

Development of an Automated Fingerprint Verification System

Martin Saveski
18 May 2010

Introduction

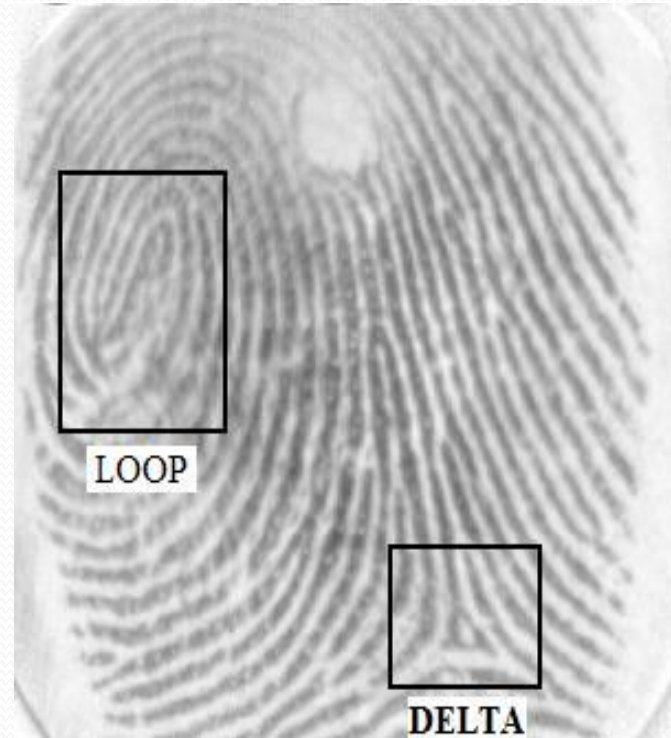
- Biometrics – the use of distinctive anatomical and behavioral characteristics or identifiers for automatically recognizing person
- Fingerprints are considered to be *immutable*
- Probability that two fingerprints are identical is:
 - 1 / 1900000000000000000
- Manual recognition is slow and labor intensive
- Inspiration for many IP and PR researchers

Fingerprint Representation

- Depending on the different scales of analysis and types of features, FP patterns are structured in 3 levels:
 - 1) Global level
 - 2) Local level
 - 3) Very fine level

Global Level

- Examines the line flow of the ridges
- Singular points: loops and deltas identified.

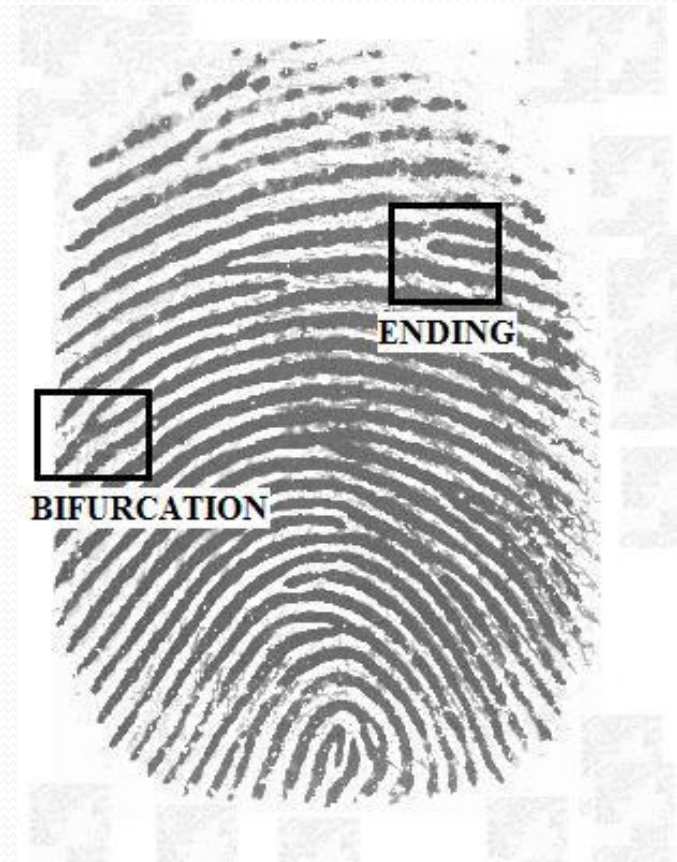


Global Features

(FVC2000, DB2, FP Impression 103-2)

Local Level

- Identifies local ridge characteristics
- Common characteristics called minutiae are: ridge endings, and bifurcations



Local Features
Minutiae

(Maltoni et al., 2009)

Very Fine Level

- Intra-ridge details
 - width
 - shape
 - curvature
 - edge contours
- Most important: swear pores
- Considered to be highly distinctive



Very-fine Level
Features

(Maltoni et al., 2009)

Main Stages

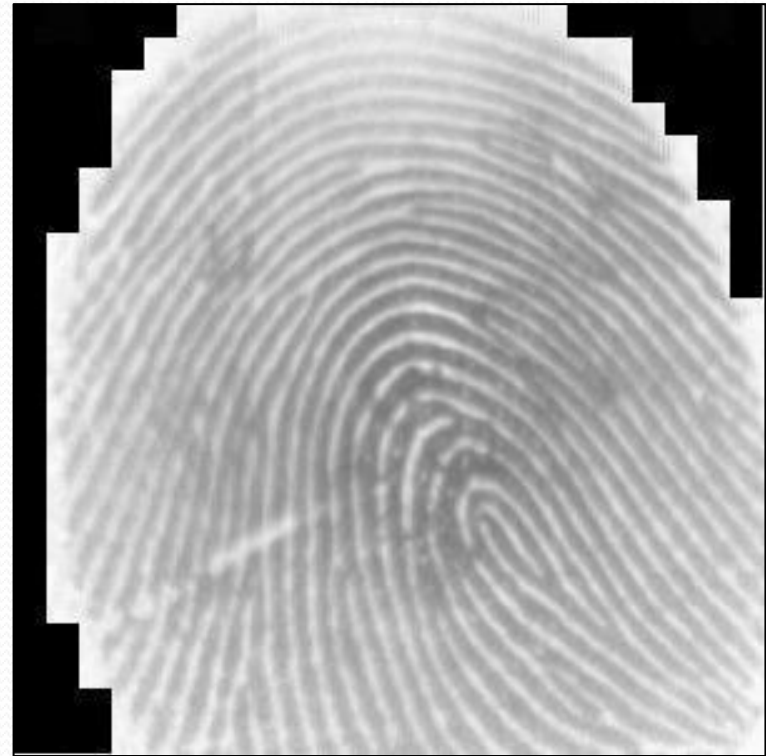
- Fingerprint Segmentation
- Image Enhancement
 - Normalization
 - Orientation Estimation
 - Frequency Estimation
 - Filtering
- Binarization
- Skeletonization
- Feature Extraction (Minutiae)
- Fingerprint Matching

Fingerprint Segmentation

- Separates foreground from background regions
- Fingerprint regions have higher gray scale variance



Before Segmentation



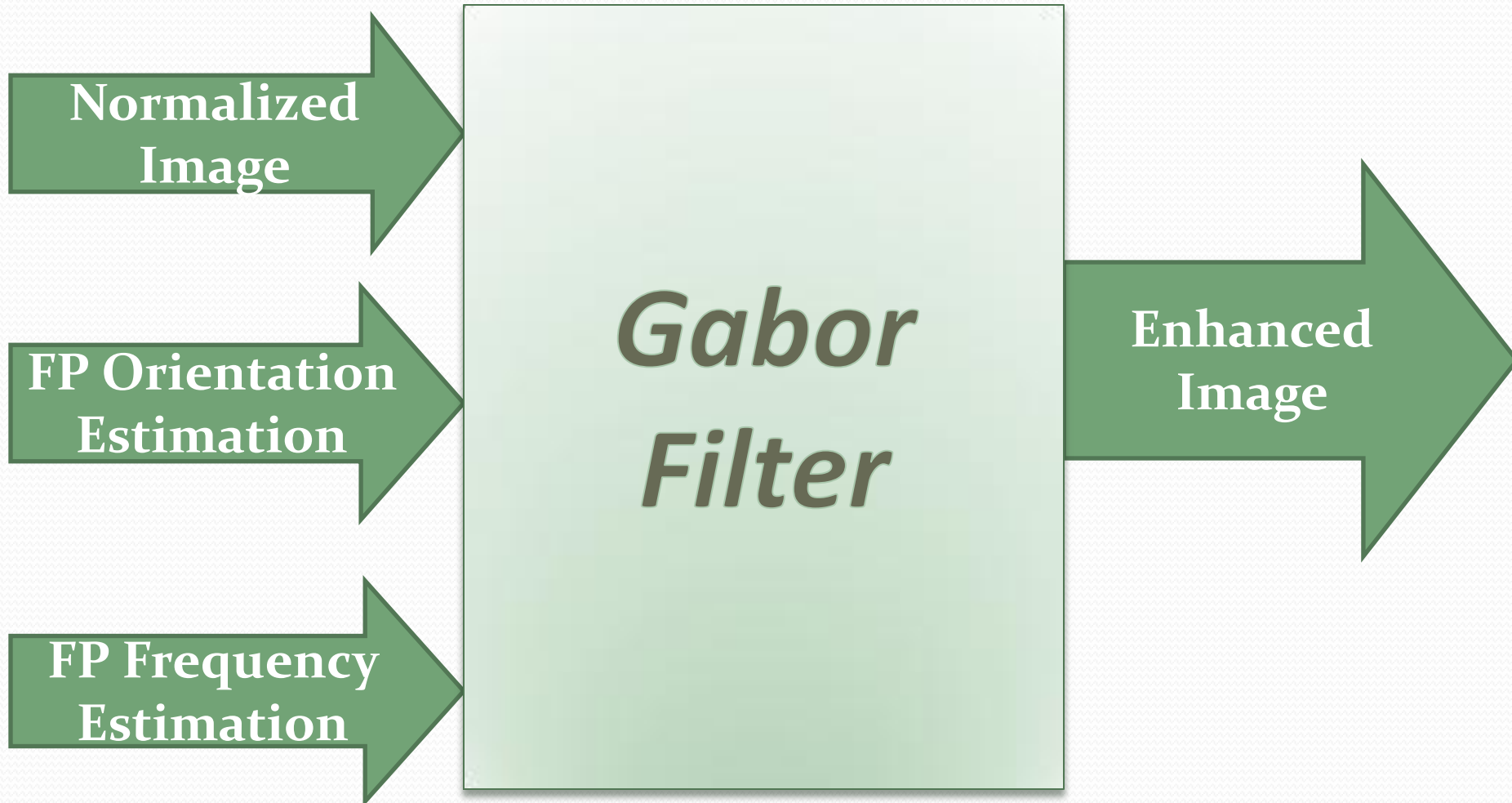
After Segmentation

(Original image taken from: FVC2000, DB2, FP Impression 105-8)

Fingerprint Image Enhancement

- The quality of ridge structure of the FP image is *essential* for successful feature extraction
- Gabor Filtering adopted
- Both frequency and orientation selective
- The main steps:
 - Normalization
 - Orientation Estimation
 - Ridge Frequency Estimation
 - Filtering

Gabor Filter



Normalization

- Ensures that the image has a specified mean and variance
- Reduces the distortion effects along the ridges and valleys



Before Normalization

After Normalization

(Original image taken from: FVC2000, DB2, FP Impression 107-6)

Orientation Estimation

- Orientation: the angle that the FP ridges crossing through an arbitrary small neighborhood form with the horizontal axis



Normalized Image



Orientation Estimations

(Original Image taken from: FVC2000, DB2, FP Impression 107-6)

Ridge Frequency Estimation

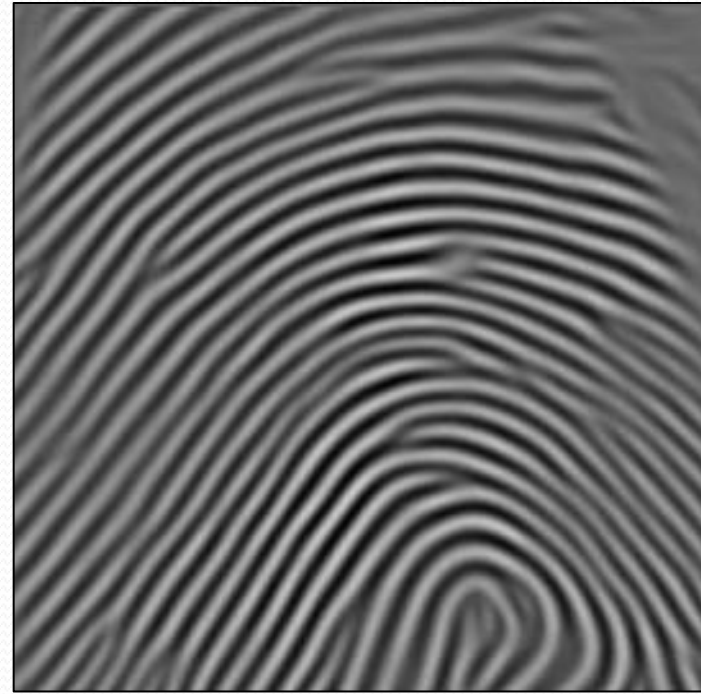
- Computed by projecting the grayscale values around the orientation orthogonal
- This projection has sinusoidal form where the ridges are local minima
- The spacing between the ridges is estimated by counting the median number of pixels between consecutive minima points
- The frequency is:
 - $1 / \text{spacing between the ridges}$

Filtering

- Orientation and Frequency estimations used for calculating the masks for each block
- Removes the noise while preserving the ridge structure



Original FP Image

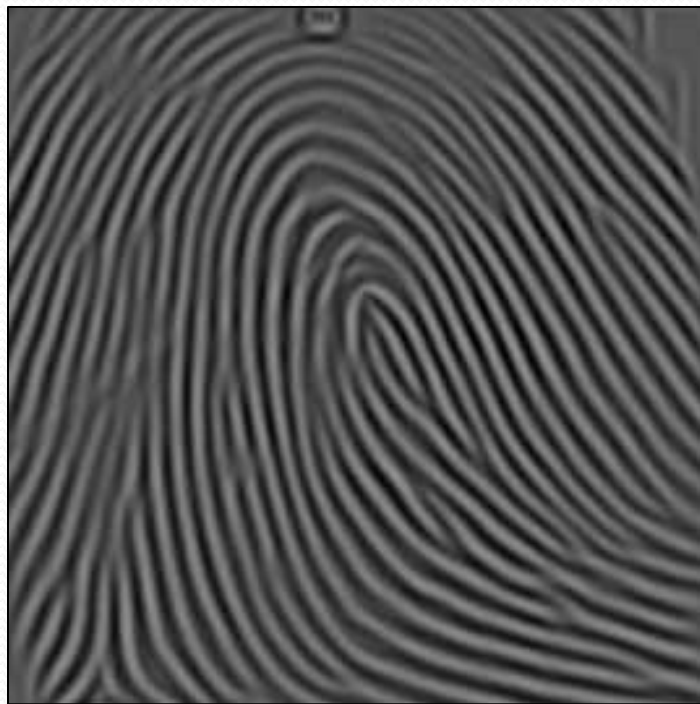


Enhanced Image

(Original Image taken from: FVC2000, DB2, FP Impression 101-5)

Binarization

- Grayscale -> Binary Image
- Improves the contrast between the ridges and valleys
- Global binarization VS Local binarization



Enhanced Image



Binary Image (Global Threshold)

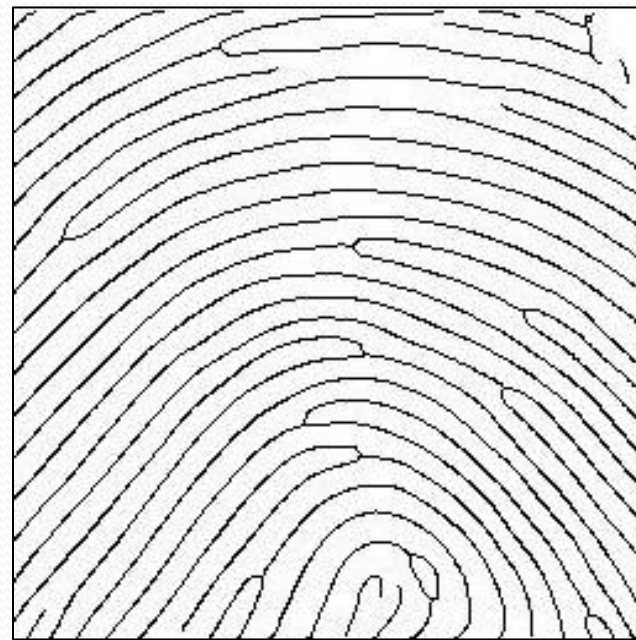
(Original Image taken from: FVC2000, DB2, FP Impression 105-2)

Skeletonization

- Thinning the foreground regions until one pixel wide
- Morphological skeletonization is not suitable, it does not guarantee connectivity
- More sophisticated method adopted (Gonzalez & Woods, 2008)



Binary Image



Skeletonized Image

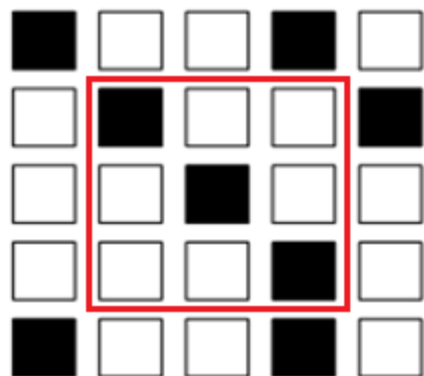
(Original Image taken from: FVC2000, DB2, FP Impression 101-2)

Minutiae Extraction

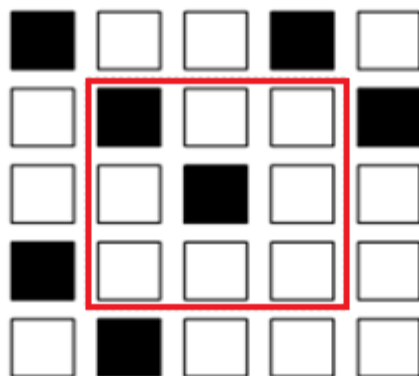
- Performed by using the concept of Crossing Number

$$CN(p) = \frac{1}{2} \sum_{i=1 \dots 8} |val(p_{i \bmod 8}) - val(p_{i-1})|$$

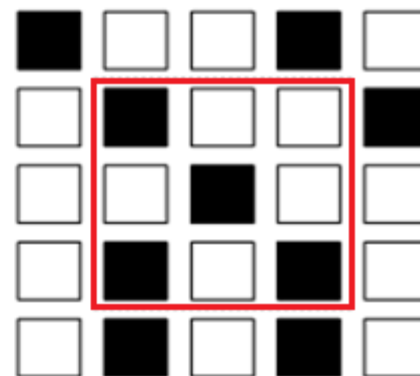
- All minutiae extracted by a simple image scan of the skeletonized image
 - CN = 1, correspond to ridge ending
 - CN = 3, corresponds to bifurcation



a) $cn(p) = 2$



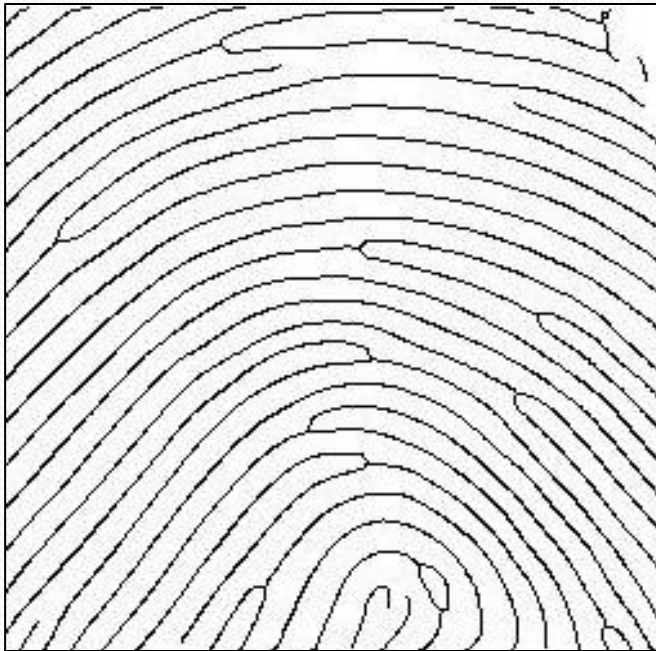
b) $cn(p) = 1$



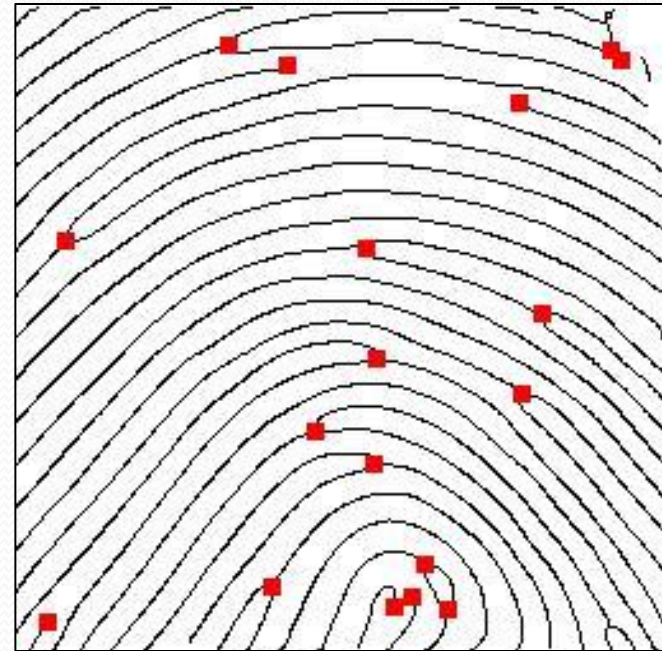
c) $cn(p) = 3$

Minutiae Extraction (cont.)

- All minutiae stored as (x, y, θ, CN) quadruples where,
 - x, y : the spatial coordinates
 - θ : orientation
 - CN : the Crossing Number



Skeletonized Image



Minutiae Detected

(Original Image taken from: FVC2000, DB2, FP Impression 101-2)

Fingerprint Matching

- Determines the degree of similarity between two fingerprint images
- Attempts to find the alignment of the images which will result in maximum number of minutiae pairings
- Must cope with
 - Displacement
 - Rotation
 - Non-linear distortion
 - Noise

Fingerprint Matching (cont.)

- The matching algorithm adopted consists of 3 steps:
 - 1) Registration
 - 2) Minutiae Pairing
 - 3) Matching Score Computation

Fingerprint Matching (cont.)

- Registration: is finding the 'best' transformation which when applied to the one of the images will result in maximum overlapping minutiae.
- Minutiae Pairing: minutiae are paired if their difference in x, y, θ is within the range of the tolerance box.
- Matching Score:

$$MS(p, q) = \frac{m^2}{(n_p * n_q)}$$

m – paired minutiae,

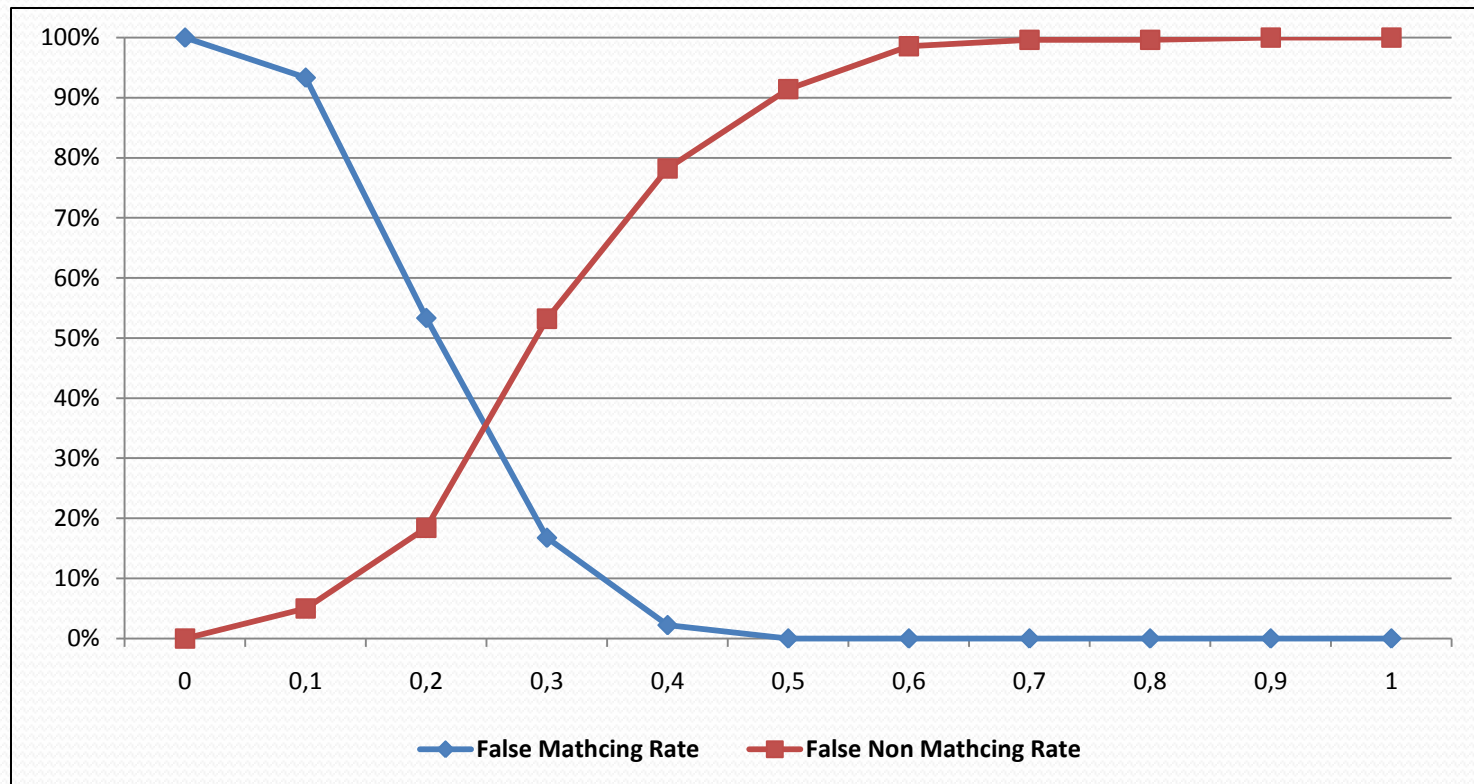
n - minutiae within the bounding box

Performance Evaluation

- A subset of the Fingerprint Verification Competition 2000 (FVC) Database 2 was used
 - 10 fingers wide
 - 8 impressions deep
- Performance Measures defined by FVC and widely adopted in the research community,
 - Genuine Matching Score - *gms*
 - Impostor Matching Score - *ims*
 - False Match Rate above threshold t - $FMR(t)$
 - False Non-Match Rate above threshold t - $FNMR(t)$
 - Equal Error Rate - (EER)
- EER is a single value which assesses the performance of the system

Performance Evaluation (cont.)

- The Equal Error Rate of the system developed was **35%**
- The chart below show the FMR(t) and FNMR(t) curves



(AFVS, FMR and FNMR evaluation curves)

Future Work

- *Filtering Extracted Minutiae:*
 - Technique which detects and filters spurious minutiae
 - Significant improvement of the performance
- *Fingerprint Classification:*
 - Classification of DB samples
 - Reduced number of comparisons
 - Improved response time

Questions





***Thank You For Your
Attention***