

ระบบการระบุนโยบายพิมพ์ฝ่ามือโดยใช้การเทียบรูปร่างและขั้นตอนวิธีข้อมูลข้างเคียงที่ใกล้ที่สุด k ตัว

นางสาวพัชรประภา ตั้งเพียร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

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PALMPRINT IDENTIFICATION SYSTEM USING SHAPE MATCHING AND
K-NEAREST NEIGHBOR ALGORITHM

Miss Patprapa Tunkpien

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Computer Science and
Information Technology

Department of Mathematics and Computer Science

Faculty of Science

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การระบุลายพิมพ์ฝ่ามือเป็นหนึ่งในวิธีทางไบโอเมทริกซ์ที่ใช้ในการระบุบุคคล การตรวจ
สิทธิหรือแสดงตน ถึงแม้ว่าลายพิมพ์ฝ่ามือมิได้เป็นลักษณะทางกายภาพที่นิยมมากที่สุดที่ใช้กันทุก
วันนี้ แต่ก็ยังเป็นทางเลือกหนึ่งที่มีประสิทธิภาพที่ใช้ในการระบุตัวบุคคลในเทคโนโลยีอนาคต
เนื่องจากลายพิมพ์ฝ่ามือเป็นสิ่งที่มีความเฉพาะ มีความเสถียร สะดวกและง่ายต่อการใช้งาน
จากงานวิจัยที่ได้ทำการศึกษาพบว่า มีลักษณะหลายอย่างบนฝ่ามือที่สามารถนำมาใช้ในการเรียน
รู้จำอัตโนมัติได้ แต่อย่างไรก็ตามเส้นหลักบนฝ่ามือจะนำมาใช้ในงานวิจัยนี้ ระบบสามารถแบ่งได้
สองระบบย่อย ส่วนแรกเกี่ยวข้องกับการสกัดลายเส้นบนฝ่ามือโดยการใช้การดำเนินการกรอง
ต่อเนื่อง ซึ่งจะได้สามเส้นหลักบนฝ่ามือ เพื่อให้ระบบสมบูรณ์ การเรียนรู้จำ จะใช้ในส่วนที่สองเพื่อ
จำแนกรูปภาพลายเส้นหลัก ขั้นตอนแรกฮิสโทแกรมแบบรูปร่างจะสร้างจากรูปภาพที่สกัดแล้วโดย
การฉายภาพในแนวนอนและในแนวอน หลังจากนั้นจะนำฮิสโทแกรมของรูปภาพสอบถามและ
รูปภาพในฐานข้อมูลมาเปรียบเทียบกันโดยการวัดความคล้ายคลึงเชิงมุม ขั้นตอนสุดท้ายจะใช้
ขั้นตอนวิธีการเพื่อนบ้านที่ใกล้ที่สุดในการระบุบุคคล ผลการทดลองแสดงให้เห็นระบบที่มี
ประสิทธิภาพมีความแม่นยำสูงในการเรียนรู้จำ (98.53%)

ภาควิชาคณิตศาสตร์และวิทยาการคอมพิวเตอร์.....ลายมือชื่อ.....

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Palmprint identification is one of biometric methods to ascertain the identity of person. Although palmprint is not the most popular characteristic that we currently use, it is a powerful alternative for identifying in the future technology due to its uniqueness, stableness, convenience and ease of use. In recent surveys, there are many features on palm that can be used for automated recognition such as principle lines, wrinkles, ridges and datum points. Principle line which is the main line is proposed in this thesis. The system is divided into two main subsystems. The first part concerns with palmprint feature extraction using a cascade of consecutive filters to obtain the principle lines. To achieve the proposed system, recognition is provided as the second part to classify principle line image. Firstly, shape histogram is constructed from the extracted image by projections along vertical and horizontal axes. Then, the histogram of query image and the image in database are compared by using cosine similarity measure. Finally, K-Nearest Neighbor is employed to identify a person. The experimental results demonstrate the efficient system yielding high recognition accuracy (98.53%).

Department : Mathematics and Computer Science Student's Signature.....

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CHAPTER I

INTRODUCTION

1.1 Motivation and Problem Description

Nowadays, the spread of information technology greatly increases in the era of globalization. The technology has become an important role that can improve daily life of human. Furthermore, a lot of innovations and developments in technology have been applied to business, government, organization and education such as companies, industries, banks, militaries and universities to enhance their performance and also to manage their data and assets. However, the advantages of them always come with the drawbacks: if they are used in the wrong way, they can create harm to people, for instance, infringement of human rights and security. With regard to these problems, one significant security solution that could provide authentication and recognition is “Biometrics”.

Biometrics is an automated method that is used for recognizing person's identity in identification [1] and verification systems based on physiological or behavioral characteristics. Examples of these characteristics include face, fingerprint, palmprint [2], iris, voice, signature and gait. Among the physiological characteristics, palmprint might be considered as one of the efficient characteristic because of its uniqueness and stableness. Moreover, it can also provide an accurate recognition with cost effectiveness.

Palmprint-based biometric identification is comprised of feature extraction and recognition system. Feature extraction is an essential preprocessing step used to extract the input data into the set of features as vector. These features can be principle lines, wrinkles, ridges and minutiae points which are the unique feature of human. The remaining step usually involves recognizing or classifying the considered vector into the suitable class to identify people.

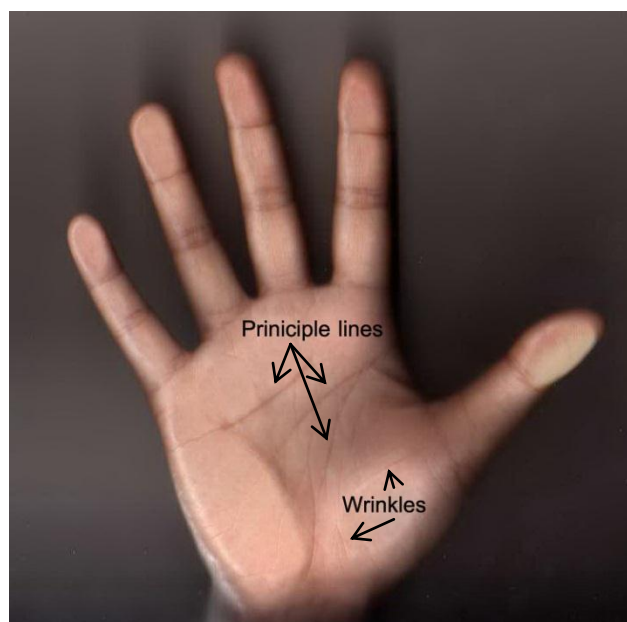


Figure 1.1: Palmprint features in a low resolution image

As mentioned above, this thesis proposes a palmprint identification system based on principle lines. The system is divided into two main subsystems. The first part concerns with palmprint feature extraction. To archive the proposed system, recognition is provided as the second part to classify principle line image.

1.2 Problem Formulation

1. How to extract the principle line of palmprint with simple method and also taking less processing time.
2. How to design the system for identifying person from the principle line of palmprint.

1.3 Research Objectives

The objectives of this research are as follows:

1. To develop principle line extraction that is strongly compatible for palmprint identification system.

2. To develop the person identification system from palmprint with higher accuracy than the existing methods.

1.4 Scope of Research

1. In this thesis, the system can be only applied to bitmap image file format with size of 150x150.
2. Color image is acceptable but it will be converted into gray scale format before feeding.
3. Image occlusion is not allowed because insufficient data yield wrong decision.

1.5 Thesis Organization

The research methodology in this thesis is comprised of eight main tasks. To understand and study knowledge of this research, literature review is the first task that provides the information of previous related researches. After review process, background knowledge, research methodologies, the experiments and results, future works and advantages and disadvantages of these developments are concluded as described in Chapter 2. The second task is analyzing and defining problems from the study. Then a designed system with proposed methods will be done for the third task. Fundamental knowledge of the proposed methods and the procedures of the experiment are explained in Chapter 3 and Chapter 4, respectively. After that, an extraction phase corresponding to the first subsystem and its evaluation will be finished in the fourth task. The fifth task is developing a recognition phase and combining two phases to create an identification system. Subsequently, testing and evaluating tasks for the system to improve the accuracy and preprocessing time are needed in the sixth and seventh tasks. Finally, the last task is conclusion and discussion of the experiment.

Table 1.1: Task Schedule

No.	Task	Month Sequence																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Literature review	■	■	■	■															
2	Difining problems of the study			■	■															
3	Designing the methodologies of experimnt				■	■														
4	Developing a new extraction method and evaluating the experimental results				■	■	■	■	■	■										
5	Preparing for proceeding								■	■										
6	Preparing for propasal test										■									
7	Developing a new recognition method and combining two methods to create an identification system											■	■	■						
8	Testing and evaluatong the experiment												■	■	■					
9	Improving the system													■	■					

Table 1.1: Task Schedule (cont'd)

No.	Task	Month Sequence																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
10	Concluding and discussing the results																			
11	Preparing for proceeding																			
12	Preparing for dissertation																			

1.6 Expected Outcomes

1. A method for principle line extraction which is uncomplicated and fast to process within the limitation of time interval.
2. A person identification system with high accuracy based on principle line of palmprint.

CHAPTER II

LITERATURE REVIEWS

2.1 Database

There are many databases used in palmprint extraction and recognition such as PolyU Palmprint database, Visgraph database, and CASIA Palmprint Image database. PolyU Palmprint database is widely used database collected by The Biometric Researcher Center (UGC/CRC) at the Hong Kong Polytechnic University, the largest government-funded tertiary institution in Hong Kong. Most researchers employed this database to evaluate their experiments. The database consists of 7,752 grayscale images corresponding to 386 palms, including left palm and right palm, around twenty samples for each in bitmap image format. These palms were captured by a real time palmprint capture device and collected in two sessions; each session contains around 10 samples. Furthermore, the second session applied the light source and the focus of the CCD camera is different from the first session. The resolution of palmprint is 384x284 pixels at 75 dpi. Table 2.1 represents a detail of this database. Visgraph database was acquired by the Hong Kong University of Science and Technology using a digital camera with the image size of 960x1280. This database can be used for palmprint and hand recognition. CASIA Palmprint Image database contains 5,502 8-bit grayscale images in jpeg format captured from 312 different persons. In addition, other databases that researchers used to evaluate the palmprint recognition were captured by their own captured device. An example of each database shows in figures 2.1-2.4

Table 2.1: Overview of PolyU Palmprint Database

Subjects	
Number of subjects	193
Male	131
Female	62
Age	
< 30 years	166
> 50 years	6
30 - 50 years	21



Figure 2.1: Example of palm image in PolyU Palmprint database



Figure 2.2: Example of palm image in Visgraph database



Figure 2.3: Example of palm image in CASIA-Palmpoint database



Figure 2.4: Example of palm image collected by researcher's captured device

2.2 Palmpoint Feature Extraction

Sakdanupab et al. [3] have proposed and implemented a palmpoint classification method based on principle lines. The phase of principle line extraction is based on profiles of gray values within a window of size 3x3 in four directions (0, 45, 90, and 135 degrees). The principle lines consisting of heart line, head line and life line are extracted and used for recognizing people afterwards. The drawback of this method is that noise is not completely eliminated by the proposed noise reduction process. In addition, their algorithms take too much processing time.

Huang et al. [4] have proposed a palmpoint verification approach based on principle lines. In the process of principle line extraction, the lines are extracted by using the modified finite Radon transform. When the transformation is applied, lines in Cartesian coordinate are converted to lines in energy and direction. The energies and

directions are used to detect the differences between principle lines and wrinkles. After that, those differences are finally used to verify people.

Wong et al. [5] have described the palmprint identification based on features from lines in palmprint. In this work, Sobel mask of two sizes (3x3 and 5x5) in four directions together with an appropriate threshold are mainly used to extract feature vectors.

Zhu et al. [6] have applied an approach for major line extraction of palmprint using gradient images in 4 directions which are overlapped, and then merged with Canny edge image. To obtain better results, palmprint image will be dilated and then blurred with the probable template to acquire the major lines. Figure 2.1 has shown the flowchart of method proposed by Zhu. The disadvantage of this method is that their algorithm is somewhat complicated to generate the principle palmprints. The flowchart of this approach is illustrated as figure 2.5

Table 2.2: Summary of palmprint feature extraction approach

Method	Authors
Gray level profiles	Sakdanupab et al. [3]
Modified Finite Radon Transform	Huang et al. [4]
Sobel masks	Wong et al. [5]
Hierarchical Extraction	Zhu et al. [6]

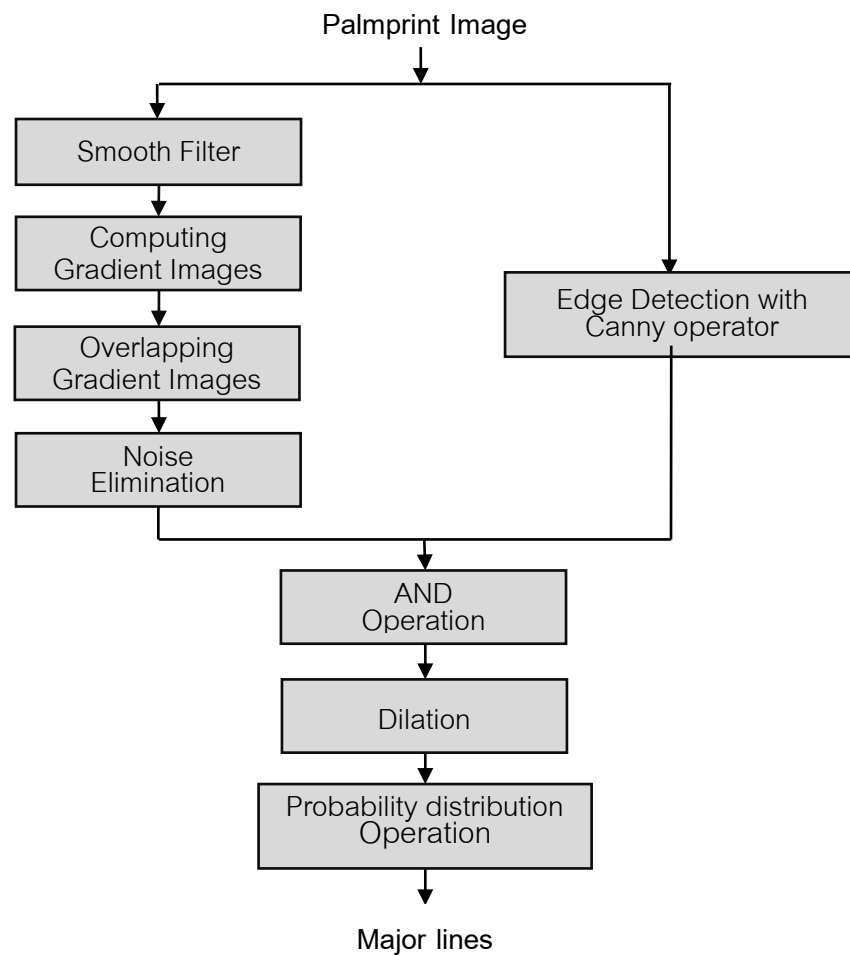


Figure 2.5: Flowchart of extraction method proposed by Zhu

2.3 Palmpoint Identification

Laadjel et al. [7] have proposed an approach for palmpoint recognition based on an assembly of Fisher linear discriminant (FLD) and Gabor Wavelet to obtain palm texture as the feature extraction. The City Block Distance is used to measure the similarity between a query palmpoint image and images in a database.

Zhu et al. [8] have described a palmpoint recognition algorithm based on principle lines which are obtained from their palmpoint extraction approach [6] as mentioned above. Probability Feature Image (PFI) is used to establish a template library as well as fuzzy logic is applied for palmpoint matching.

Zhu et al. also have employed a hierarchical recognition algorithm [6] to use two features which are major lines, extracted by the same method [6], together with texture feature obtained by dual tree complex wavelet. The flowchart of this approach is depicted as figure 2.6 and the experimental results of methods proposed by Zhu are shown in table 2.3.

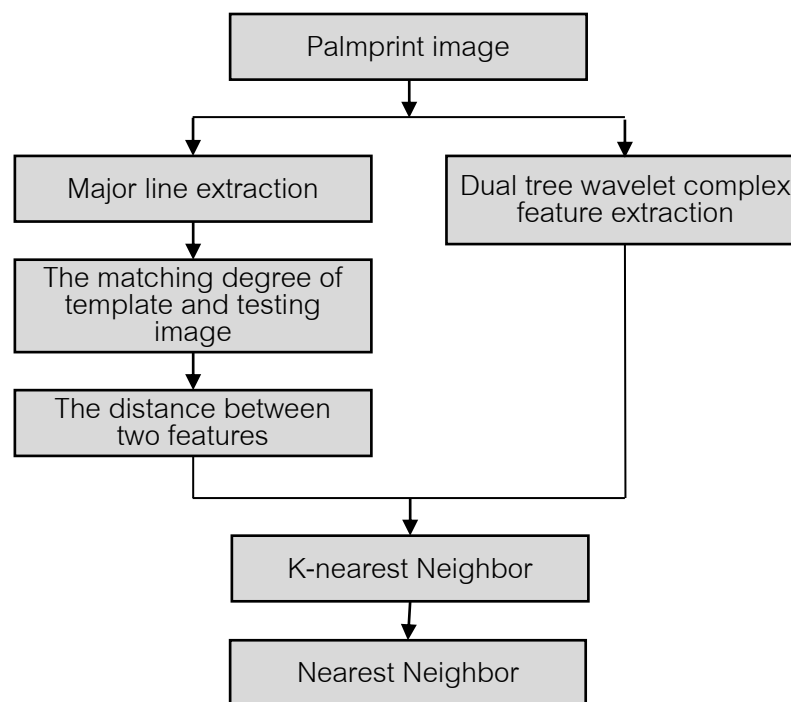


Figure 2.6: Flowchart of hierarchical recognition method proposed by Zhu

Table 2.3: Experimental results of Fuzzy logic and hierarchical method proposed by Zhu

Method	Database size (palms)	Recognition accuracy (%)
Fuzzy logic	3860/386	98.13
Hierarchical method	3860/386	97.82

Meraoumia et al. [9] have proposed a scheme for palmprint identification. The feature extraction technique is based on two-dimensional Block based Discrete Cosine Transform (2D-BDCT). After applying 2D-BDCT, the multivariate Gaussian Probability Density Function (GPDF) is used for modeling the 2D-BDCT coefficients as feature vector. In the classification phase of their scheme, Log-likelihood scores are used for palmprint matching.

Table 2.4: Summary of palmprint identification approach

Method	Authors
Fisher linear discriminant	Laadjel et al. [7]
Fuzzy logic	Zhu et al. [8]
Hierarchical Recognition	Zhu et al. [6]
Log-likelihood	Meraoumia et al. [9]

CHAPTER III

FUNDAMENTAL KNOWLEDGE

3.1 Smoothing filter

Smoothing filter is commonly used signal processing technique to enhance noisy images at the expense of blurring by removing a contaminated signal to reveal significant signal features and components. This filter is also called low-pass filter because it allows only low frequency components pass and filter out the high frequency components. There are different types of smoothing filter which are mean filter, median filter and Gaussian filter, but mean filter is employed in this thesis.

The mean filter is one of the simplest low-pass filters implemented by a local averaging operation. Each pixel value is replaced by an average of all the pixel

$$\hat{I}(i, j) = \frac{1}{M} \sum_{p=1}^M I_p(i, j) \quad (3.1.1)$$

value in the corresponding neighborhood:

where $\hat{I}(i, j)$: The value at the position (i, j) in the result image
 $I_p(i, j)$: The value at the position (i, j) in the image p
 M : The total number of pixels in the neighborhood N

$$\hat{I}(i, j) = \frac{1}{9} \sum_{k=i-1}^{i+1} \sum_{l=j-1}^{j+1} I(k, l) \quad (3.1.2)$$

Frequently, a 3x3 neighborhood (mask) is used:

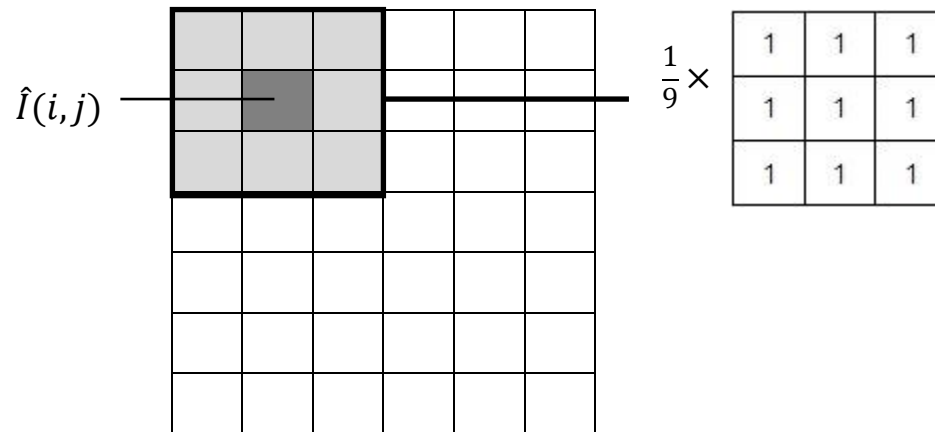


Figure 3.1: The mean filtering using a 3x3 neighborhood

An example of the calculation of mean filtering of a 3x3 neighborhood is shown below

Example:

Image =

3	6	2
7	4	5
1	9	8

Calculation: $(3 + 6 + 2 + 7 + 4 + 5 + 1 + 9 + 8) / 9 = 45 / 9 = 5$

Therefore, the center pixel value after using mean filtering would be changed from 4 to 5.

The center pixel ($\hat{I}(i,j)$) is

*	*	*
*	5	*
*	*	*

When the size of neighborhood increases, more severe smoothing will be produced. The effect of the smoothing filter is shown in figure 3.2



(a)



(b)

Figure 3.2: (a) the noisy image and (b) the result of 3x3, 5x5, and 7x7

3.2 Gradient Edge Detection

Edge detection is a kind of image segmentation techniques which identifies object boundaries in an image. In general, an edge is caused by a variety of factors such as depth discontinuity, surface normal discontinuity, surface color discontinuity, and illumination discontinuity. From these conditions, the edge can be defined when a point in the image rapidly changes in intensity as depicted in figure 3.3.

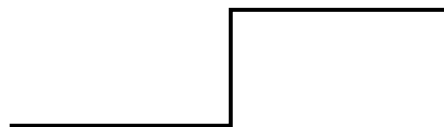


Figure 3.3: Rapidly change in intensity on an edge

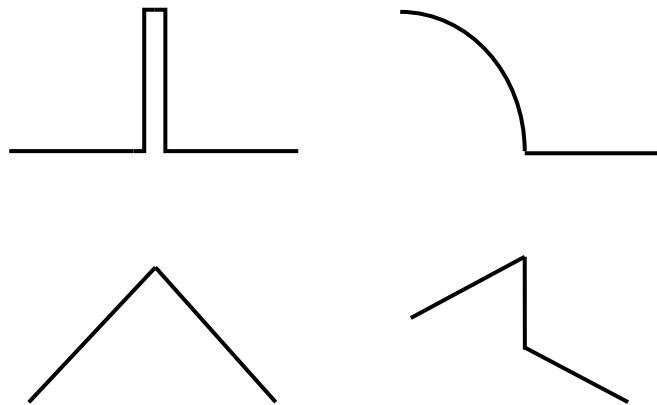


Figure 3.4: Shapes of image intensity edges

Moreover, if considering the point in direction, the change of that point is called the gradient point.

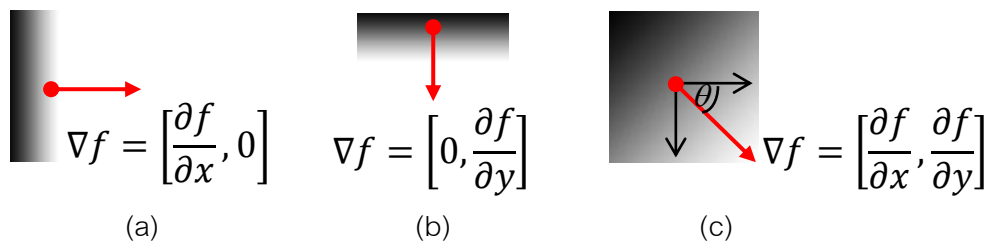


Figure 3.5: Gradient point, (a) the gradient in horizontal axis, (b) the gradient in vertical axis, and (c) the gradient in two directions

The gradient of an image is defined as:

$$\nabla f = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y} \right] \quad (3.2.1)$$

And the gradient direction is given by

$$\theta = \tan^{-1} \left(\frac{\frac{\partial f}{\partial x}}{\frac{\partial f}{\partial y}} \right) \quad (3.2.2)$$

Sometimes the gradient in horizontal axis and the gradient in vertical axis must be combined to get only one measure value called gradient magnitude. This gradient magnitude is obtained by taking the root sum square of the result of $\frac{\partial f}{\partial x}$ and $\frac{\partial f}{\partial y}$

$$\|\nabla f\| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2} \quad (3.2.3)$$

In a digital image, the easy way to differentiate $f[x, y]$ is achieved by taking discrete derivative on an image:

$$\frac{\partial f}{\partial x}[x, y] \approx f[x + 1, y] - f[x, y] \quad (3.2.4)$$

$$\frac{\partial f}{\partial y}[x, y] \approx f[x, y] - f[x, y + 1] \quad (3.2.5)$$

The derivatives can be implemented by the convolution the image with the templates.

-1	1	Represents	$\frac{\partial f}{\partial x}[x, y]$
----	---	------------	---------------------------------------

1	-1	Represents	$\frac{\partial f}{\partial y}[x, y]$
---	----	------------	---------------------------------------

Example: Finding gradient magnitude of this image

0	0	0	1	1
0	0	0	1	1
0	0	1	1	1
1	1	1	1	1
1	1	1	1	0

The results of $\frac{\partial f}{\partial x}[x, y]$ and $\frac{\partial f}{\partial y}[x, y]$ are

$\frac{\partial f}{\partial x}[x, y]$	=	0	0	1	0	*
		0	0	1	0	*
		0	1	0	0	*
		0	0	0	0	*
		0	0	0	-1	*

$$\frac{\partial f}{\partial y}[x, y] = \begin{matrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ * & * & * & * & * \end{matrix}$$

The gradient magnitude of this image is obtained

by

(3.2.5)

$$\left| \frac{\partial f}{\partial x}[x, y] \right| + \left| \frac{\partial f}{\partial y}[x, y] \right|$$

Therefore,

$$\text{Magnitude of gradient} = \begin{matrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 1 & 2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \end{matrix}$$

The gradient operators that are currently used in image processing technique are depicted as follows:

Robert's Cross Operator

0	1
-1	0

and

1	0
0	-1

Sobel Operator

-1	0	1
-2	0	2
-1	0	1

and

1	2	1
0	0	0
-1	-2	-1

3x3 Prewitt Operator

-1	0	1
-1	0	1
-1	0	1

and

1	1	1
0	0	0
-1	-1	-1

4x4 Prewitt Operator

-3	-1	1	3
-3	-1	1	3
-3	-1	1	3
-3	-1	1	3

and

3	3	3	3
1	1	1	1
-1	-1	-1	-1
-3	-3	-3	-3

3.3 Morphological Operation

Morphological image processing is a technique which collects non-linear operations corresponding to the morphology or shape of features in a binary image and also in grayscale image. The purpose of this technique is to remove imperfections such as noise and hole by accounting for the form and structure of the image. The basic morphological operation includes dilation, erosion, and skeleton. Hit and miss algorithm is applied to this working operation. A small binary shape or template with odd dimensions, generally used 3x3, is employed in the process. This template is called structuring element, examples are depicted as figure 3.6. The structuring element is compared with the neighboring pixels in the image by positioning at all possible locations. If the image matches the template, the output of the pixel corresponding to the center of the template is set to 1 or 0 otherwise. An example of hit and miss algorithm is illustrated as below

Example: Finding the left-top corner of an image A by using hit and miss algorithm

A =

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	1	0	0	0
0	1	1	1	0	0	0	1	1	0	0	0
0	1	1	1	1	0	1	1	1	1	0	0
0	0	0	1	1	0	1	1	1	1	0	0
0	0	0	1	1	0	0	1	1	0	0	0
0	0	0	1	1	0	0	1	1	1	1	0
0	1	1	1	1	0	0	1	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0

S =

0	0	
0	1	1
	1	

The result is

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

1	1	1
1	1	1
1	1	1

(a)

1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

(b)

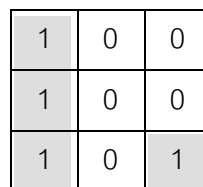
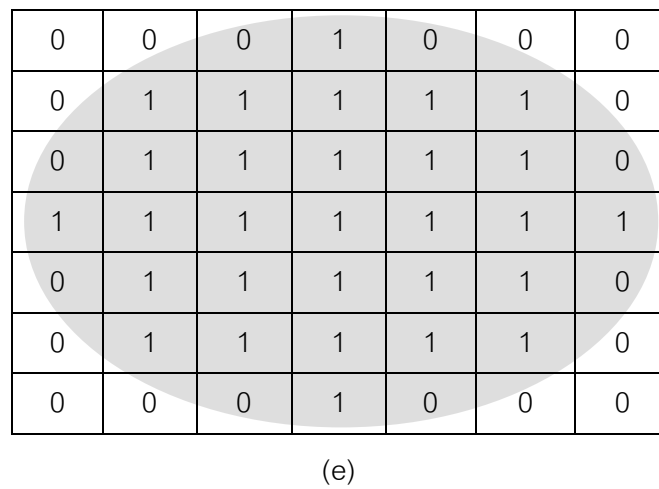
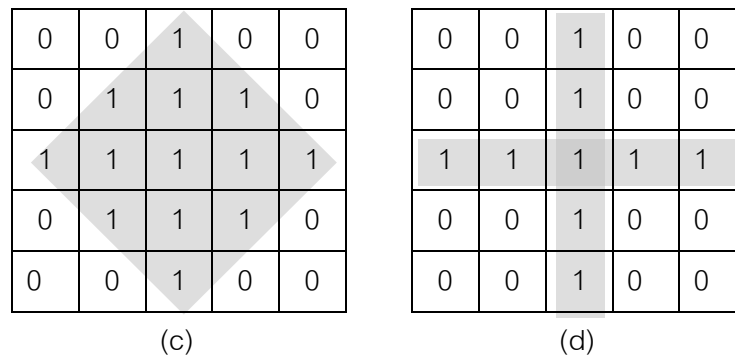


Figure 3.6: Examples of structuring elements, (a) square 3x3 element, (b) square 5x5 element, (c) diamond-shaped 5x5 element, (d) cross-shaped 5x5 element, (e) disk-shaped 7x7 element, and (f) arbitrary 3x3 element

3.3.1 Dilation

Dilation is an operator which is applied to enlarge the boundaries of areas of foreground pixels in an image. The effect of this expansion is the holes and gaps within those areas become smaller. The dilation operator of image A by structuring element S is defined as the set operation:

$$A \oplus S = \{p \in \varepsilon^2 : p = a + s, a \in A, s \in S\} \quad (3.3.1.1)$$

where ε^2 : The set element, a : The pixel value in A
 $+$: The translation operator, s : The pixel value in S

The dilation process is illustrated in example 1 and example 2

Example 1:

$$A = \begin{array}{|c|c|c|} \hline & & \\ \hline & 1 & \\ \hline & & \\ \hline \end{array}$$

$$S = \begin{array}{|c|c|c|} \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}$$

The result of $A \oplus S$ is

$$\begin{array}{|c|c|c|} \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}$$

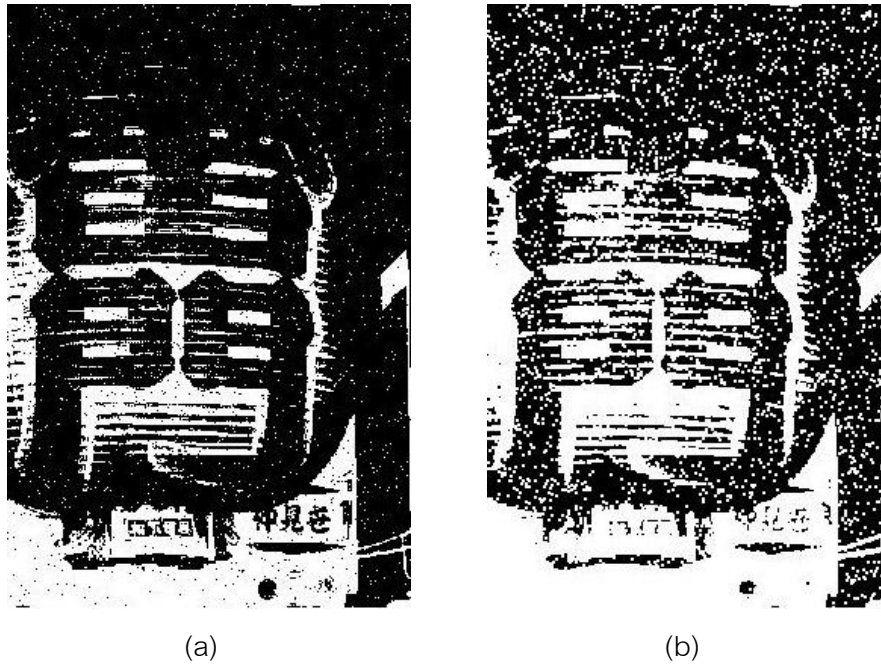


Figure 3.7: (a) original image (b) image after applying dilation

3.3.2 Erosion

Erosion is an operator which is applied to erode the boundaries of areas of foreground pixels in an image. The effect of this shrink is the holes and gaps within those areas become larger. The erosion operator of image A by structuring element S is defined as the set operation:

$$A \ominus S = \{p | p \in \varepsilon^2 : p + s \in A, \forall s \in S\} \quad (3.3.2.1)$$

Where ε^2 : The set element, a : The pixel value in A

$+$: The translation operator, s : The pixel value in S

The erosion process is illustrated in example 1 and example 2

Example 1:

$$A = \begin{array}{|c|c|c|} \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}$$

The result of image after applying the erosion process is depicted as

figure 3.8

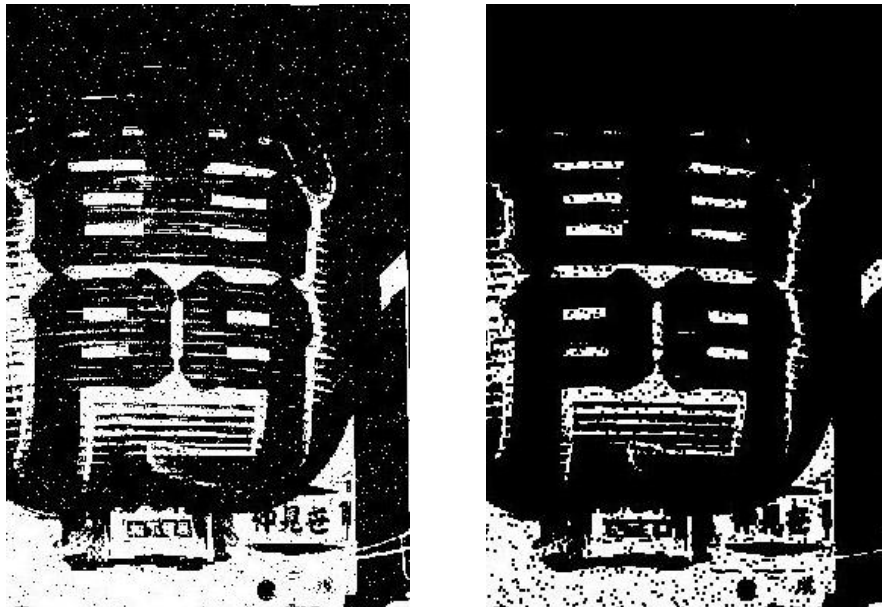


Figure 3.8: (a) original image (b) image after applying erosion

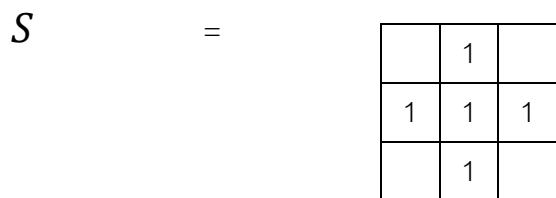
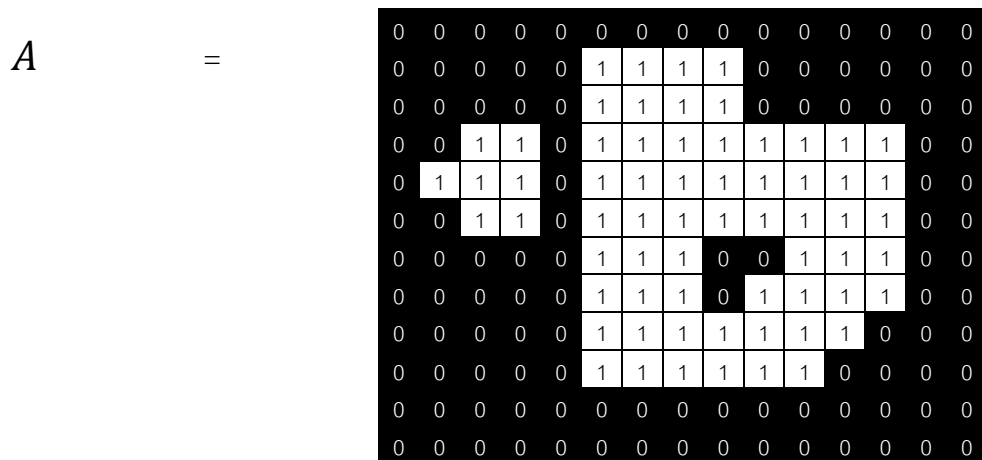
3.3.3 Closing

Closing is an operator that consists of two basic morphological operations, dilation and erosion, using the same structuring element. This operator applies a dilation followed by an erosion which can be used to smoothen contour and fill small holes in the edge image. The closing operator of image A by structuring element S is defined as:

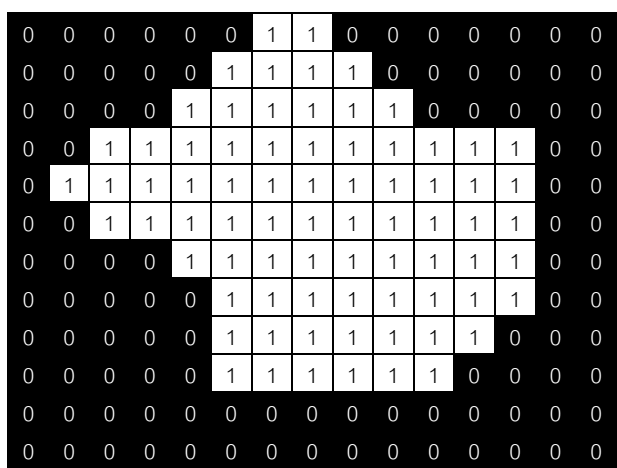
$$A \bullet S = (A \oplus S) \ominus S \quad (3.3.3.1)$$

The closing process is illustrated in example 1

Example 1:



The result of $A \bullet S$ is



The result of image after applying the closing process is depicted as

figure 3.9

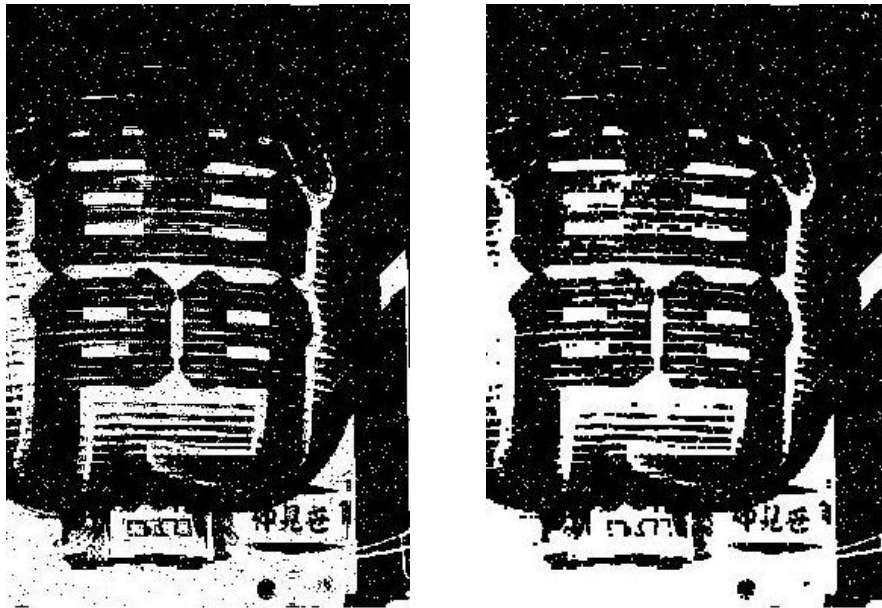


Figure 3.9: (a) original image (b) image after applying closing

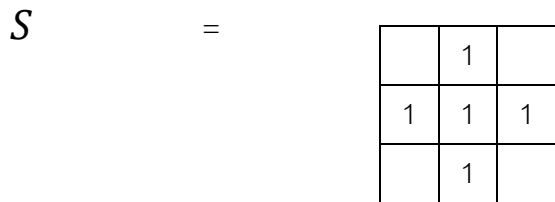
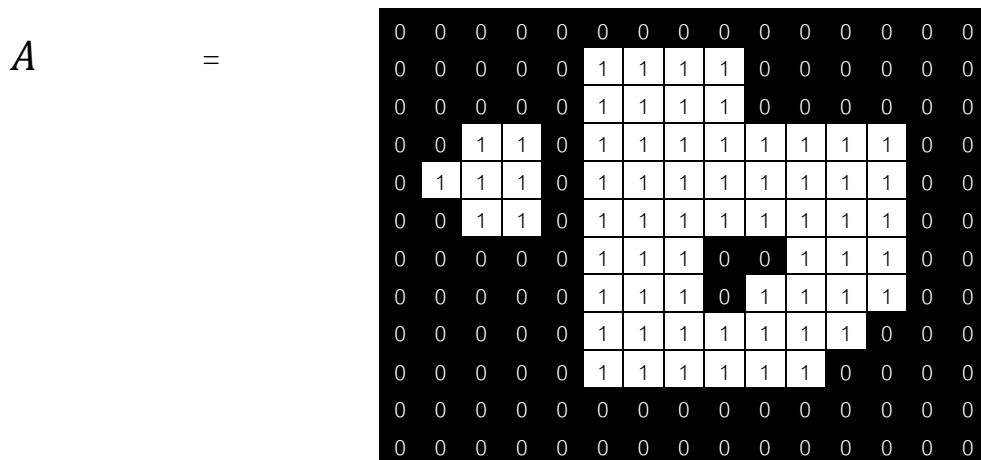
3.3.4 Opening

Opening is an operator that consists of two basic morphological operations, dilation and erosion, using the same structuring element as same as closing, but the order of the operations is different. This operator applies an erosion followed by a dilation which can be used to eliminate small pixels that might be noise from the foreground. The opening operator of image A by structuring element S is defined as:

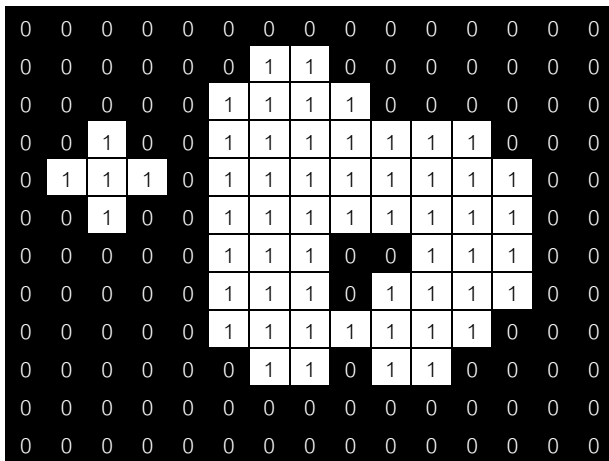
$$A \circ S = (A \ominus S) \oplus S \quad (3.3.4.1)$$

The opening process is illustrated in example 1

Example 1:



The result of AoS is



The result of image after applying the opening process is depicted as

figure 3.10

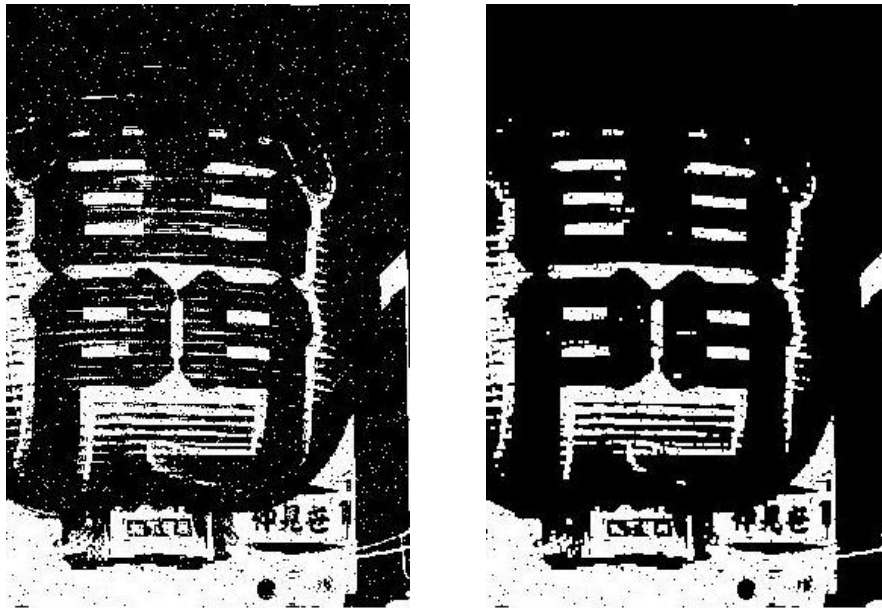


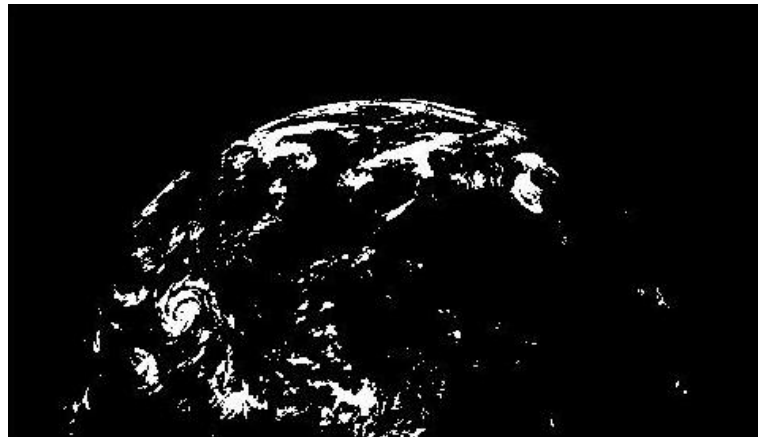
Figure 3.10: (a) original image (b) image after applying opening

3.4 Binarization

Image binarization is a quantization process of images that is typically treated as simply a thresholding operation on a grayscale image. The image can be binarized by specifying a thresholding value. Each pixel in an image is converted into one bit, '0' or '1', if a pixel is less than the thresholding value then it is changed to '0' otherwise its '1'. After binarizing, the result is shown in figure 3.11



(a)

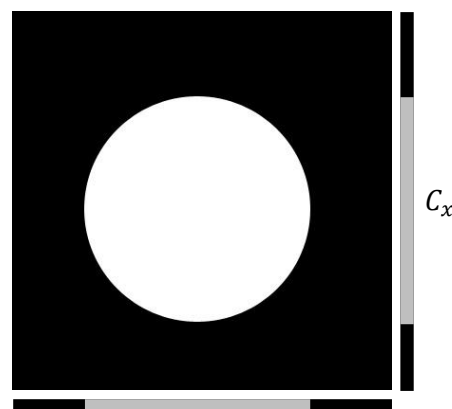


(b)

Figure 3.11: (a) Gray image and (b) Image after binarizing

3.5 Shape Matching

The shape matching is a way to determine the difference of two or more images by using some features. A histogram displayed the physical shape called shape histogram can be used as such feature. With this histogram, a graph is commonly used to depict the frequency or shape of the data distribution that is useful to see how often each different value occurs and where the majority of values fall in which range of graph. The shape histogram can be created from vertical or horizontal projection of an image as displayed in figure 3.12 and figure 3.13.

 C_y

(a)

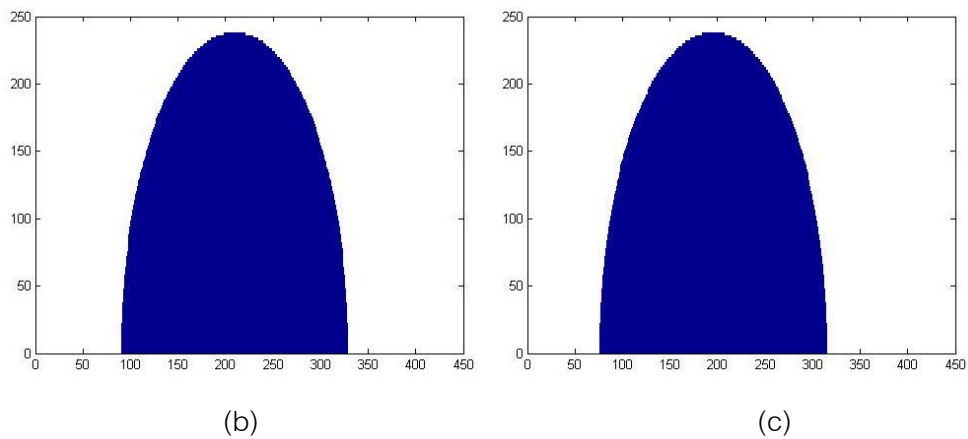


Figure 3.12: Example of shape histogram, (a) circle image, (b) the histogram of horizontal projection (C_x), and (c) the histogram of vertical projection (C_y)

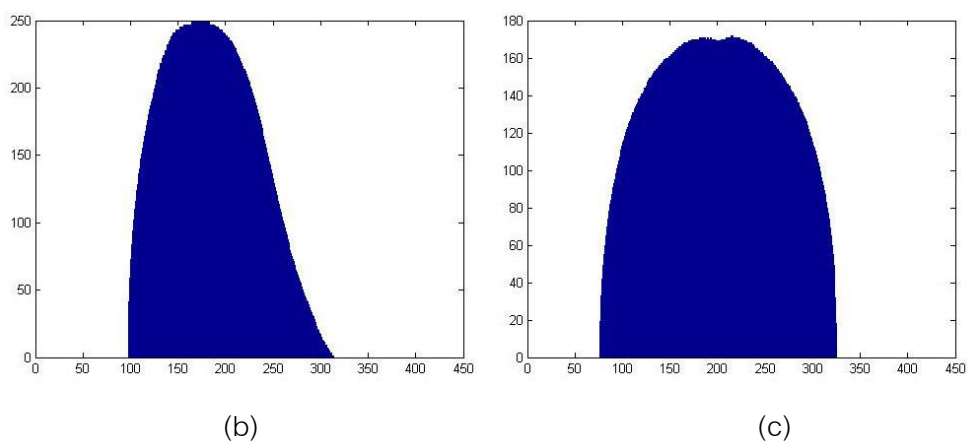
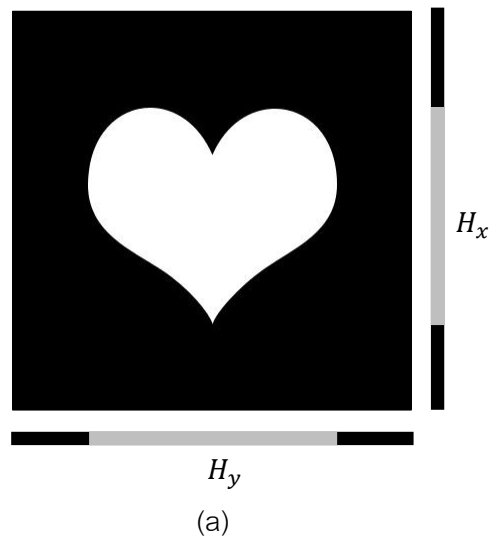


Figure 3.13: Example of shape histogram, (a) heart image, (b) the histogram of horizontal projection (H_x), and (c) the histogram of vertical projection (H_y)

From figures 3.12 and 3.13, it can be noticed that the histograms of the circle image and heart image are quite different. Therefore the shape matching can be used to conclude that these two images are different in shape.

3.6 Cosine Similarity

Cosine Similarity is a simple measure used to compare the similarity of two vectors by calculating the cosine of the angle between them. The result of this calculation is ranged from '0' to '1', if it approaches '1', it, meaning that the two vectors are getting closer, means that the similarity of whatever is represented by the vectors is high. This is frequently used to compare documents in text mining and also used to measure cohesion within clusters in field of data mining. Cosine similarity is expressed

$$\begin{aligned} \text{Similarity}(A, B) &= \text{cosine}(\theta) = \frac{A \cdot B}{\|A\| \|B\|} & (3.6.1) \\ &= \frac{\sum_{i=1}^n A_i B_i}{\sqrt{\sum_{i=1}^n (A_i)^2} \sqrt{\sum_{i=1}^n (B_i)^2}} \end{aligned}$$

by the formula:

From the equation, the dot product and magnitude of two vectors must be calculated. The dot product is multiplying the coordinates of A and B then combining the product together. This operation is also known as inner product and scalar product. The $A \cdot B$ is given by

$$A \cdot B = \sum_{i=1}^n A_i B_i = a_1 b_1 + a_2 b_2 + \dots + a_n b_n \quad (3.6.2)$$

The magnitude is literally the length of a vector. It is defined by the usual Euclidean Distance:

$$\|A\| = \sqrt{\sum_{i=1}^n (A_i)^2} = \sqrt{a_1^2 + a_2^2 + \dots + a_n^2} \quad (3.6.3)$$

To normalize the $A \cdot B$, the dot product will be divided by the Euclidean Distance. So this ratio defines the cosine angle between the vectors as shown in figure 3.14.

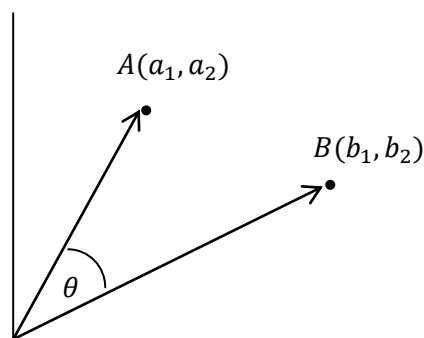


Figure 3.14: The cosine similarity (cosine angle) between vector A and B

3.7 K-nearest Neighbor

K-nearest neighbor is a supervised learning algorithm which is used for data classification and pattern recognition. In the algorithm, an unknown object is classified into the class based on the similarity measurement. The similarity or the distance between that object and all the data points in the training set is computed. Then only the closest “k” points are considered (usually k is an odd number). After that the object is assigned to the class of its k nearest neighbors that appears most frequently called majority vote. As illustrated in the figure 3.15 (a) and (b), k=3 and k=5, respectively, are used to determine an object class.

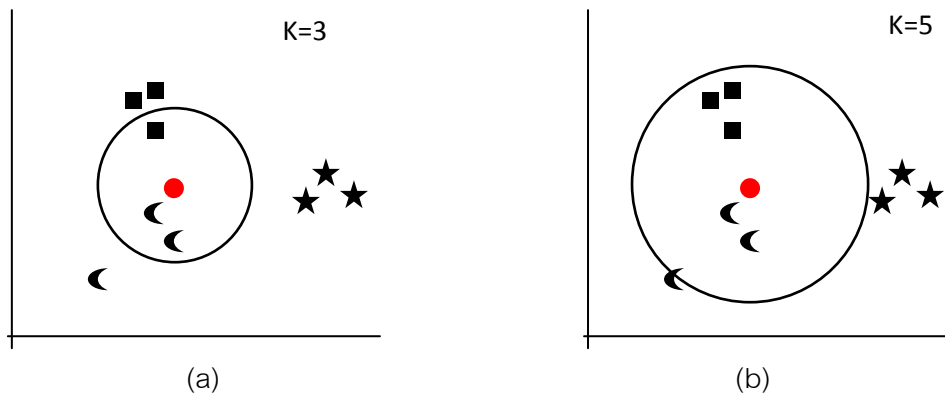


Figure 3.15: K-nearest neighbor, (a) $k=3$ and (b) $k=5$

In the figure 3.15 (a), \bullet is represented as an unknown object. The $k=3$ would be considered. The three nearest neighbors that are closest to the object are \smile , \smile , and \blacksquare . Therefore, this object would be classified to the class of \smile . In the figure 3.15 (b), \bullet is represented as an unknown object. The $k=5$ would be considered. The five nearest neighbors that are closest to the object are \smile , \smile , \blacksquare , \blacksquare , and \blacksquare . Therefore, this object would be classified to the class of \blacksquare .

CHAPTER IV

RESEARCH METHODOLOGY

4.1 Database

PolyU Palmprint Database [10], collected by Biometric Researcher Center at The Hong Kong Polytechnic University, is widely used database in palmprint research area. The images were captured by a real time palmprint captured device. The PolyU palmprint database contains 7,752 grayscale images corresponding to 386 different palms with 20-21 samples for each in bitmap image format. Totally, 3,860 images, 10 samples for each palm, are randomly selected to test in this thesis with 70:30, the ratio of training and testing.

4.2 Overview

In this dissertation, a new approach for person identification system based on principle lines of palmprint is proposed. This system is divided into two phases: palmprint feature extraction and recognition. For extraction, the principle lines would be detected by using consecutive filtering operations. After that, the recognition phase with three concepts is applied to classify a person. Firstly, original shape histogram is constructed according to the extracted image. Then, to overcome translational-invariance problem, shape histogram is translated into eight directions. Then all translated histograms including original histogram of an image are compared with that of a query image based on cosine similarity measure. Finally, the K-Nearest Neighbor would be applied to classify the query image into its appropriate class. The overview of the whole system is illustrated as figure 4.1

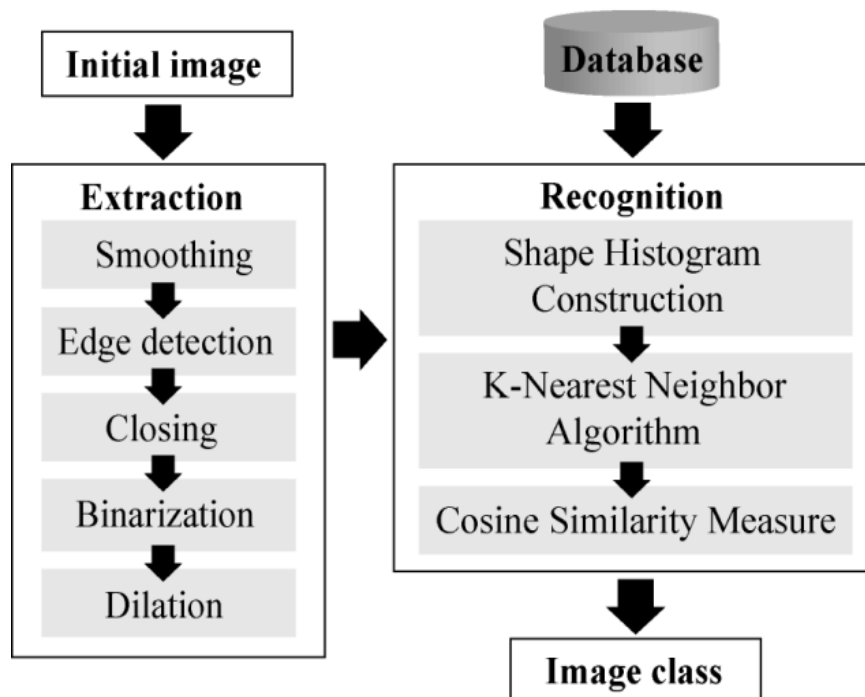


Figure 4.1: The overview of palmprint identification system

4.3 Palmprint Feature Extraction

Principle lines comprising of the head line, the heart line and the life line are selected as the main feature. The initial image is obtained by finding the central point of palm then cropping a Region of Interest (ROI) of size 150x150. After the initialization step, the feature extraction can be divided into five major steps as follows:

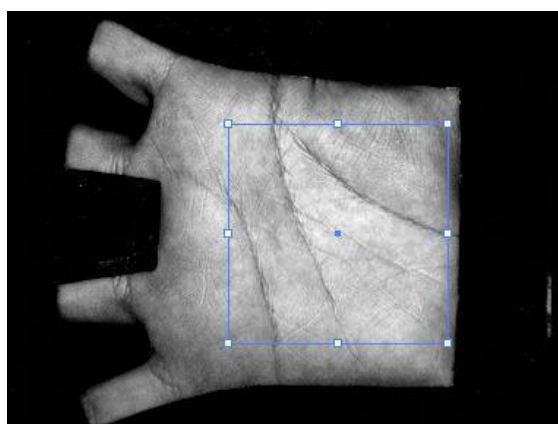


Figure 4.2: Original image

4.3.1 Smoothing

Smoothing filter, a simple 3x3 mean rectangular filter, is applied to blur the image to reduce noise. It can also be used to get objects of interest which makes the image easy to detect.

1	1	1
1	1	1
1	1	1

Figure 4.3: 3x3 mean rectangle filter

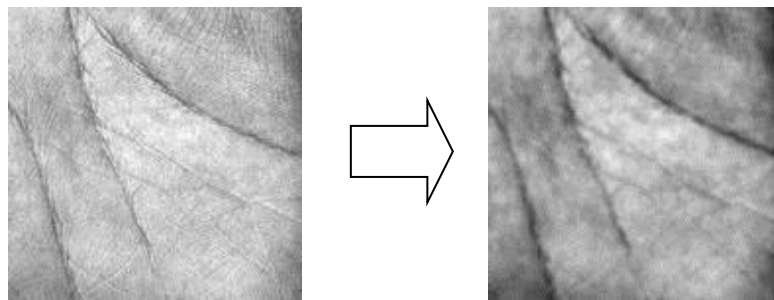


Figure 4.4: Applying smoothing filter into an ROI

4.3.2 Edge Detection

Edge detection is implemented by gradient operator as the second filter in the whole process. Firstly, mask of size 2x2 in two directions (0° and 90°) are used as illustrated in figure 4.5. With this small size, edge can be easily detected with simple computation and less processing time. Subsequently, the smoothed image is convolved with the masks in 0° and 90° respectively to enhance the edge in both directions. These results are shown as figure 4.6 (a) and (b). Finally, the magnitude of gradient is obtained by taking the root sum square of G_x and G_y :

$$\text{Magnitude of gradient} = \sqrt{G_x^2 + G_y^2} \quad (4.3.2.1)$$

where G_x and G_y are image gradients in two directions

$$G_x = \begin{array}{|c|c|} \hline -2 & -2 \\ \hline 2 & 2 \\ \hline \end{array}, \quad G_y = \begin{array}{|c|c|} \hline -2 & 2 \\ \hline -2 & 2 \\ \hline \end{array}$$

Figure 4.5: Mask of size 2x2 in two directions (0° and 90°)

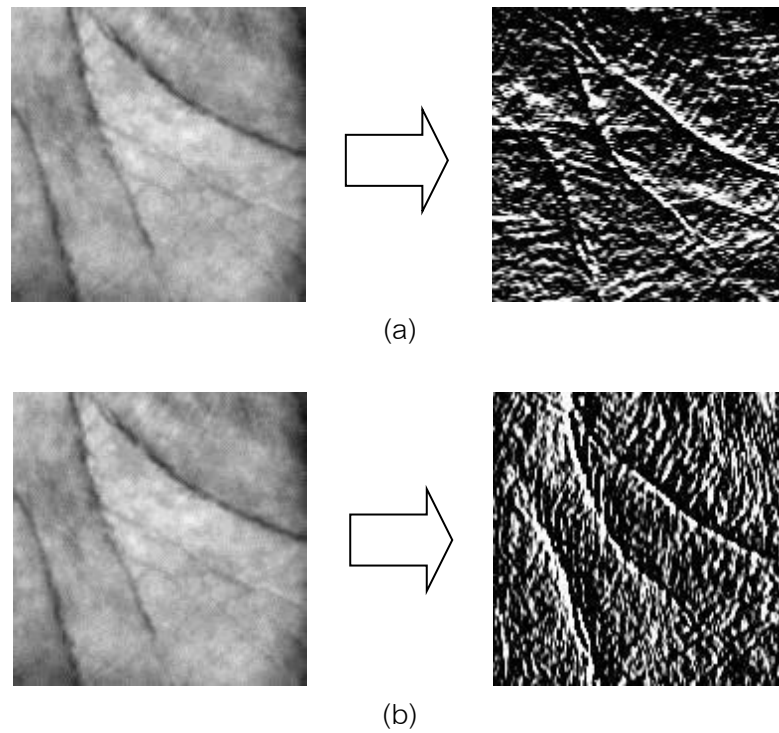


Figure 4.6: (a) Extracting horizontal edge image (b) extracting vertical edge image

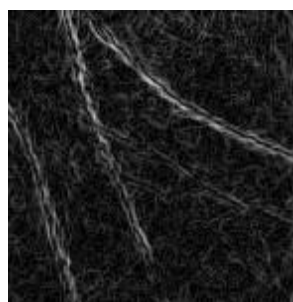


Figure 4.7: Magnitude image

4.3.3 Closing

Closing, the third operator, is the one of morphological operations which uses the basic operations of dilation followed by erosion. The closing of image G by structuring element S is denoted by $G \bullet S$ as follows

$$G \bullet S = (G \oplus S) \ominus S \quad (4.3.3.1)$$

where \oplus and \ominus are basic mathematical morphology techniques called dilation and erosion respectively.

The edge image is performed by closing operator with disk-shaped structuring element as demonstrated in figure 4.8 to smooth contours and fill small holes. After applying closing, the result of image is shown as figure 4.9

strel =

0	1	0
1	1	1
0	1	0

Figure 4.8: The structuring element

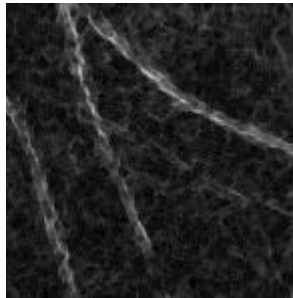


Figure 4.9: Image after closing

4.3.4 Binarization

Binarization technique with pre-defined threshold is employed for removing some tiny components that might be noise as shown in figure 4.10

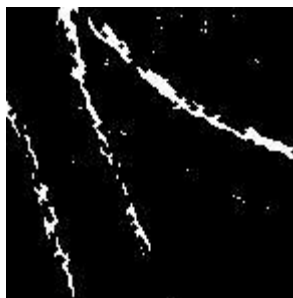


Figure 4.10: Binary image

4.3.5 Dilation

Dilation operation is repeatedly used to enlarge the area of principle line in order to accomplish more efficient in the recognition system.



Figure 4.11: Dilated image

Overall process of palmprint feature extraction is depicted in figure 4.12

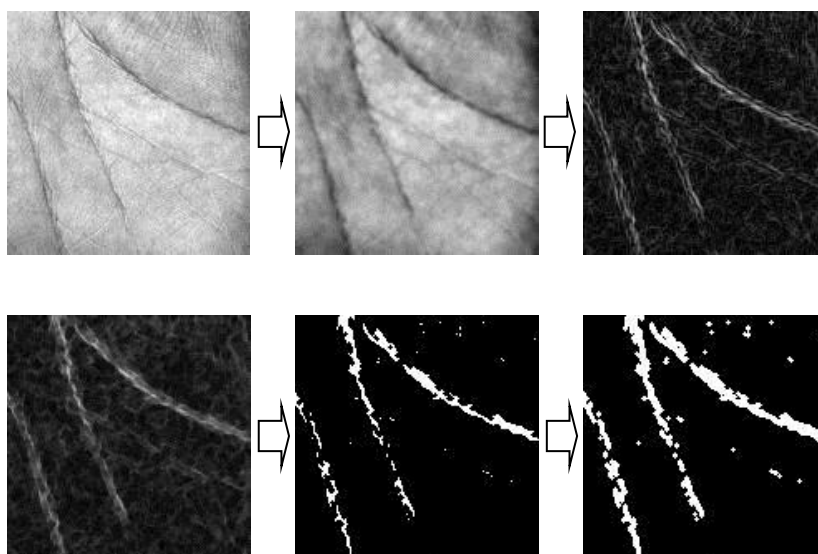


Figure 4.12: The procedures of principle line extraction

4.4 Recognition

After the palmprint feature is successfully extracted with the first phase, it would be used for this recognition phase to identify a person. In this system, there are three consecutive concepts yielding high precision.

4.4.1 Shape Matching

The shape histogram is a popular way to display the physical shape of an image. The histogram can be denoted as a vector representing image shape. The similarity between vectors of two images can be easily calculated by cosine similarity. This process is called shape matching. In this paper, shape histogram is created from horizontal and vertical projections of the shape. With this method, a binary image

obtained from extraction phase is used to define the histogram. Pixels '1' that appear in each row or each column are counted and stored in a bin of the histogram of vertical projection, $\overrightarrow{h_x}$, or horizontal projection, $\overrightarrow{h_y}$. Because of projections in two directions, these histograms are combined with each other by concatenation to form shape histogram as the equation

$$\vec{h} = [\overrightarrow{h_y}, \overrightarrow{h_x}] \quad (4.4.1.1)$$

The number of the values or bins in histogram would be equivalent to the sum of number of rows and columns of the image. The result shows in figure 4.13

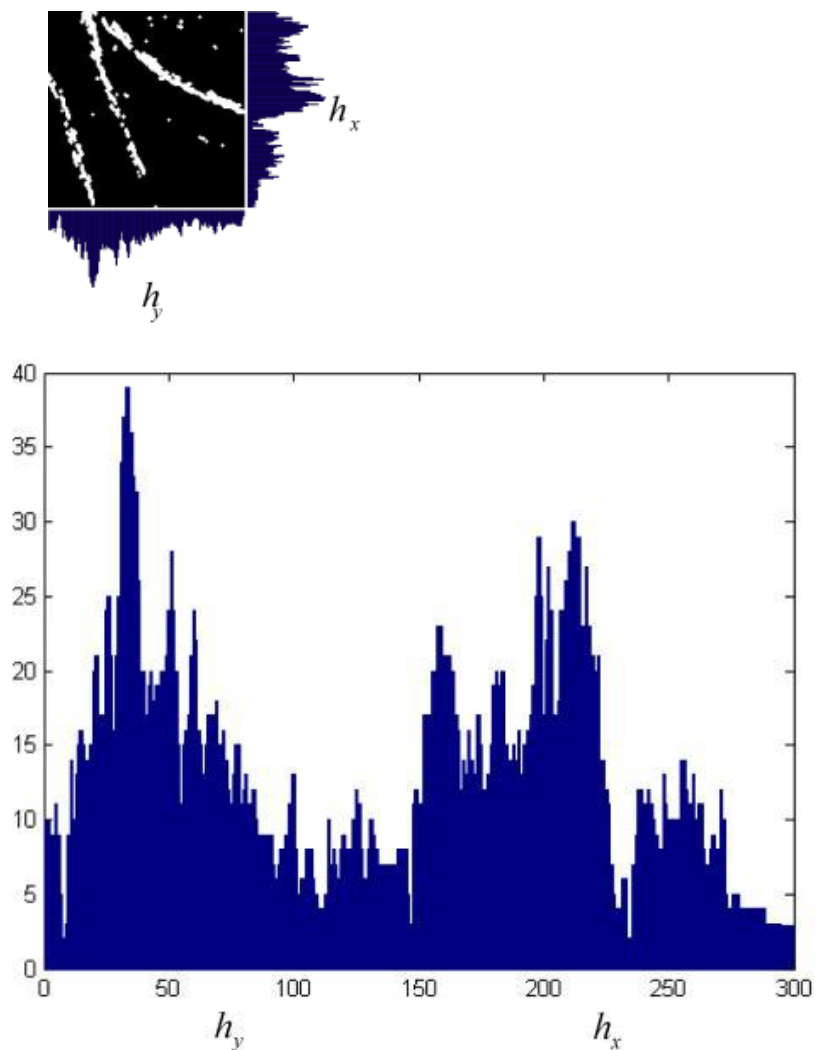


Figure 4.13: The histogram of the principle line image

To improve the recognition phase more flexible, eight histograms corresponding to eight directions of translation are provided. The rotation of histograms of vertical and horizontal projections affects the translation of object in the image along vertical and horizontal axes, respectively. In other words, there are eight ways for histogram rotation to translate object in eight directions. Consequently, total nine possibilities including original horizontal without rotation for object translation are employed in the recognition phase. In addition, the translation step size is two pixels in each direction. This might help the shape matching yielding more precision.

4.4.2 Cosine Similarity

Cosine Similarity is a simple measure used to compare two vectors by calculating the angular difference between them. The result of this calculation is ranged from '0' to '1', if it approaches '1', it means that the similarity of two vectors is high. The equation is given as:

$$\begin{aligned} \text{Similarity}(u, v) &= \text{cosine}(\theta) = \frac{\vec{u} \cdot \vec{v}}{\|\vec{u}\| \|\vec{v}\|} & (4.4.2) \\ &= \frac{\sum_{i=1}^n u_i v_i}{\sqrt{\sum_{i=1}^n (u_i)^2} \sqrt{\sum_{i=1}^n (v_i)^2}} \end{aligned}$$

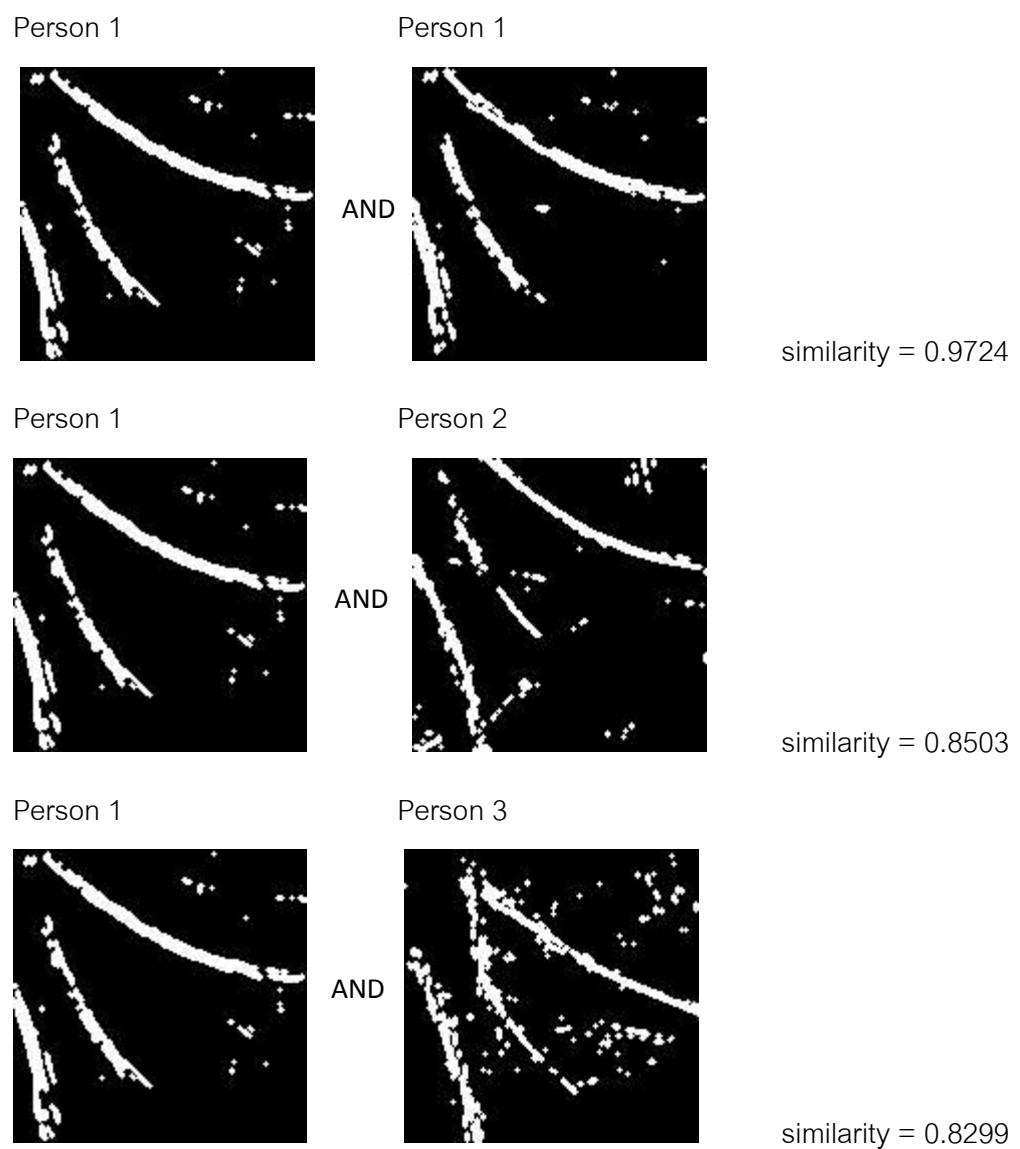
where θ represents the angular between \vec{u} and \vec{v} . In this thesis, the histogram of a query image is denoted by vector u while the histogram of an image in database is denoted by vector v .

4.4.3 K-Nearest Neighbor (K-NN)

K-Nearest Neighbor is a classification method classifying unknown feature vectors or objects into the class based on their similarity with examples in the training set. In the algorithm, an unknown vector would find the closest "k" examples and is assigned to the class of its k nearest neighbors that appears most frequently. This

classification method is simple to implement and it is unnecessary to know the vector distribution before the decision process. In the experiment, $k=3$ is selected for the algorithm to find majority class for the unknown vector.

The examples of comparing two extracted palmprint images with cosine similarity are depicted as figure 4.14. It is obvious that the highest similarity is given when two extracted palmprint from the same person are compared. The other comparisons are depicted in appendix A.



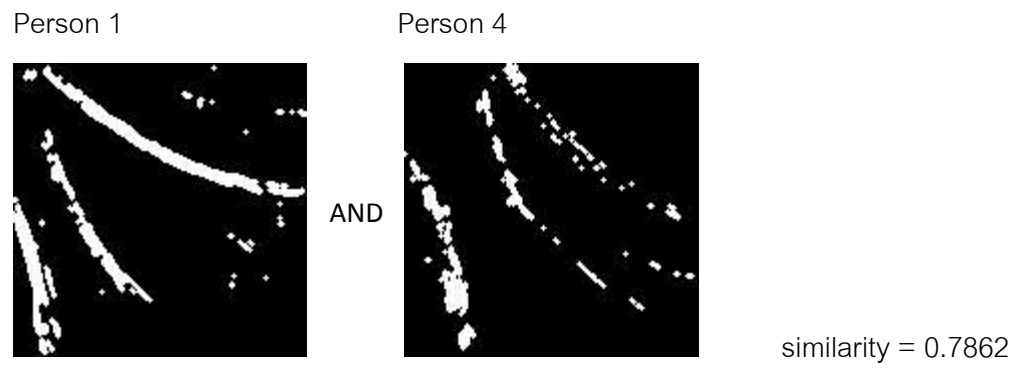


Figure 4.14: The similarity of two extracted palmprint images

CHAPTER V

EXPERIMENTAL RESULTS

5.1 Experimental Results

To evaluate the proposed system, 193 images are used in the extraction phase. These images are selected to test at random by filtering only right palms from 386 different palms in the PolyU palmprint. However, to perform palmprint identification, both right palm and left palm are used in this phase. 2,702 images are employed for training and 1,158 images are employed for testing. The images are also randomly chosen from 386 different palms containing 10 samples for each palm with the ratio 70:30.

5.2 Accuracy Evaluation

5.2.1 Accuracy of Feature Extraction

According to the experiment, the accuracy of principle line extraction is compared with other existing methods. With 193 images, the accuracy of principle line extraction along with the processing time is concluded in table 5.1. The accuracy is taken into account by the average percentage of number of principle lines that can be displayed in the image result.

$$\text{Percentage (\%)} = \frac{\text{Number of displayed principle lines}}{\text{Total number of principle lines}} \quad (5.2.1.1)$$

in images

The results achieve accuracy of 86.23% with 34 ms of execution time. It is noticed that the accuracy of our methods approaches that of Zhu's method, but the execution time is about five times faster. Similarly, the proposed method is better than Sakdanupab's method in terms of both accuracy and execution time as well.

Table 5.1: Comparison of accuracy and execution time among different principle line extraction methods

Methods	Extraction accuracy (%)	Execution time
Proposed Method	86.23	34 ms
Zhu et al.	87.04	629 ms
Sakdanuparb et al.	85.49	5.4 s

5.2.2 Accuracy of Identification

The accuracy of person identification is measured by

$$Accuracy = \frac{\text{Number of the correct identifications}}{\text{Number of all identifications}} \times 100 \quad (5.2.2.1)$$

The proposed system can reach a recognition rate of 98.53% taking 3.73 s by the average of five times testing. The best rate can achieve 98.70% accuracy as illustrated in appendix B. The result is compared with other methods under the same database as depicted in table 5.2.

Table 5.2: Comparison of recognition accuracy with other methods

Methods	Database size (palms)	Recognition accuracy (%)
Proposed method	3860/386	98.53
Discrete cosine transform (2010) [9]	1600/100	98.93
Hierarchical method (2008) [6]	3860/386	97.82
Fuzzy logic (2008) [8]	3860/386	98.13
Wavelet transformation (2006) [11]	100/50	96.3

It can be seen that the proposed method is better than other existing methods using hierarchical method [6], fuzzy logic [8], and wavelet transformation [11] in term of accuracy whilst the discrete cosine transform method [9] obtained a bit higher accuracy than the proposed method. However, such the method takes only 1600 palms for testing, so this cannot guarantee that such the method yields higher accuracy with the entire database.

CHAPTER VI

CONCLUSIONS

6.1 Conclusions

This dissertation presents palmprint identification system consisting of feature extraction and recognition phases based on principle line. The extraction method is applied to obtain the principle line feature vector by using a cascade of consecutive filters. Smoothing filter is used as the preprocessing step to discard noise. First derivative filter and closing filter are applied for finding the location of principle lines. To become apparent, the thresholding filter is subsequently applied. In addition, dilation is finally used as the post-processing step to widen the area of principle lines. The recognition method consisting of three concepts, that are shape matching, k-nearest neighbor and cosine similarity, is then proposed to use the feature vector to generate the system that can be classified a person. From the experimental results, the proposed method was evaluated with 1158 test images from 386 palms (3 images for one palm). The identification system gets the 98.53% accuracy which achieves better results than other systems in terms of accuracy and generality.

6.2 Discussions

Failure identification occurs in some palmprints. This is mainly caused by extraction phase. The failure cases can be performed in three types as follows:

1. Palmprint with many messy lines. According to high contrast of original image, each principle line is displayed as a group of messy line. It is difficult to determine which messy line mainly represents the principle line as shown in figure 6.1 (a).
2. Connectivity of principle lines and minor lines. Since the lines are connected to some lines appearing on background, the algorithm

handles them as the same connected component. This effect is very sensitive to define the suitable threshold as shown in figure 6.1 (b).

3. Flood light image. Image with inappropriate light condition might not be used to find the principle lines. Flood light can vanish the image features before extraction as shown in figure 6.1 (c).

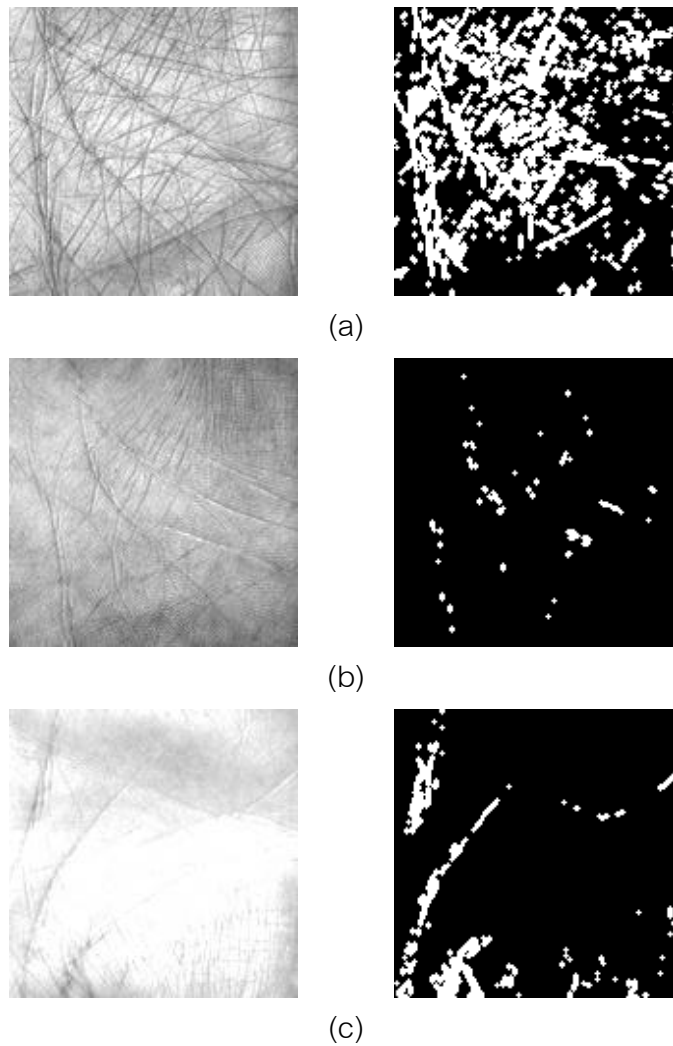


Figure 6.1: Failure cases of three types

6.3 Suggestion

To improve the system, the future works are required as follows:

1. Other databases with various kinds of conditions are needed to test for optimizing the palmprint identification system.
2. The effect of rotation, scaling in palmprint images will be reconsidered for improving the performance of the palmprint identification system.

REFERENCES

- [1] Kong, J., Lu, Y., Wang, S., Qi, M., and Li., H. A Two Stage Neural Network-Based Personal Identification System Using Handprint. Neurocomputing archive 71 (2008): 641-647.
- [2] Kong, A., Zhang, D., and Kamel, M. A Survey of Palmprint Recognition. Pattern Recognition 42 (July 2009): 1408-1418.
- [3] Sakdanupab, M., and Covavisaruch, N. An Efficient Approach for Automatic Palmprint Classification. In Proceedings of the IEEE International Conference on Signal Image Technology and Internet Based Systems (2008): 229-234.
- [4] Huang, D.S., Jia,W., and Zhang D. Palmprint verification based on principal lines. Pattern Recognition 41 (2008): 1316-1328.
- [5] Wong, K.Y.E., Chekima, A., Dargham, J.A., and Sainarayanan, G. Palmprint Identification Using SobelOperator. In Proceedings of the 10th International Conference on Control, Automation, Robotics and Vision (2008): 1338-1341.
- [6] Zhu, L., and Xing, R. Hierarchical Palmprint Recognition Based on Major Line Feature and Dual Tree Complex Wavelet Texture Feature. In Proceedings of the Sixth International Conference on Fuzzy Systems and Knowledge Discovery (2009): 15-19.
- [7] Laadjel, M., Bouridance, A., Kurugollu, F., and Boussakta, S. Palmprint Recognition using Fisher-Gabor Feature Extraction. In Proceedings of the IEEE Interational Conference on Acoustics, Speech and Signal Processing (April 2008): 1709-1712.
- [8] Zhu, L., Zhang, S., Xing, R., and Zhang, Y. Palmprint Recognition Based on

- PFI and Fuzzy Logic. In Proceedings of the IEEE International Conference on Fuzzy Systems and Knowledge Discovery 3 (November 2008): 178-182.
- [9] Meraoumia, A., Chitroub, S., and Bouridance, A. Gaussian Modeling And Discrete Cosine Transform For Efficient And Automatic Palmprint Identification. In Proceedings of the IEEE International Conference on Machine and Web Intelligence (2010): 121-125.
- [10] Zhang, D., Kong, W., You, J., and Wong, M. PolyU Palmprint Databases. [Online]. 2003 Available from: <http://www4.comp.polyu.edu.hk/~biometrics/> [2009, November 16]
- [11] Lu, Y., Jiang, L., Kong, J., Wang, Y., Li, Y., and Li, Y. An adaptive and robust hand-based personal identification. In Proceedings of the IEEE Mediterranean Electrotechnical Conference (2006): 494-497.

APPENDIX

APPENDIX A
EXAMPLE OF COMPARING TWO EXTRACTED PALMPRINT IMAGES

Two extracted palmprint image are compared by using cosine similarity measure. The examples of the result of this calculation are depicted as follows:

Person 1



Person 2



AND

similarity = 0.8371

Person 1



Person 3



AND

similarity = 0.6151

Person 1



Person 4



AND

similarity = 0.8516

Person 1



Person 5



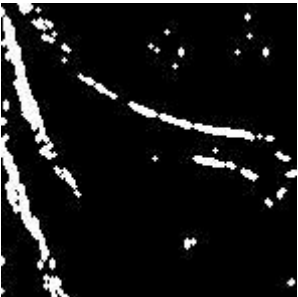
AND

similarity = 0.7295

Person 1



Person 6



AND

similarity = 0.8503

Person 1



Person 7



AND

similarity = 0.7868

Person 1



Person 8



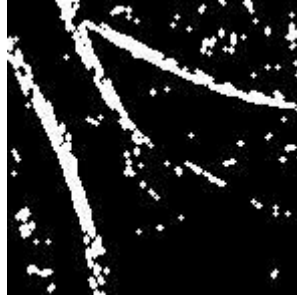
AND

similarity = 0.7376

Person 1



Person 9



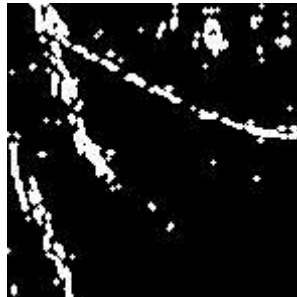
AND

similarity = 0.8431

Person 1



Person 10



AND

similarity = 0.8008

Person 1



Person 11



AND

similarity = 0.8253

Person 1



Person 12



AND

similarity = 0.8076

Person 1



Person 13



AND

similarity = 0.8584

Person 1



Person 14



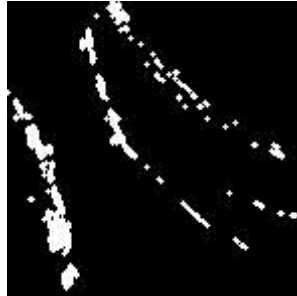
AND

similarity = 0.7089

Person 1



Person 15



AND

similarity = 0.8026

Person 1



Person 16



AND

similarity = 0.8837

APPENDIX B

ILLUSTRATION OF THE IDENTIFICATION RESULT OF TEST SET

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
1	✓		✓		✓	
2	✓		✓		✓	
3	✓		✓		✓	
4	✓		✓		✓	
5	✓		✓		✓	
6	✓		✓		✓	
7	✓		✓		✓	
8	✓		✓		✓	
9	✓		✓		✓	
10	✓		✓		✓	
11	✓		✓		✓	
12	✓		✓		✓	
13	✓		✓		✓	
14	✓		✓		✓	
15	✓		✓		✓	
16	✓		✓		✓	
17	✓		✓		✓	
18	✓		✓		✓	
19	✓		✓		✓	
20	✓		✓		✓	
21	✓		✓		✓	
22	✓		✓		✓	
23	✓		✓		✓	
24	✓		✓		✓	
25	✓		✓		✓	
26	✓		✓		✓	
27	✓		✓		✓	
28	✓		✓		✓	
29	✓		✓		✓	
30	✓		✓		✓	
31	✓		✓		✓	
32	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
33	✓		✓		✓	
34	✓		✓		✓	
35	✓		✓		✓	
36	✓		✓		✓	
37	✓		✓		✓	
38	✓		✓		✓	
39	✓		✓		✓	
40	✓		✓		✓	
41	✓		✓		✓	
42	✓		✓		✓	
43	✓		✓		✓	
44	✓		✓		✓	
45	✓		✓		✓	
46	✓		✓		✓	
47	✓		✓		✓	
48	✓		✓		✓	
49	✓		✓		✓	
50	✓		✓		✓	
51	✓		✓		✓	
52	✓		✓		✓	
53	✓		✓		✓	
54	✓		✓		✓	
55	✓		✓		✓	
56	✓		✓		✓	
57	✓		✓		✓	
58	✓		✓		✓	
59	✓		✓		✓	
60	✓		✓		✓	
61	✓		✓		✓	
62	✓		✓		✓	
63	✓		✓		✓	
64	✓		✓		✓	
65	✓		✓		✓	
66	✓		✓		✓	
67	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
68	✓		✓		✓	
69	✓		✓		✓	
70	✓		✓		✓	
71	✓		✓		✓	
72	✓		✓		✓	
73	✓		✓		✓	
74	✓		✓		✓	
75	✓		✓		✓	
76	✓		✓		✓	
77	✓		✓		✓	
78	✓		✓		✓	
79	✓		✓		✓	
80	✓		✓		✓	
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86	✓		✓		✓	
87	✓		✓		✓	
88	✓		✓		✓	
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91	✓		✓		✓	
92	✓		✓		✓	
93	✓		✓		✓	
94	✓		✓		✓	
95	✓		✓		✓	
96	✓		✓		✓	
97	✓		✓		✓	
98	✓		✓		✓	
99	✓		✓		✓	
100	✓		✓		✓	
101	✓		✓		✓	
102	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
103	✓		✓		✓	
104	✓		✓		✓	
105	✓		✓		✓	
106	✓		✓		✓	
107	✓		✓		✓	
108	✓		✓		✓	
109	✓		✓			x
110	✓		✓		✓	
111	✓		✓		✓	
112	✓		✓		✓	
113	✓		✓		✓	
114	✓		✓		✓	
115	✓		✓		✓	
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132	✓		✓		✓	
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134	✓		✓		✓	
135	✓		✓		✓	
136	✓		✓		✓	
137	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
138	✓		✓		✓	
139	✓		✓		✓	
140	✓		✓		✓	
141	✓		✓		✓	
142	✓		✓		✓	
143	✓		✓		✓	
144	✓		✓		✓	
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158	✓		✓		✓	
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164	✓		✓		✓	
165	✓		✓		✓	
166	✓		✓		✓	
167	✓		✓		✓	
168	✓		✓		✓	
169	✓		✓		✓	
170	✓		✓		✓	
171	✓		✓		✓	
172	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
173	✓		✓		✓	
174	✓		✓		✓	
175	✓		✓		✓	
176	✓		✓		✓	
177	✓		✓		✓	
178	✓		✓		✓	
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190	✓		✓		✓	
191	✓		✓		✓	
192	✓		✓		✓	
193	✓		✓		✓	
194	✓		✓		✓	
195	✓		✓		✓	
196	✓		✓		✓	
197	✓		✓		✓	
198	✓		✓		✓	
199	✓		✓		✓	
200	✓		✓		✓	
201	✓		✓		✓	
202	✓		✓		✓	
203	✓		✓		✓	
204	✓		✓		✓	
205	✓		✓		✓	
206	✓		✓		✓	
207	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
208	✓		✓		✓	
209	✓		✓		✓	
210	✓		✓		✓	
211	✓		✓		✓	
212	✓		✓		✓	
213	✓		✓		✓	
214	✓		✓		✓	
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216	✓		✓		✓	
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226	✓		✓		✓	
227	✓		✓		✓	
228	✓		✓		✓	
229	✓		✓		✓	
230	✓		✓		✓	
231	✓		✓		✓	
232	✓		✓		✓	
233	✓		✓		✓	
234	✓		✓		✓	
235	✓		✓		✓	
236	✓		✓		✓	
237	✓			x	✓	
238	✓		✓		✓	
239	✓		✓		✓	
240	✓		✓		✓	
241	✓		✓		✓	
242	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
243	✓		✓		✓	
244	✓		✓		✓	
245	✓		✓		✓	
246	✓		✓		✓	
247	✓		✓		✓	
248	✓		✓		✓	
249	✓		✓		✓	
250	✓		✓		✓	
251	✓		✓		✓	
252	✓		✓		✓	
253	✓		✓		✓	
254	✓		✓		✓	
255	✓		✓		✓	
256	✓		✓		✓	
257	✓		✓		✓	
258	✓		✓		✓	
259	✓		✓		✓	
260	✓		✓		✓	
261	✓		✓		✓	
262	✓		✓		✓	
263	✓		✓		✓	
264	✓		✓		✓	
265	✓		✓		✓	
266	✓		✓		✓	
267	✓		✓		✓	
268	✓		✓		✓	
269	✓			x	✓	
270	✓		✓		✓	
271		x	✓		✓	
272	✓		✓		✓	
273	✓		✓		✓	
274	✓		✓		✓	
275	✓		✓		✓	
276	✓		✓		✓	
277	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
278	✓		✓		✓	
279	✓		✓		✓	
280	✓		✓		✓	
281	✓		✓		✓	
282	✓		✓		✓	
283	✓		✓		✓	
284	✓		✓		✓	
285	✓		✓		✓	
286	✓		✓		✓	
287	✓		✓		✓	
288	✓		✓			x
289	✓		✓		✓	
290	✓		✓		✓	
291	✓		✓		✓	
292	✓		✓		✓	
293	✓		✓		✓	
294	✓		✓		✓	
295	✓		✓		✓	
296	✓		✓		✓	
297	✓		✓		✓	
298	✓		✓		✓	
299	✓		✓		✓	
300	✓		✓		✓	
301	✓		✓		✓	
302	✓		✓		✓	
303	✓		✓		✓	
304	✓		✓		✓	
305	✓		✓		✓	
306	✓		✓		✓	
307	✓		✓		✓	
308	✓		✓		✓	
309	✓		✓		✓	
310	✓		✓		✓	
311	✓		✓		✓	
312	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
313	✓		✓		✓	
314	✓		✓		✓	
315	✓		✓		✓	
316	✓		✓		✓	
317	✓		✓		✓	
318	✓		✓		✓	
319	✓		✓		✓	
320	✓		✓		✓	
321	✓		✓		✓	
322	✓		✓		✓	
323		x	✓			x
324		x	✓			x
325	✓		✓		✓	
326		x		x		x
327	✓		✓		✓	
328	✓		✓		✓	
329	✓		✓		✓	
330	✓		✓		✓	
331	✓		✓		✓	
332	✓		✓		✓	
333	✓			x	✓	
334	✓		✓		✓	
335	✓		✓		✓	
336	✓		✓		✓	
337	✓		✓		✓	
338	✓		✓		✓	
339	✓		✓		✓	
340	✓		✓		✓	
341	✓		✓		✓	
342	✓		✓		✓	
343	✓		✓		✓	
344	✓		✓		✓	
345	✓		✓		✓	
346	✓		✓		✓	
347	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
348	✓		✓		✓	
349	✓		✓		✓	
350	✓		✓		✓	
351	✓		✓		✓	
352	✓		✓		✓	
353	✓		✓		✓	
354	✓		✓		✓	
355	✓		✓		✓	
356	✓		✓		✓	
357	✓		✓		✓	
358	✓		✓		✓	
359	✓		✓		✓	
360	✓		✓		✓	
361	✓		✓		✓	
362	✓		✓		✓	
363	✓		✓		✓	
364	✓		✓		✓	
365	✓		✓		✓	
366	✓		✓		✓	
367		x	✓			x
368	✓		✓		✓	
369	✓		✓		✓	
370	✓		✓		✓	
371	✓		✓		✓	
372	✓		✓		✓	
373	✓		✓		✓	
374	✓		✓		✓	
375	✓		✓		✓	
376	✓		✓		✓	
377	✓		✓		✓	
378	✓		✓		✓	
379	✓		✓		✓	
380	✓		✓		✓	
381	✓		✓		✓	
382	✓		✓		✓	

Person	1 st Palm		2 nd Palm		3 rd Palm	
	Accept	Reject	Accept	Reject	Accept	Reject
383	✓		✓		✓	
384	✓		✓		✓	
385	✓		✓		✓	
386	✓		✓		✓	

Number of accept = 1,143 palms and number of reject = 15 palms

Therefore,

$$\text{Recognition Accuracy} = \frac{1143}{386 \times 3} = 98.704 \%$$

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Academic Publication:

- P. Tunkpien, S. Phimoltarea, and S. Panthuwadeethorn, "Palmprint Identification System Using Shape Matching and K-Nearest Neighbor Algorithm," Proceedings of the IEEE International Conference on Imaging Systems and Techniques, 2011.
- P. Tunkpien, S. Panthuwadeethorn, and S. Phimoltarea, "Compact Extraction of Principle Lines in Palmprint Using Consecutive Filtering Operations," Proceedings of the Second International Conference on Knowledge and Smart Technologies, pp. 39-44, July 2010.