AN IMPROVED HOUGH TRANSFORM ALGORITHM IN IRIS RECOGNITION SYSTEM

SAEED KHORASHDI ZADEH

A project report submitted in partial fulfillment of the requirements for the award of the degree of Master of Computer Science (Information Security)

Faculty of Computer Science and Information Systems
Universiti Teknologi Malaysia

AUGUST 2012
AN IMPROVED HOUGH TRANSFORM ALGORITHM IN IRIS RECOGNITION SYSTEM

SAEED KHORASHDI ZADEH

A project report submitted in partial fulfillment of the requirements for the award of the degree of Master of Computer Science (Information Security)

Faculty of Computer Science and Information Systems
Universiti Teknologi Malaysia

AUGUST 2012
This dissertation is dedicated to my family for their endless support and encouragement.
ACKNOWLEDGEMENT

Special thanks go to my supervisor, Dr. Aboamama Atahar Ahmed, for his help during the course of this research. Without his time and patience much of this work could not have been accomplished.

Besides, I would like to thank Dr. Anazida about her back-to-back support all the way till the very end of this project.

Dr. Bakhtiari and Dr. Kamalrulnizam whom with their help and thoughtful advices have enriched this project significantly.

Thank to my dear classmate, Fatiha for helping out to translate the abstract to Bahasa language.

Last but not least, thank to my dear friends Masi, David, Azin and Iman to support me during hardship moments of doing my research.
ABSTRACT

The security is an important aspect in our daily life whichever the system is considered, security plays vital role. The biometric person identification technique based on the pattern of human iris is suitable to be applied to access control and provides strong e-security. Iris recognition is one of important biometric recognition approaches in human identification is very active topic in research and practical application. Iris Recognition System consists of Acquisition, Localization, Feature Extraction and Feature Matching phases. Localization stage includes Normalization and Segmentation phase. Circular Hough Transform is one the best suitable algorithm in segmentation phase, but as a result of having two for-loops in its structure; CHT algorithm consumes high time processing and uses high storage capacity. These drawbacks make it hardly appropriate for real time applications of iris recognition system. To improve time and storage complexity, firstly, a pre-processing of CUHK iris image dataset is done to eliminate unnecessarily regions and secondly, a radius-table is created based on pupil size variation of CUHK iris image dataset. The results show at least 40% efficiency in time complexity and minimum 20% efficiency in storage complexity.
ABSTRAK

## TABLE OF CONTENT

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td></td>
<td>ii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td></td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td></td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>v</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td></td>
<td>vi</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td></td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>xi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF APPENDIX</td>
<td></td>
<td>xv</td>
</tr>
</tbody>
</table>

1 INTRODUCTION  
1.1 Overview 1  
1.2 Problem Background 3  
1.3 Problem Statement 4  
1.4 Aim of the Project 5  
1.5 Project Objective 5  
1.6 Project Scope 5  
1.7 Significant of the Project 6  
1.8 Project Organization 7  

2 LITERATURE REVIEW  
2.1 Introduction 8  
2.2 Chapter Structure 8  
2.4 Biometric Context 9
2.4 Iris as a Biometric
  2.4.1 Advantages
  2.4.2 Disadvantages

2.5 Iris Recognition System Error
  2.5.1 False Match Rate and False-Non-Match Rate
  2.5.2 Equal Error Rate

2.6 Iris Recognition System
  2.6.1 Challenges in Iris Recognition

2.7 Iris Recognition Algorithm
  2.7.1 Filter-Based Methods
  2.7.2 Feature-Based Methods

2.8 Iris Recognition Phases
  2.8.1 Acquisition
  2.8.2 Segmentation
    2.8.2.1 Pupil and Iris Localization
    2.8.2.2 Hough Transform
    2.8.2.3 Discrete Circular Active Contour Model
    2.8.2.4 Noise and Artifacts in Iris Images
  2.8.3 Feature Extraction
    2.8.3.1 2D Gabor Feature
    2.8.3.2 Log-Gabor Filter
    2.8.3.3 2D Hilbert Transform
  2.8.4 Feature Matching
    2.8.4.1 Hamming Distance
    2.8.4.2 Normalized Correlation
    2.8.4.3 Weighted Euclidean Distance

2.9 Circular Hough Transform
  2.9.1 Accumulator
  2.9.2 Algorithm
  2.9.3 Implementation
  2.9.4 How to Store Data
  2.9.5 How to Draw Circle in Discrete Space
  2.9.6 How to Find Circle From the Hough
## LIST OF TABLE

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Iris segmentation, encoding and matching techniques proposed in the literature</td>
<td>24</td>
</tr>
<tr>
<td>2.2</td>
<td>Examples of iris noise images</td>
<td>30</td>
</tr>
<tr>
<td>4.1</td>
<td>Address time and storage complexity of CHT algorithm</td>
<td>70</td>
</tr>
<tr>
<td>5.1</td>
<td>The time complexity comparison of standard CHT and improved CHT algorithm</td>
<td>75</td>
</tr>
</tbody>
</table>
### LIST OF FIGURE

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Iris segmentation, encoding and matching techniques proposed in the literature</td>
<td>10</td>
</tr>
<tr>
<td>2.2</td>
<td>Eye Structure</td>
<td>12</td>
</tr>
<tr>
<td>2.3</td>
<td>Biometric System Error Rate</td>
<td>14</td>
</tr>
<tr>
<td>2.4</td>
<td>Receiver operating characteristic curve</td>
<td>16</td>
</tr>
<tr>
<td>2.5</td>
<td>Block diagram of a typical iris recognition system (Daugman, 2004)</td>
<td>18</td>
</tr>
<tr>
<td>2.6</td>
<td>Iris image showing severe specular reflections (Montgomery, 2007)</td>
<td>29</td>
</tr>
<tr>
<td>2.7</td>
<td>Phase quantization (Masek, 2003)</td>
<td>33</td>
</tr>
<tr>
<td>2.8</td>
<td>The parameter space used for CHT (Rhody, 2005)</td>
<td>39</td>
</tr>
<tr>
<td>2.9</td>
<td>A Circular Hough Transform from the x, y space (left) to the parameter space (right), for a constant radius (Besag, 1989)</td>
<td>40</td>
</tr>
<tr>
<td>2.10</td>
<td>An example of how the accumulator of the CHT looks like in the real world data. (Rhody, 2005)</td>
<td>41</td>
</tr>
<tr>
<td>2.11</td>
<td>Circular Hough Transform algorithm</td>
<td>41</td>
</tr>
<tr>
<td>2.12</td>
<td>Surface plot of the a, b-plane with radius=20</td>
<td>43</td>
</tr>
<tr>
<td>2.13</td>
<td>Kernels are used for convolution</td>
<td>48</td>
</tr>
<tr>
<td>2.14</td>
<td>Laplacian kernel</td>
<td>49</td>
</tr>
<tr>
<td>3.1</td>
<td>Research Framework</td>
<td>52</td>
</tr>
<tr>
<td>3.2</td>
<td>Iris Recognition System</td>
<td>53</td>
</tr>
<tr>
<td>3.3</td>
<td>Structural weaknesses in CHT algorithm along with diverse edge detection methods and iris datasets</td>
<td>59</td>
</tr>
<tr>
<td>3.4</td>
<td>Example of unnecessarily regions in some CUHK iris image dataset</td>
<td>61</td>
</tr>
</tbody>
</table>
3.5 Phase III, Implementation and Evaluation 62
4.1 Circular Hough Transform pseudo code 66
4.2 The diverse size of pupil in different iris images 67
4.3 Applying Radius-Table to reduce iteration of Loop-II in CHT algorithm 67
4.4 Iris image ‘iris5.bmp’ (CUHK Database) 68
4.5 Pre-processing iris image 69
4.6 CHT pseudo-code after improvement 69
4.7 Graphic User Interface Application 71
5.1 The ratio of Classic CHT to the proposed CHT 75
5.2 Information about iris image number 10. 76
5.3 Time percentage efficiency per iris image. 76
5.4 The size differentiates between the normal iris images to new ones. 77
5.5 How size differentiates can effect on efficiency ratio of CHT algorithm. 78
5.6 Time efficiency comparison between different edge detection techniques 79
5.7 The output of implementing different edge detection methods over the iris image number ten 80
5.8 Compare time processing between edge detection methods in standard CHT algorithm with after implementing the proposed techniques in CHT algorithm 81
5.9 Edge points are found by Canny in left and Sobel in right side form iris image ‘iris13.bmp’ (CUHK dataset, 2003). 82
5.10 Canny vs. Sobel time complexity by implementing standard CHT algorithm. 82
5.11 Iris image forty-seven (CUHK iris database, 2003) after applying Canny and Sobel. 83
6.1 Illustrates the potential capacity of improvement in the proposed technique. 90
6.2 Miss some edge points as a result of chosen inadequate threshold in Sobel. 90
6.3 Detect lots of edge points as a result of chosen inadequate threshold in Zero-Cross. 91
### LIST OF APPENDIX

<table>
<thead>
<tr>
<th>NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Program Source Code</td>
<td>92</td>
</tr>
<tr>
<td>2</td>
<td>Application Screenshots</td>
<td>104</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1. Overview

Biometric technology deals with recognizing the identity of individuals based on their unique physical or behavioral characteristics (Wildes, 1997). Physical characteristics such as fingerprint, palm print, hand geometry and iris patterns or behavioral characteristics such as typing pattern and hand-written signature present unique information about a person and can be used in authentication applications.

The developments in science and technology have made it possible to use biometrics in applications where it is required to establish or confirm the identity of individuals. Applications such as passenger control in airports, access control in restricted areas, border control, database access and financial services are some of the examples where the biometric technology has been applied for more reliable identification and verification.

Iris patterns are formed by combined layers of pigmented epithelial cells, muscles for controlling the pupil, stromal layer consisting of connective tissue, blood vessels and an anterior border layer (Adler, 1965). The physiological complexity of the organ results in the random patterns in iris, which are statistically unique and suitable for biometric measurements (Daugman, 1993). In addition, iris patterns are stable over time and only minor changes happen to them throughout an individual’s
life (Flom and Safir, 1987). It is also an internal organ, located behind the cornea and aqueous humor, and well protected from the external environment. The characteristics such as being protected from the environment and having more reliable stability over time, compared to other popular biometrics, have well justified the ongoing research and investments on iris recognition by various researchers and industries around the world. For instance, the developed algorithm by Daugman (1993), which is known as the state-of-the-art in the field of iris recognition, has initiated huge investments on the technology for more than a decade. IriScan Inc. patents the core technology of the Daugman’s system and several companies such as IBM, Iridian Technologies, IrisGuard Inc., Securimetrics Inc. and Panasonic are active in providing iris recognition products and services.

The information extracted from an iris is in binary format and it is stored in only 256 bytes to allow creation of nationwide IrisCode databases. The search engine is based on Boolean exclusive-OR operator (XOR) to allow extremely fast comparisons in the matching process. Moreover, the degrees-of-freedom of an IrisCode template, which indicates the statistical complexity of an iris based on the entropy theory of Shannon (2001), is about 249. The number of degrees-of-freedom of the iris templates shows that the complexity of iris patterns is relatively high compared to other biometric measures. The overall characteristics of the proposed algorithm offers real-time and high confidence identification in applications such as passenger control in airports, border control and access control in high-security areas.

The future of biometric technology is believed to be open for more investments based on the new services it has to offer to the society and the new technologies based on face recognition, hand geometry and iris recognition are expected to relatively expand this revenue in near future.
1.2. Problem Background

Iris recognition systems are the most reliable biometric system since iris patterns are unique to each individual and do not change with time. A variety of methods were developed to handle eye data in biometric systems after J. Daugman developed the first commercial system. Eye images used in iris recognition systems require images to be taken under rigid constraints. To obtain a good quality image, subjects cooperation is required like the subject must look straight into camera, still and there should be proper illumination.

These causes inconvenience to the user and are also time consuming. Moreover in cases like criminal investigations images can be taken at any moment of time and thus require unconstrained conditions. In some other cases it is possible that pictures are shot without the knowledge of subject. So images taken under such situations are often “non cooperative” in nature. Conventional techniques require subjects’ cooperation for the accuracy of results. Any unwanted data present in iris images may give false results leading to the rejection of images. Serious noise effects are present in iris images taken under unconstrained condition.

A very well known existing technique, the Circular Hough Transform (CHT) has been implemented for detection of iris and pupil boundaries (Gonzalez and Woods, 2007). Traditional segmentation techniques do not give accurate results with images containing noise. But, the fundamental structure of CHT algorithm is the reason of consuming high processing time and also utilizing high capacity of storage. These drawbacks of CHT algorithm make it hard to employing CHT algorithm for a practical usage that Iris Recognition System needs to apply for millions of users.

Table 1.1 depicts some latest researches of CHT algorithm. Despite of many enhancements that have been offered to enhance Circular Hough Transform, high time and storage complexity still are the main reason of not using the algorithm in vast area.
Table 1.1: Example of latest CHT proposed techniques in different aspects.

<table>
<thead>
<tr>
<th>Author</th>
<th>Measurement</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bendel et al.</td>
<td>Time complexity</td>
<td>Use gradient information</td>
</tr>
<tr>
<td>Alioua et al.</td>
<td>Iris detection</td>
<td>Use eye’s morphology</td>
</tr>
<tr>
<td>Koh et al.</td>
<td>Iris detection</td>
<td>Use active contour model</td>
</tr>
<tr>
<td>Wang et al.</td>
<td>Time complexity</td>
<td>Use geometrical feature and grayfeature of iris</td>
</tr>
</tbody>
</table>

1.3. Problem Statement

Among the four stages in Iris recognition system that are: Acquisition, Segmentation, Feature extraction and Feature comparison, Iris segmentation is one of the most significant steps in iris recognition system. Most of the existing iris segmentation algorithms rely on parametric models of the circle and ellipse to localize the iris. However, when the iris is severely occluded due to the eyelids and the eyelashes, the boundary of the iris may not conform to the circular or elliptical shape. Additionally, iris segmentation is the most contested issue in the iris recognition system, since poor results of this stage will mar or break the iris recognition system effectiveness. Therefore, very careful attention has to be paid in the segmentation process if only an accurate result is expected; this depends on the accuracy of the detected pupil center.

Hough Transform algorithm can be used for detection of any parametric shape (lines, circles, planes, etc.) and have found applications in many areas such as human iris recognition or fingerprint matching. Hough Transform is one the best method in segmentation state to find valid regions, unfortunately, the existing
structure consists of two for-loops that make CHT algorithm not suitable for using in real time applications of Iris Recognition System.

Improving Hough Transform algorithm in term of time complexity and storage complexity makes it much more practical in respect of using in segmentation phase of iris recognition system and as a result the enhancement helps to have more productive iris biometric applications in real world.

1.4. **Aim of the Project**

To improve performance of Hough Transform algorithm in terms of time complexity and storage utilization.

1.5. **Project Objective**

In order to achieve the aim of the project, the following objectives must be followed:

i. To study techniques and structures of iris recognition system;

ii. Pre-processing iris image dataset to improve quality of the input iris image.

iii. Develop an improved CHT algorithm by reducing iteration in its for-loops structure in Matlab.
1.6. **Project Scope**

The research scope is geared towards the limits of the research such as:

i. Circular Hough Transform (CHT) as an algorithm that has been used in segmentation phase of iris recognition system is studied in detail;

ii. Matlab programming is used to get analysis and do comparison;

iii. MacBook pro OSX 10.8 with 2.4 GHz i5 processor and 4 GB DDR3 memory is used for doing the analysis;

iv. The evaluation is measured based on time complexity and storage utilization of Hough Transform algorithm;

v. CUHK iris image dataset is used for experiment. The findings and conclusion made in this study is based on experiments done on this dataset.

vi. A prototype of the proposed CHT has been developed in Matlab.

1.7. **Significant of the Project**

Considering the algorithm of Circular Hough Transform, the execution speed of this algorithm is highly dependent on the number of edge pixels in the input image. Moreover, decrease in the number of edge pixels generally can effect on reducing storage utilization by the algorithm. The gain in efficiency does not affect the robustness of the technique. Efficiency in terms of time and storage complexity in Circular Hough Transform algorithm can make it a powerful and proper scheme at using in segmentation phase of iris recognition system.
1.8. **Project Organization**

This research covers six chapters, which are introduction, literature review, methodology, implementation, analysis and discussion and conclusion and recommendation.

Chapter 1 of this report consists of overview of the study, problem background, problem statement, objectives, scopes and significance of this study.

Chapter 2 of this report presents a review of the literature related to study. These literature covers biometric context, iris dataset, Biometric System Error, iris recognition algorithms, iris recognition system and Hough Transform technique.

Chapter 3 consists of wide description on research methodology, which provides a rich discussion about the flow of this research. This includes how the operational and experimental work has been carried out for the study.

Chapter 4 modifications and enhancements of the Circular Hough Transform are explained in this chapter. And the steps to implement an application for getting adequate results are elaborated.

Chapter 5 the overall result of the analysis is displayed and the evaluation of standard Circular Hough Transform algorithm with the proposed techniques are discussed and expanded.

And in chapter 6 the objectives of the project are elaborated and the recommendation of the study are proposed.


Chun Nam Ben (2003), CUHK Iris Image Dataset, Computer Vision Laboratory, Department of Automation & Computer-Aided Engr., The Chinese University of Hong Kong, Hong Kong.


characterizing key local variations. *IEEE Transactions on Image Processing*, 13(6), 739–750.


