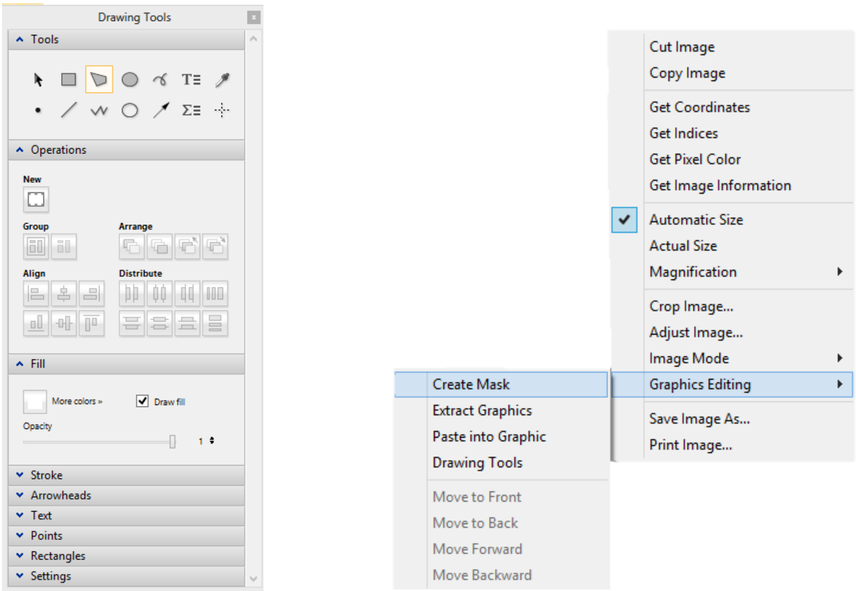


Figure 3.2: Mask creation using a list of predefined steps

3.3.2 Interactive Mask Creation

The other way to get the ROI is by using the built-in feature provided by Mathematica. This method is simple, but required some manual action from the user. The first step is to draw a filled polygon to cover ROI in fingerprint images using drawing tools as shown in Figure 3.3. The next step is using the “Create Mask” feature in “Graphic Editing” as shown in Figure 3.3. Figure 3.4 showed polygon drawn to cover ROI and mask created respectively.



(a) (b)

Figure 3.3: Drawing tools and Create Mask feature in Mathematica 9

(a) (b)

Figure 3.4: Create mask interactively (a) Draw polygon (b) Mask created