

A  
Dissertation  
On

## **Fingerprint Based Fuzzy Vault**

Submitted in partial Fulfilment of the requirement  
For the award of the Degree of

**Master of Technology**  
**In Computer Technology and Applications**

By

**J. JAYAKUMAR**

Roll No. 08/CTA/2010

Under the guidance of

**Dr. Daya Gupta**

HOD, Computer Engineering Department, DTU, Delhi



**DELHI TECHNOLOGICAL UNIVERSITY, 2012**

# **CERTIFICATE**

This is to certify that the dissertation titled “Fingerprint Based Fuzzy Vault” is a bonafide record of work done at Delhi Technological University, Delhi, by J Jayakumar for partial fulfilment of the requirements for degree of Master of Technology in Computer Technology and Applications.

This project was carried out at DRDO under the guidance of Mr. A K Bhateja, with my supervision and has not been submitted elsewhere, either in part or full, for the award of any other degree or diploma to the best of my knowledge and belief.

**Dr. Daya Gupta,  
HOD, Computer  
Engineering Dept,  
DTU, Delhi**

## **Acknowledgements**

I would like to express our deepest gratitude to all the people who have supported and encouraged me during the course of this project without which, this work could not have been accomplished. First of all, I am very grateful to my project supervisors Mr. A K Bhateja and Dr. Daya Gupta for providing the opportunity of carrying out this project under their guidance. I am deeply indebted to them for their support, advice and encouragement without which the project could not have proceeded smoothly. I am highly thankful to all my friends and family for their continued support and encouragement throughout the research work.

I would like to make a special mention of Mr. A K Bhateja from DRDO under whose guidance I completed this work. I would like to thank him for his sparking ideas, inspiring discussions, his trust and belief, and his support throughout the process of the thesis. I gained a lot from his vast knowledge and skill in many areas (e.g., biometrics, image processing, cryptography, programming and optimizations, ethics, interaction with participants), and appreciate his assistance in writing this dissertation.

J. Jayakumar

Roll No. 08/CTA/2010

M.Tech (Computer Technology & Applications)

Department of Computer Engineering,

DTU, Delhi

## Abstract

Through this project we intend to create a biometrics cryptosystem where one can send and receive secure information using just the biometric features like fingerprints, signatures etc. For this purpose we have used a fingerprint based fuzzy vault technique. Reliable information security mechanisms are required to combat the rising magnitude of identity theft in our society. While cryptography is a powerful tool to achieve information security, one of the main challenges in cryptosystems is to maintain the secrecy of the cryptographic keys. Though biometric authentication can be used to ensure that only the legitimate user has access to the secret keys, a biometric system itself is vulnerable to a number of threats. A critical issue in biometric systems is to protect the template of a user which is typically stored in a database or a smart card. The fuzzy vault construct is a biometric cryptosystem that secures both the secret key and the biometric template by binding them within a cryptographic framework. We present a fully automatic implementation of the fuzzy vault scheme based on fingerprint minutiae. The 128 bit secret key used in RSA and other cryptosystems are secured with the help of fingerprint minutiae. Since the fuzzy vault stores only a transformed version of the template, aligning the query fingerprint with the template is a challenging task. We extract high curvature points derived from the fingerprint orientation field and use them to obtain an intermediate coordinate system, with the fingerprint core point as the origin. Firstly, we have explored the possibility of using the high curvature points to create an axis for the Cartesian system and then we have used that as a reference axis for polar coordinate system. Finding the core point with accuracy is in itself a very challenging task. We have proposed a new algorithm which finds the core point for all the fingerprints with complete accuracy. Thus unlike the

existing fuzzy vault implementation, we don't need to send the helper data for aligning the query and the template minutiae, which significantly reduces the overhead whilst hiding the details of the fingerprint completely. We demonstrate the performance of the vault implementation on two different fingerprint databases.

# Contents

|   |      |
|---|------|
| Certificate.....                                  | ii   |
| Acknowledgement.....                              | iii  |
| Abstract.....                                     | iv   |
| Contents.....                                     | vi   |
| List of figures.....                              | viii |
| List of Tables.....                               | xi   |
| <br>  |      |
| 1. Introduction.....                              | 1    |
| 1.1 Motivation.....                               | 2    |
| 1.2 Related work.....                             | 3    |
| 1.3 Problem Statement.....                        | 7    |
| 1.4 Scope of the work.....                        | 7    |
| 1.5 Organization of the Thesis.....               | 8    |
| 2. Biometrics.....                                | 10   |
| 2.1 Introduction.....                             | 10   |
| 2.2 Fingerprint Analysis.....                     | 12   |
| 2.3 Fingerprint Enhancement Techniques.....       | 15   |
| 2.3.1 Pixel-wise enhancement.....                 | 18   |
| 2.3.2 Contextual filtering.....                   | 19   |
| 2.3.3 FFT Enhancement.....                        | 20   |
| 2.3.4 Gabor Filters.....                          | 21   |
| 2.4 Core Point Detection.....                     | 25   |
| 2.4.1 Poincaré index.....                         | 25   |
| 2.4.2 Geometry of Region Technique (GR).....      | 27   |
| 2.4.3 Detection of Curvature Technique (DC).....  | 28   |
| 2.4 Minutiae Extraction.....                      | 29   |
| 3. Biometric Cryptosystems.....                   | 31   |
| 3.1 Cryptography.....                             | 31   |
| 3.1.1 Problem of Key Sharing.....                 | 33   |
| 3.2 Biometric Cryptosystems: An Introduction..... | 34   |
| 3.3 Fuzzy Vault.....                              | 35   |

|  |    |
|--|----|
| 4. Fuzzy Vault Implementation.....           | 38 |
| 4.1 Architecture of the Proposed System..... | 38 |
| 4.2 Fingerprint Enhancement.....             | 40 |
| 4.2.1 Segmentation.....                      | 41 |
| 4.2.2 Normalization.....                     | 42 |
| 4.2.3 Orientation estimation.....            | 43 |
| 4.2.4 Ridge Frequency Estimation.....        | 44 |
| 4.2.5 Gabor filtering.....                   | 46 |
| 4.3 Minutia extraction.....                  | 48 |
| 4.3.1 Binarization.....                      | 48 |
| 4.3.2 Thinning.....                          | 49 |
| 4.3.3 Mark Minutiae.....                     | 50 |
| 4.4 Translation.....                         | 52 |
| 4.4.1 Core Point Determination.....          | 53 |
| 4.4.2 High Curvature Points.....             | 55 |
| 4.4.3 Determination of Axis.....             | 59 |
| 4.4.4 Translation and Rotation.....          | 60 |
| 4.5 Fuzzy Vault Encoding.....                | 61 |
| 4.6 Decoding.....                            | 65 |
| 5. Experiments and Results.....              | 67 |
| 5.1 Experimental Analysis.....               | 67 |
| 5.2 Experimental Setup.....                  | 69 |
| 5.3 Results.....                             | 70 |
| 6. Conclusion and Future work.....           | 73 |
| References.....                              | 75 |

## List of figures

|   |    |
|---|----|
| Figure 2.1 Ridges and valleys in a fingerprint image.....   | 12 |
| Figure 2.2. Singular regions (white boxes) and core points (small circles) in fingerprint images.....   | 13 |
| Figure 2.3 One fingerprint from each of the five major classes defined by Henry (1990).....   | 14 |
| Figure 2.4 Seven most common minutiae types.....  | 14 |
| Figure 2.5 a) A ridge ending minutia.....   | 15 |
| b) A bifurcation minutia.....   | 15 |
| Figure 2.6 a) A good quality footprint.....   | 16 |
| b) A medium quality fingerprint characterized by scratches and ridge breaks.....  | 16 |
| c) A poor quality fingerprint containing a lot of noise.....  | 16 |
| Figure 2.7 A fingerprint image containing regions of different quality:   |    |
| a) A well-defined region.....   | 18 |
| b) A recoverable region.....  | 18 |
| c) An unrecoverable region.....   | 18 |
| Figure 2.8 An example of normalization using ( $m_0=100$ , $v_0=100$ ).....   | 19 |
| Figure 2.9 Enhancement of the fingerprint image I using FFT.....  | 21 |
| Figure 2.10 Graphical representation (lateral view and top view) of the Gabor filter defined by the parameters $\theta = 135^\circ$ , $f = 1/5$ , and $\sigma_x = \sigma_y = 3$ ..... | 24 |
| Figure 2.11 The Poincaré index computed over a curve C immersed in a vector field G.....  | 25 |
| Figure 2.12 Examples of Poincaré index computation in the 8-neighborhood of points belonging (from left to right) to a whorl, loop, and delta singularity, respectively.....          | 27 |
| Figure 2.13 Examples of a ridge ending and bifurcation pixel :  |    |
| (a) A Crossing Number of one corresponds to a ridge ending pixel.....   | 30 |
| (b) A Crossing Number of three corresponds to a bifurcation pixel.....  | 30 |
| Figure 3.1 Traditional cryptography:  |    |
| (a) Symmetric key system.....   | 32 |
| (b) Asymmetric key system.....  | 32 |
| Figure 3.2 Two modes of combining biometrics with cryptography:   |    |



|  |    |
|--|----|
| (a) Key release.....   | 36 |
| (b) Key generation.....  | 36 |
| Figure 3.3 Fuzzy vault scheme.....   | 37 |
| Figure 4.1 Flowchart of the proposed fuzzy fingerprint vault:  |    |
| (a) Feature Extraction.....  | 39 |
| (b) Vault Encoding.....  | 39 |
| (c) Vault Decoding.....  | 39 |
| Figure 4.2 Pictorial representation of system variables:   |    |
| (a) Polynomial.....  | 40 |
| (b) Evaluation of the polynomial (black: genuine points,<br>red: chaff points).....  | 40 |
| (c) Final vault list.....  | 40 |
| Figure 4.3 Segmentation:   |    |
| (a) Input Image.....   | 42 |
| (b) Segmentation Boundary.....   | 42 |
| Figure 4.4 The orientation of a ridge pixel in a fingerprint.....  | 43 |
| Figure 4.5 The projection of the intensity values of the pixels along a direction<br>orthogonal to the local ridge orientation : |    |
| (a) A 32 x 32 block from a fingerprint image.....  | 45 |
| (b) The projected waveform of the block.....   | 45 |
| Figure 4.6 An even-symmetric Gabor filter in the spatial domain.....   | 47 |
| Figure 4.7 Gabor filtering:  |    |
| (a) Original Fingerprint image.....  | 48 |
| (b) After applying gabor filter.....   | 48 |
| Figure 4.8 Thinning:   |    |
| (a) Filtered image.....  | 50 |
| (b) Thinned image.....   | 50 |
| Figure 4.9: Examples of a ridge ending and bifurcation pixel:  |    |
| (a) A Crossing Number of one corresponds to a ridge ending<br>pixel.....   | 51 |
| (a) A Crossing Number of three corresponds to a bifurcation<br>pixel.....  | 51 |
| Figure 4.10 Minutia points.....  | 52 |

|  |    |
|--|----|
| Figure 4.11 Plot of $\text{sign}(\varnothing)$ . Positive is denoted by green and negative by red..... | 54 |
| Figure 4.12 Core point (marked in red).....  | 55 |
| Figure 4.13 Orientation field flow curves.....   | 57 |
| Figure 4.14 High Curvature Points.....   | 58 |
| Figure 4.15 Fingerprint image showing the axis.....  | 60 |

## List of Tables

|                                     |    |
|-------------------------------------|----|
| Table 5.1 Experimental Results..... | 71 |
|-------------------------------------|----|