Development of an Automated Fingerprint Verification System

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Introduction

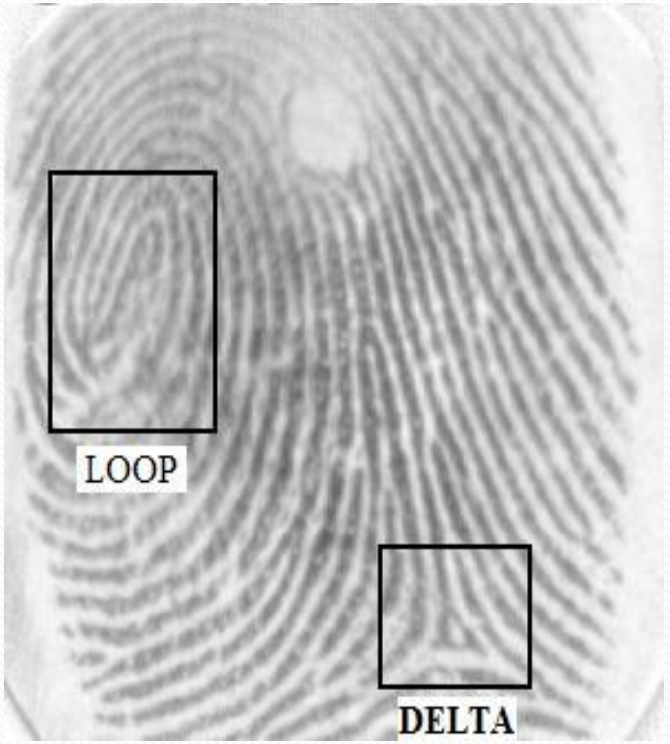
- *Biometrics* – the use of distinctive anatomical and behavioral characteristics or identifiers for automatically recognizing person
- Fingerprints are considered to be *immutable*
- Probability that two fingerprints are identical is:
  - 1 / 1900000000000000
- Manual recognition is slow and labor intensive
- 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.

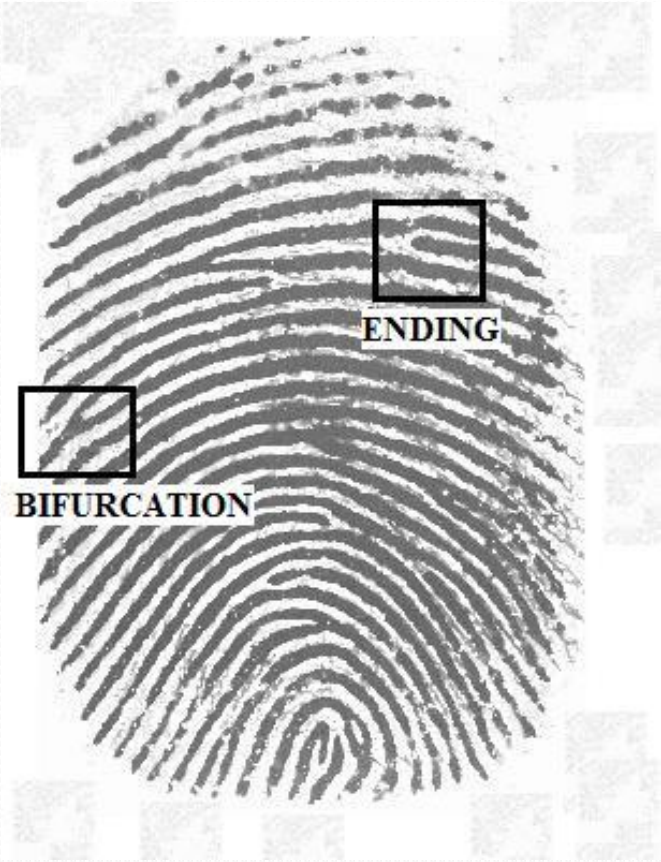


Global Features

(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)

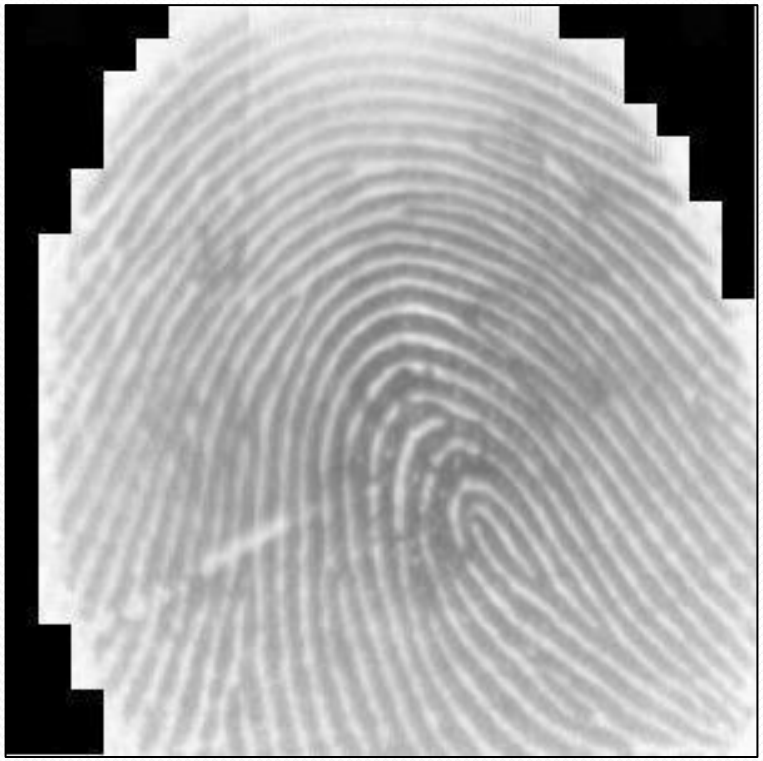
Main Stages

- 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



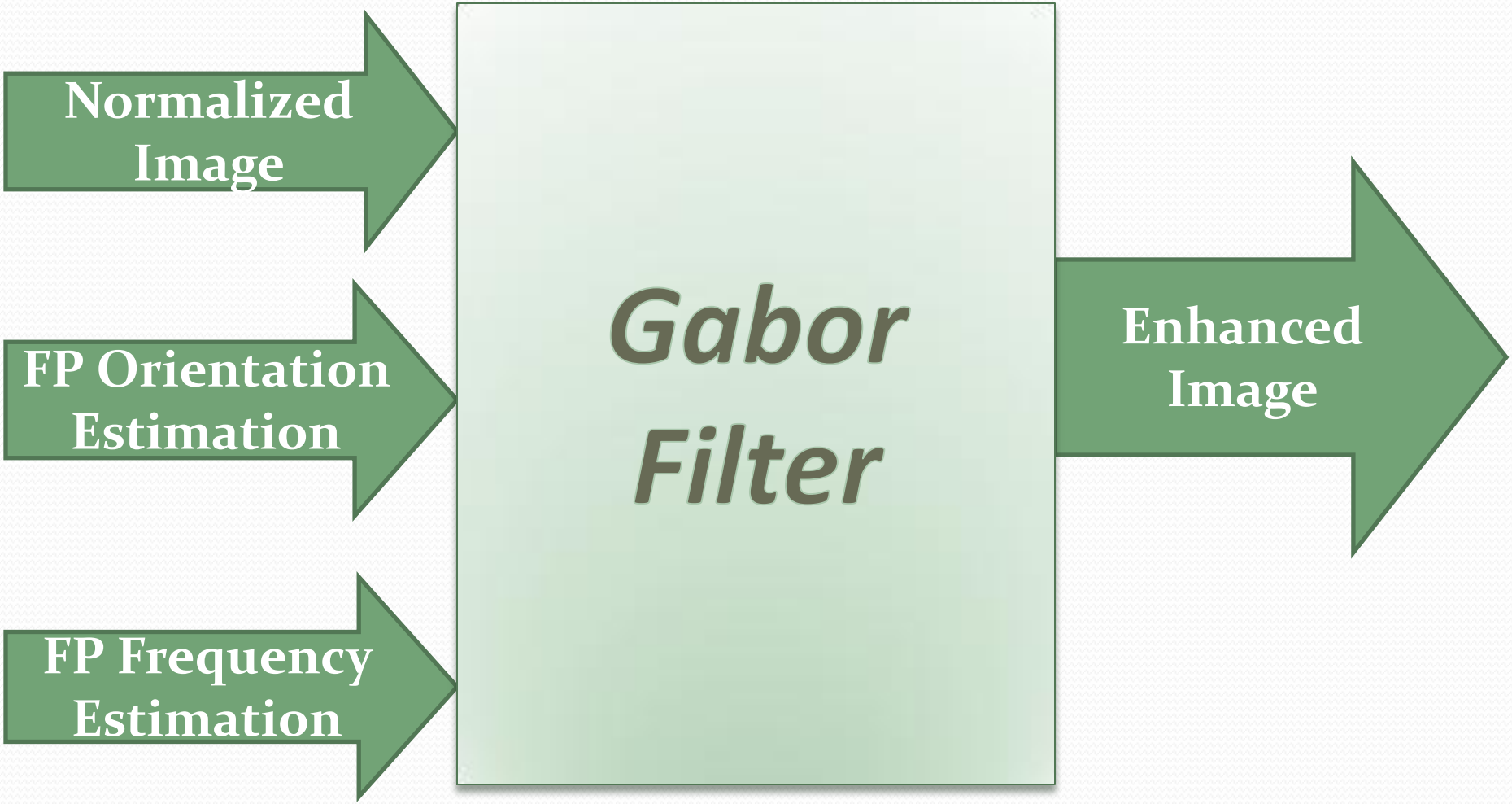
After Segmentation

(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)

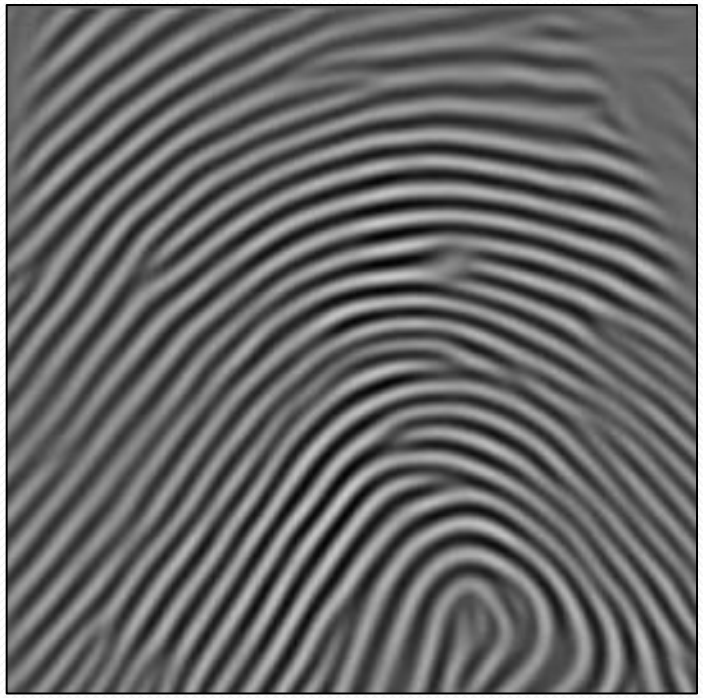
Ridge Frequency Estimation

- 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 / 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

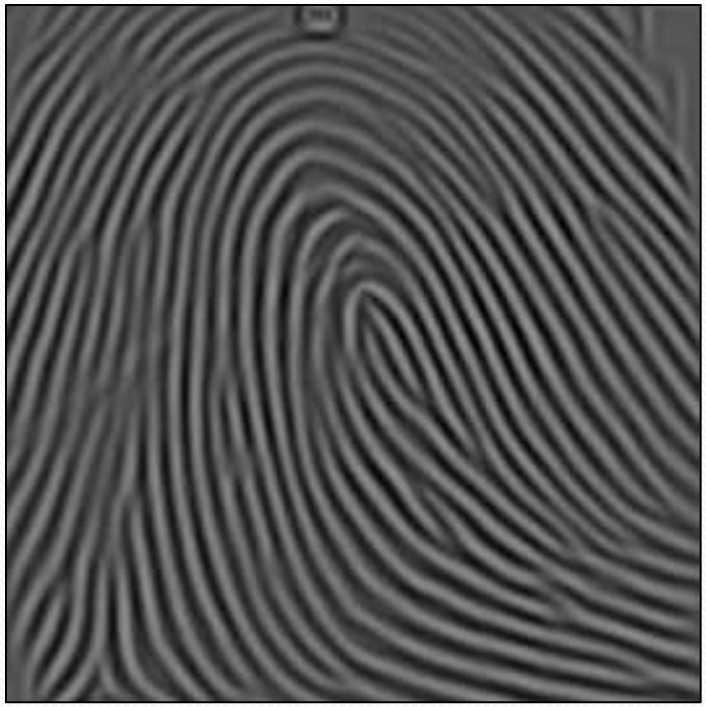


Enhanced Image

(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

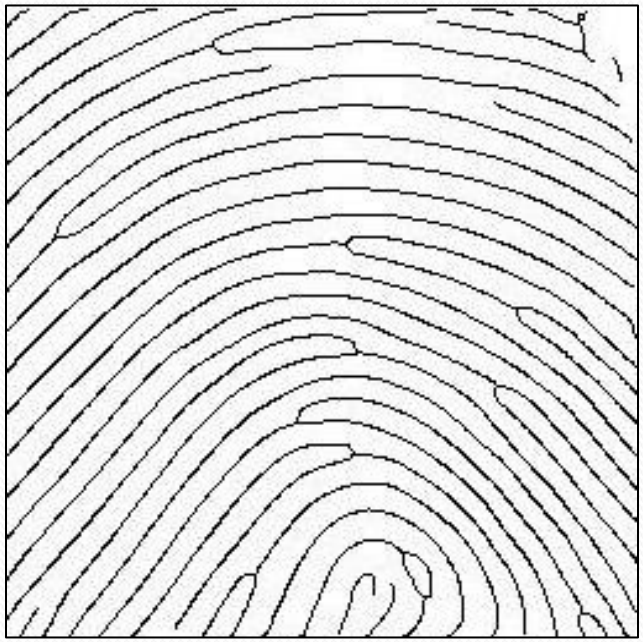
Binary Image (Global Threshold)

(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

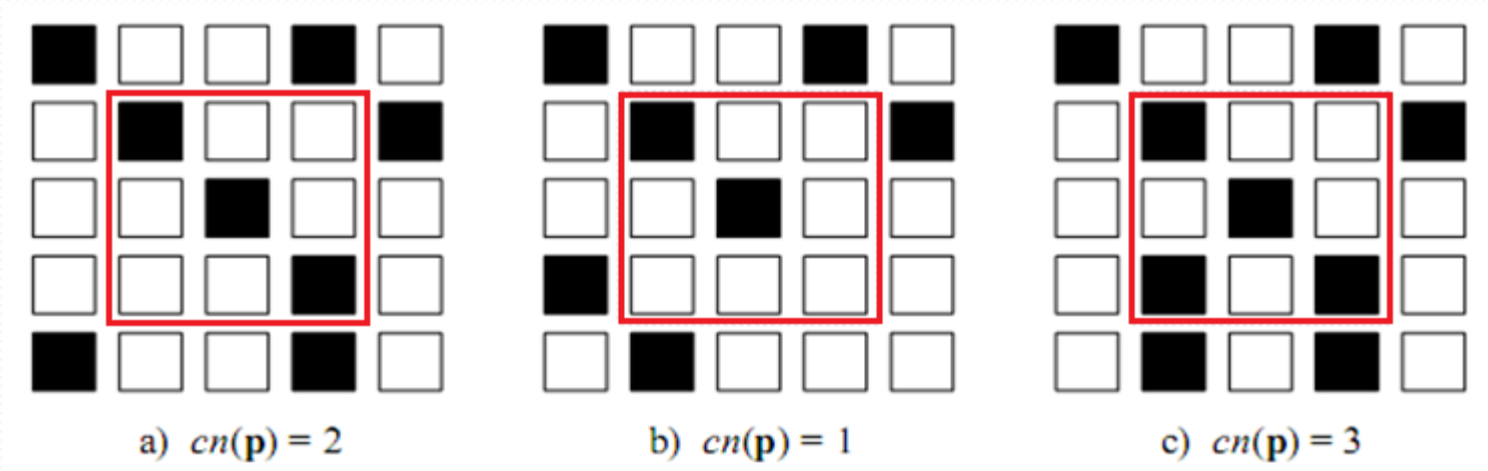
(Original Image taken from: FVC2000, DB2, FP Impression 101-2)

Minutiae Extraction

- Performed by using the concept of *Crossing Number*

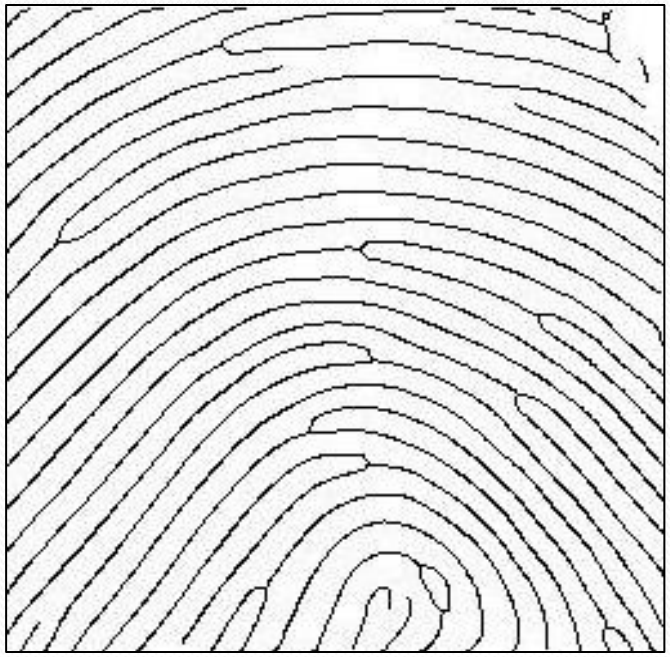
$$CN(p) = \frac{1}{2} \sum_{i=1\ldots8} |val(p_{i \bmod 8}) - val(p_{i-1})|$$

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

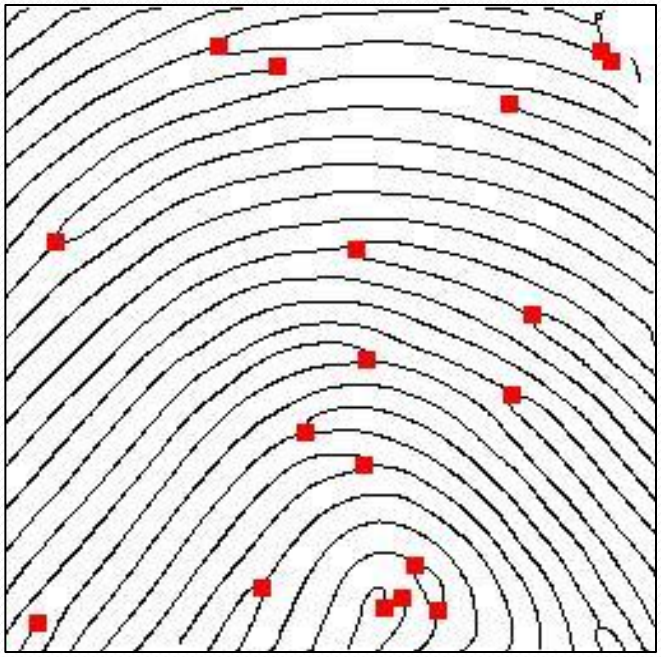


Minutiae Extraction (cont.)

- 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,

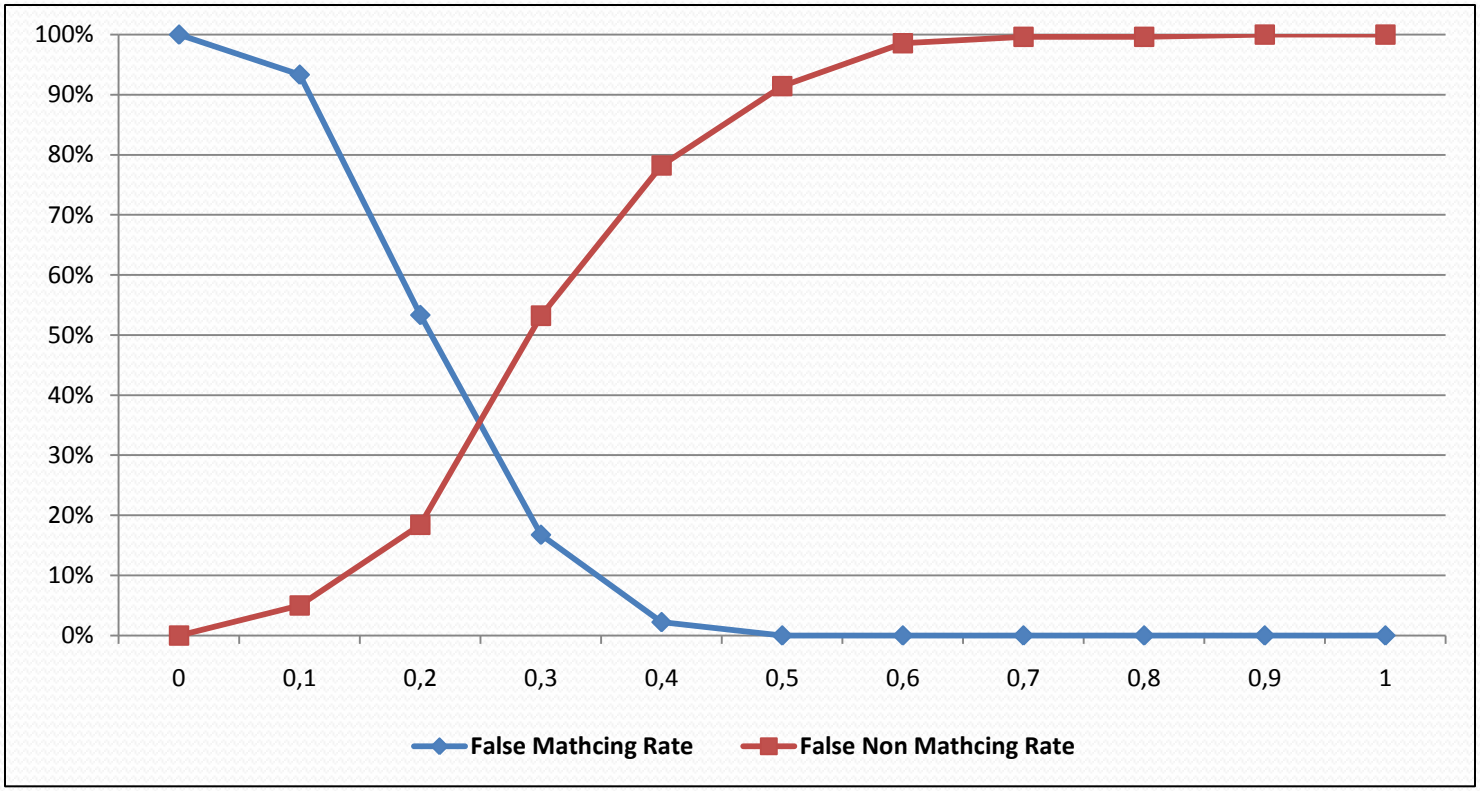
n - minutiae within the bounding box

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