

# **Development of an Automated Fingerprint Verification System**

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**18 May 2010**

# Introduction

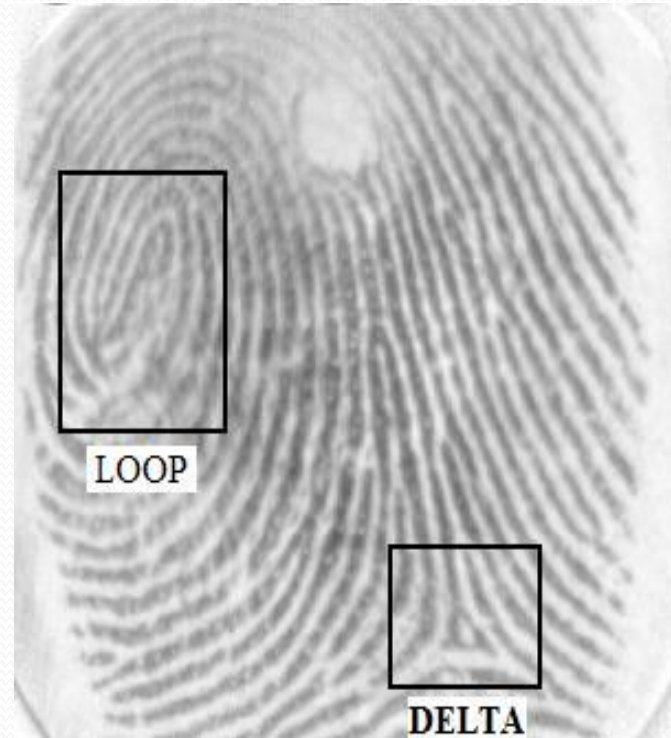
- Biometrics – the use of distinctive anatomical and behavioral characteristics or identifiers for automatically recognizing person
- Fingerprints are considered to be *immutable*
- Probability that two fingerprints are identical is:
  - 1 / 1900000000000000000
- Manual recognition is slow and labor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



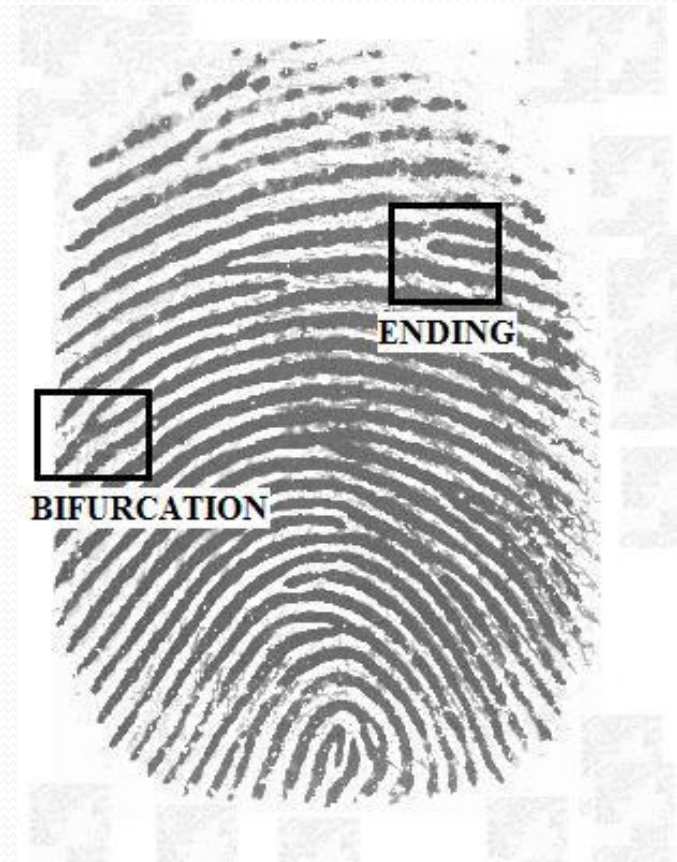
## Global Features

(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

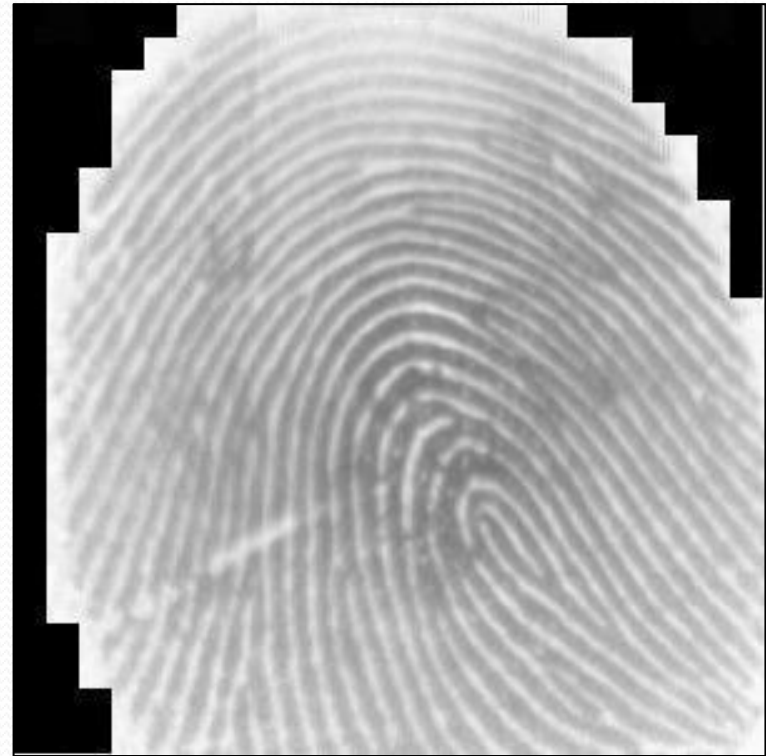
- Fingerprint Segmentation
- Image Enhancement
  - Normalization
  - Orientation Estimation
  - Frequency Estimation
  - Filtering
- Binarization
- Skeletonization
- Feature Extraction (Minutiae)
- Fingerprint Matching

# Fingerprint Segmentation

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



Before Segmentation



After Segmentation

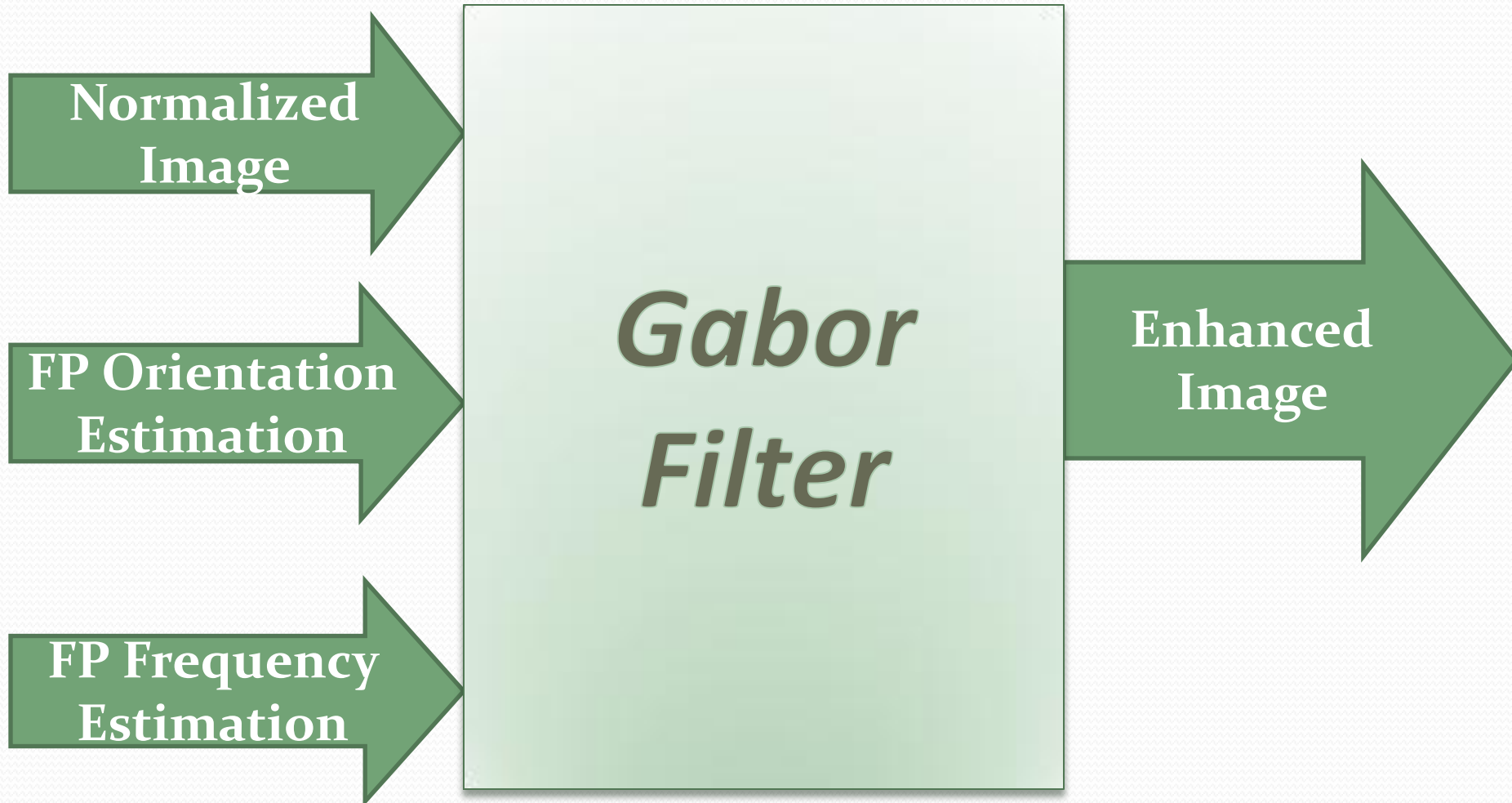
(Original image taken from: FVC2000, DB2, FP Impression 105-8)



# 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:
  - $1 / \text{spacing between the ridges}$

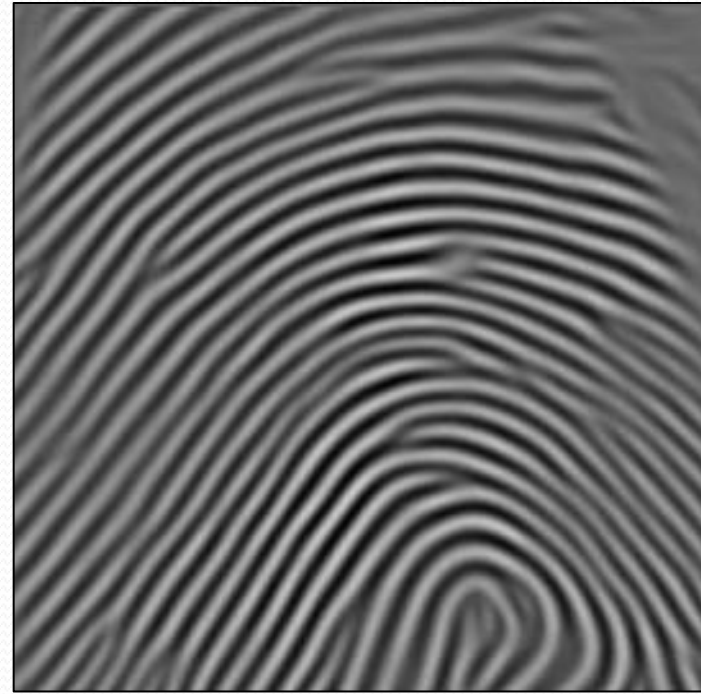


# Filtering

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



Original FP Image

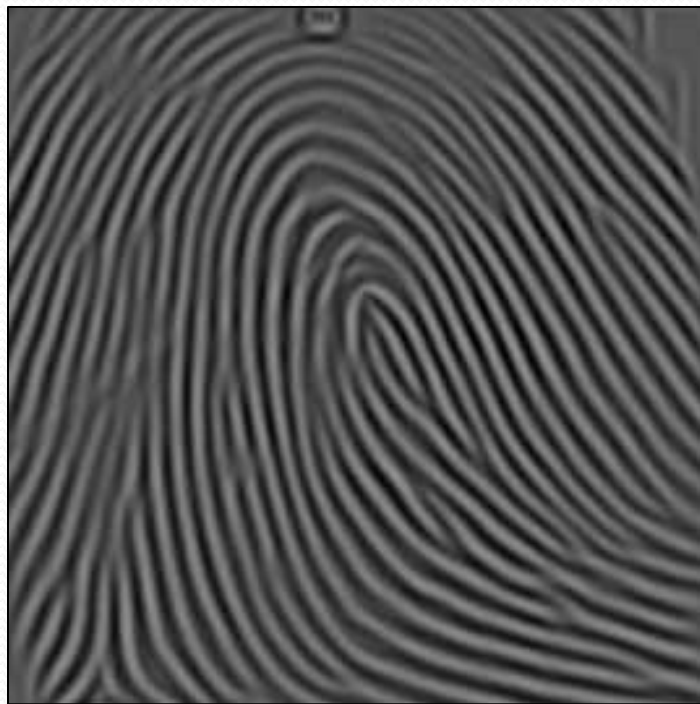


Enhanced Image

(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)

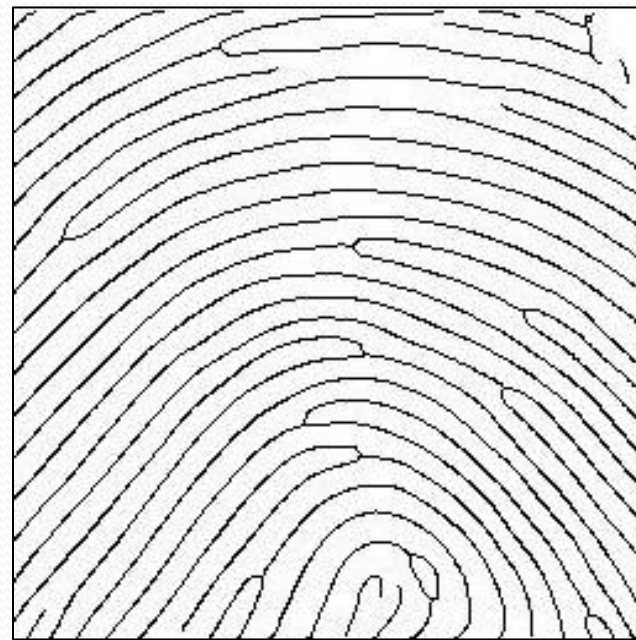
(Original Image taken from: FVC2000, DB2, FP Impression 105-2)

# 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

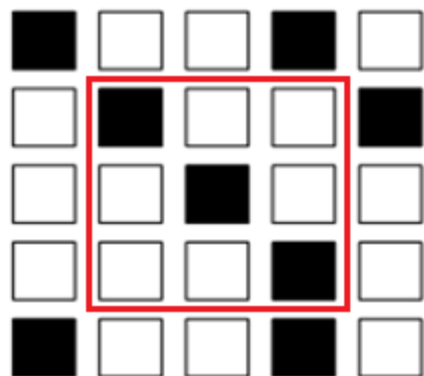
(Original Image taken from: FVC2000, DB2, FP Impression 101-2)

# Minutiae Extraction

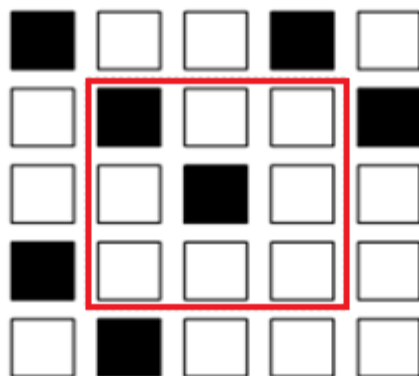
- Performed by using the concept of Crossing Number

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

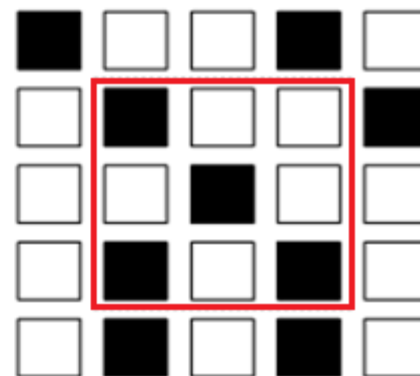
- All minutiae extracted by a simple image scan of the skeletonized image
  - CN = 1, correspond to ridge ending
  - CN = 3, corresponds to bifurcation



a)  $cn(p) = 2$



b)  $cn(p) = 1$

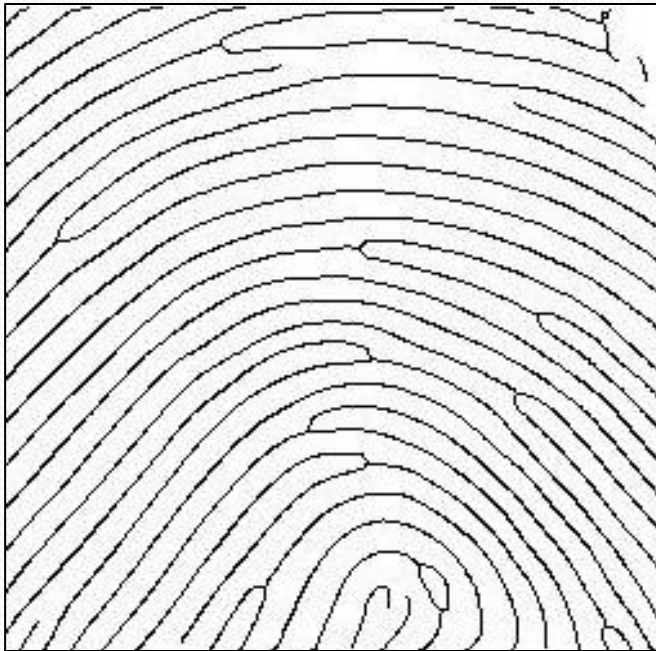


c)  $cn(p) = 3$

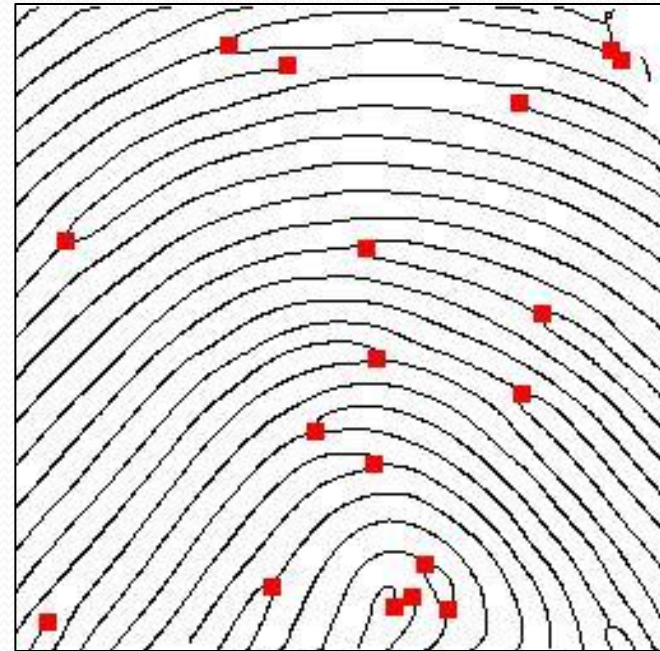


# Minutiae Extraction (cont.)

- All minutiae stored as  $(x, y, \theta, CN)$  quadruples where,
  - $x, y$ : the spatial coordinates
  - $\theta$ : 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,  $\theta$  is within the range of the tolerance box.
- Matching Score:

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

$m$  – paired minutiae,

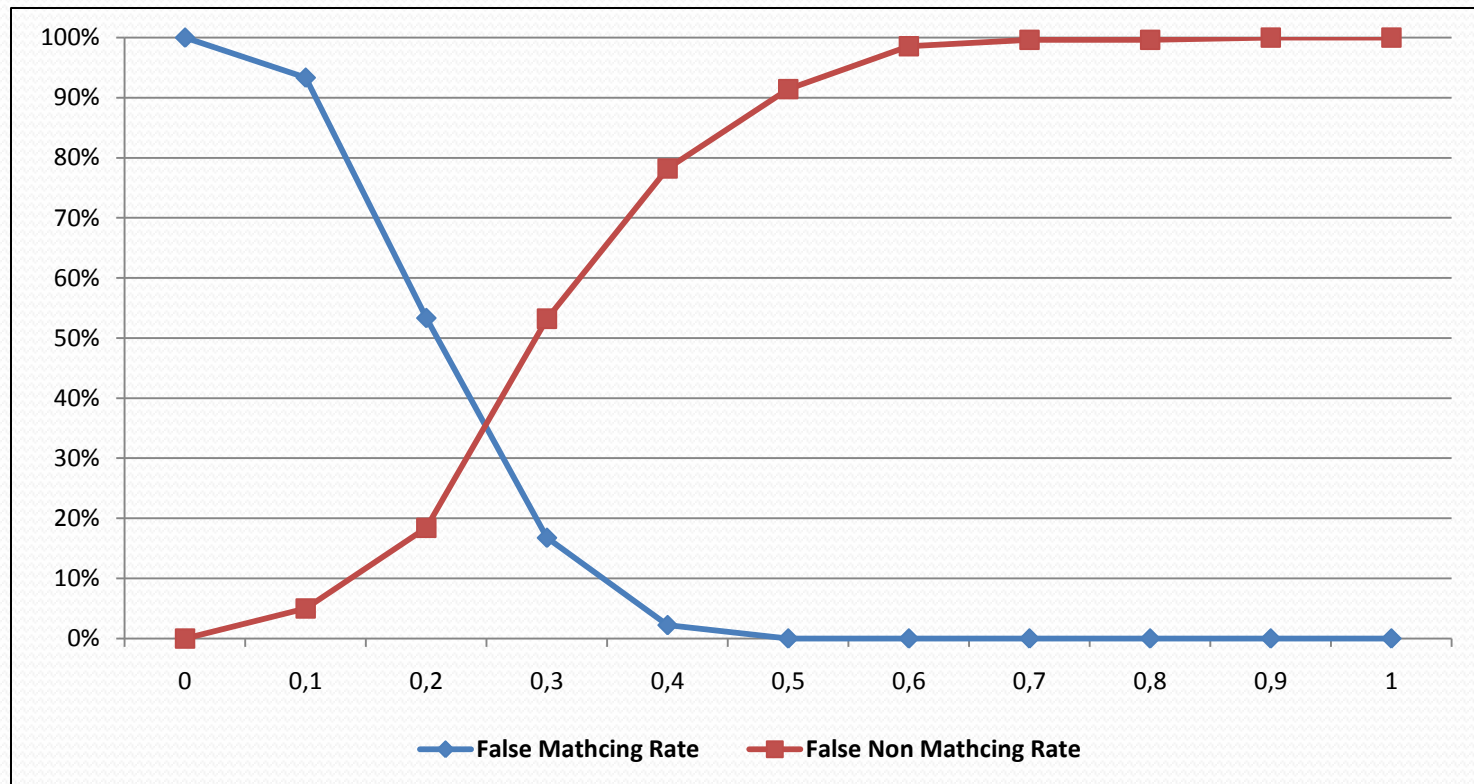
$n$  - minutiae within the bounding box

# 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***