Identification Systems
Lecture 11

Piotr Syga

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Motivation

- High discrimination rate
- Forensics: samples easily left on objects; Devices: easily obtainable samples
- Rising social acceptance
- Stability in time
- Mitigated tracking in case of database leakage
- Naturally hindered real-time sample acquisition from unaware subject
- Disadvantages of other biometric systems (more 'collisions' – face, palm geometry, DNA; requiring more sophisticated readers – iris)

Sample

Artificial fingerprint from SFinGe
R. Capelli: *SFinGe: an Approach to Synthetic Fingerprint Generation*



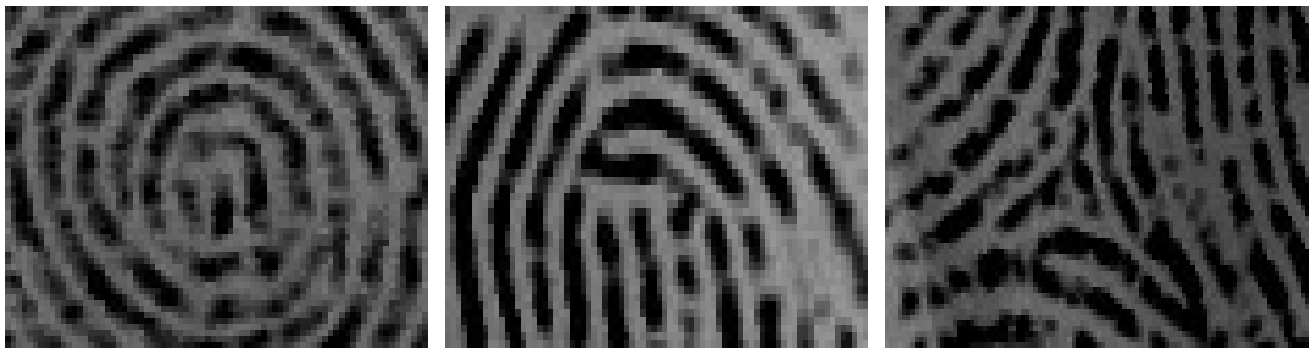
The hierarchy of features

Base features – ridges (black), valleys (white)



The hierarchy of features

Level 1 – singular points and cores

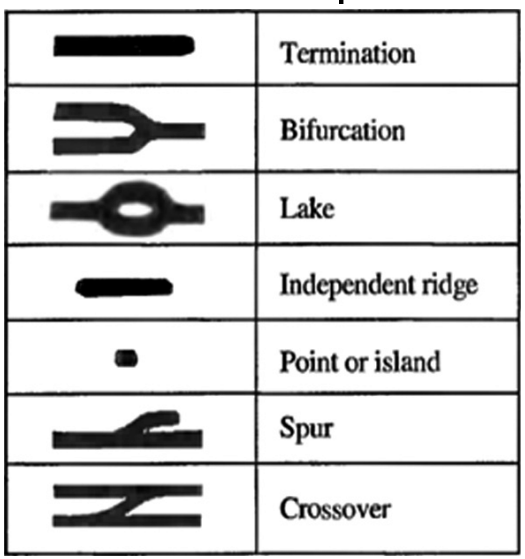


whorl loop delta

The hierarchy of features

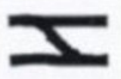
Level 2 – minutiae

Most common patterns:



The hierarchy of features

Extended list:

Minutiae	Example	Minutiae	Example
ridge ending		bridge	
bifurcation		double bifurcation	
dot		trifurcation	
island (short ridge)		opposed bifurcations	
lake (enclosure)		ridge crossing	
hook (spur)		opposed bifurcation/ridge ending	

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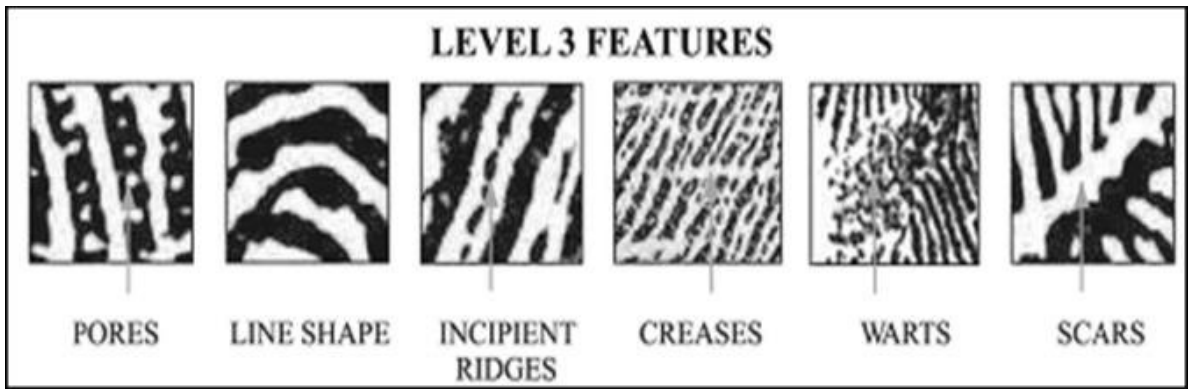
The hierarchy of features

Level 3 – scars, warts, sweat pores, torous and torn ridges, creases



B.N. Dhannoon

Methods of acquisition

Digital images may acquired directly by reading the data directly form the subject or indirectly by scanning or photographing dactyloscopy cards or latent fingerprints.
Most common biometric acquisition methods used include:

- Optical sensors (VL, UV, . . .)
- Capacitive sensors
- Pressure sensors
- Thermal sensors
- Touchless sensors (2D or 3D)
- Ultrasound sensors

Methods of acquisition

Magnetic powder

- Using powder on a latent fingerprint
- Image capture
- Color filtering

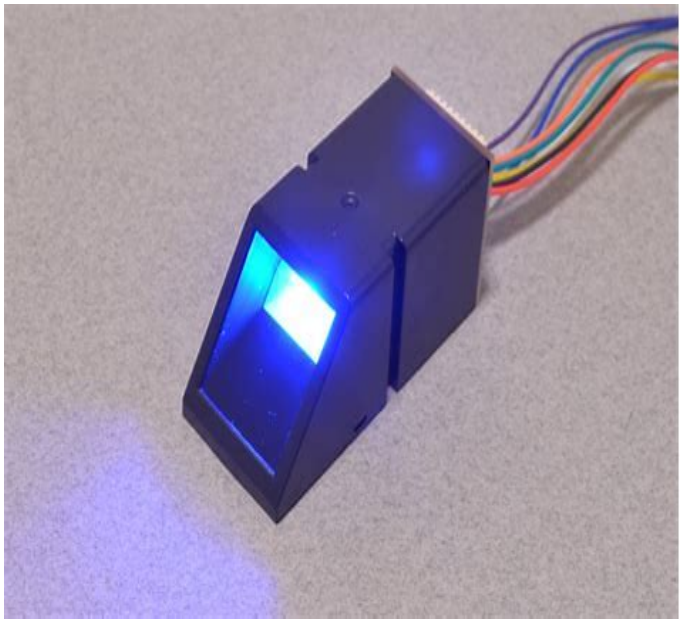


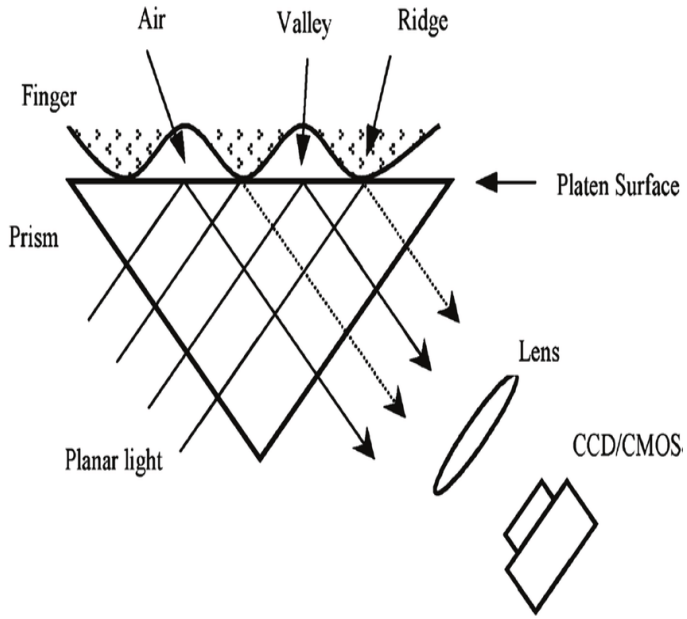




Methods of acquisition

Optical sensor



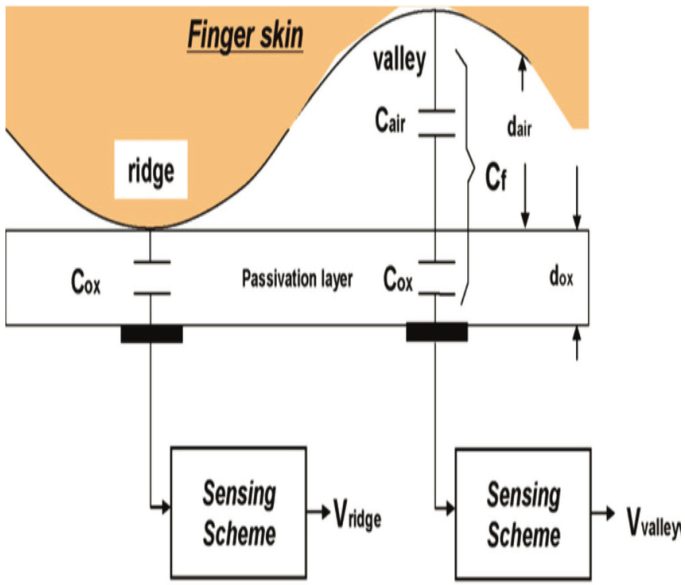


Reflection occurs where there's no contact with the sensor (i.e., valleys), ridges remain black. Resolution around 600dpi.

Methods of acquisition

Capacitive sensor

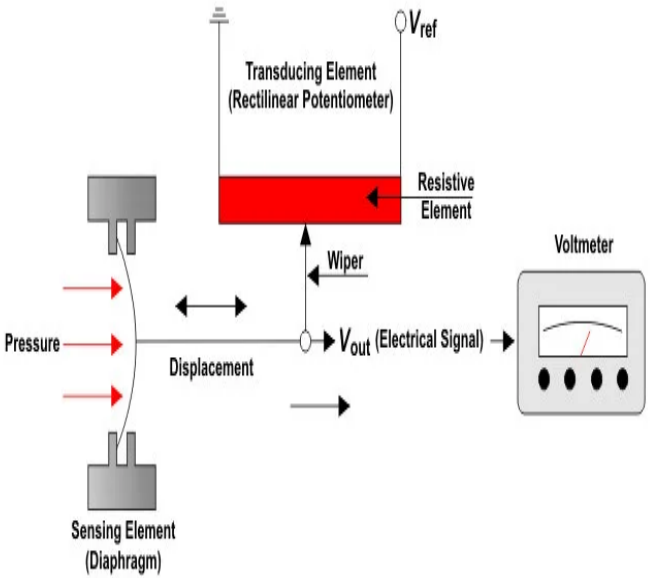


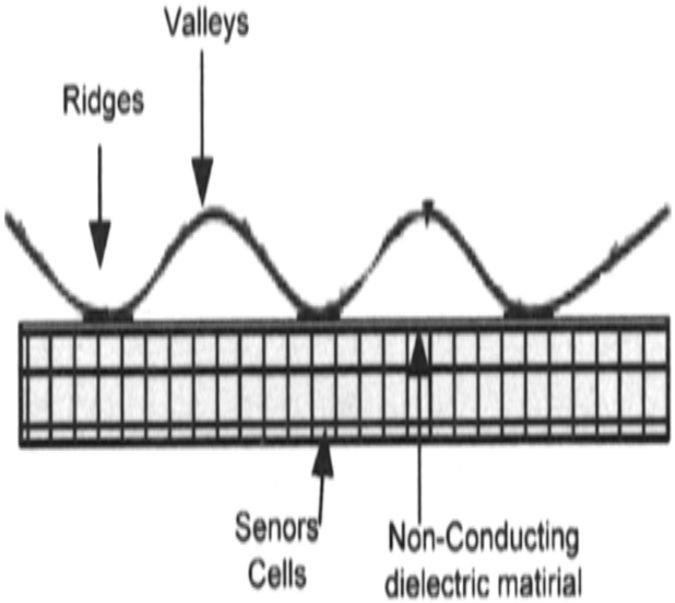


Accumulated charge depends on the distance between the skin and the sensor (and on the noise, moisture, . . .). Resolution around 400dpi.

Methods of acquisition

Pressure sensor

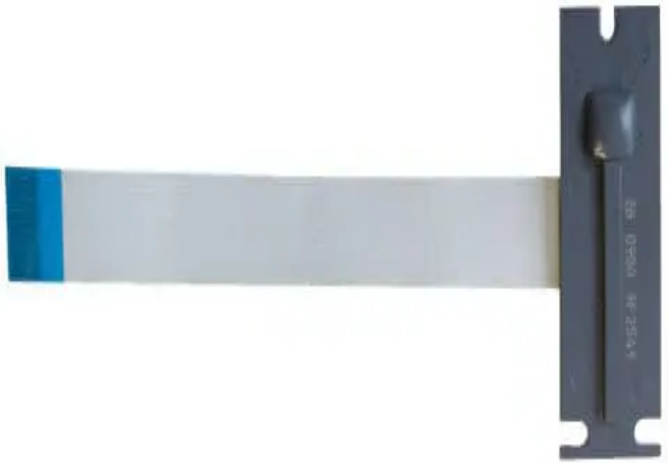


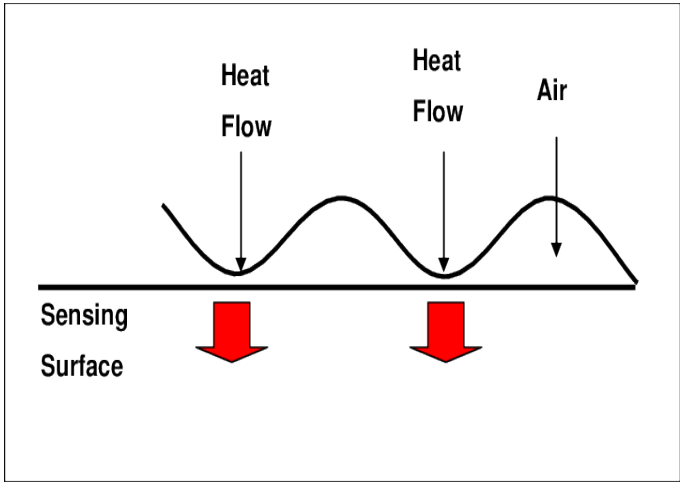


Matrix of piezoelectric sensors measures local pressure, making it robust against noise and moisture. Resolution around 400dpi.

Methods of acquisition

Thermal sensor

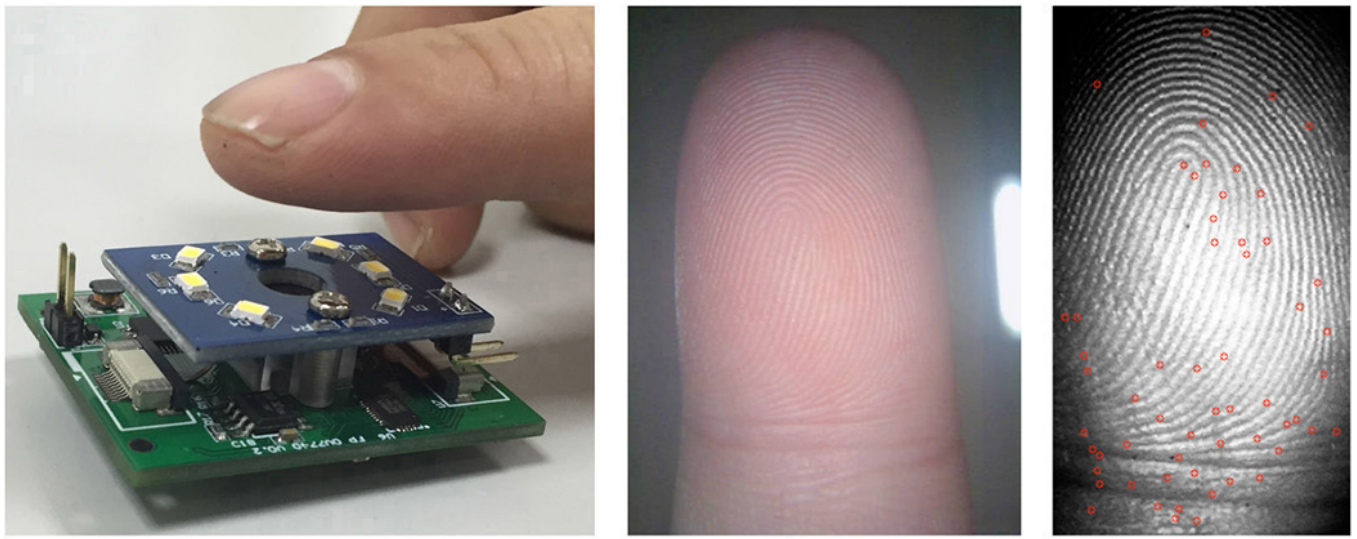




Measures difference of the temperature during finger scan through the sensor tape. The accuracy depends on measurement frequency (typically over 2kHz). Resolution around 500dpi.

Methods of acquisition

Touchless sensor

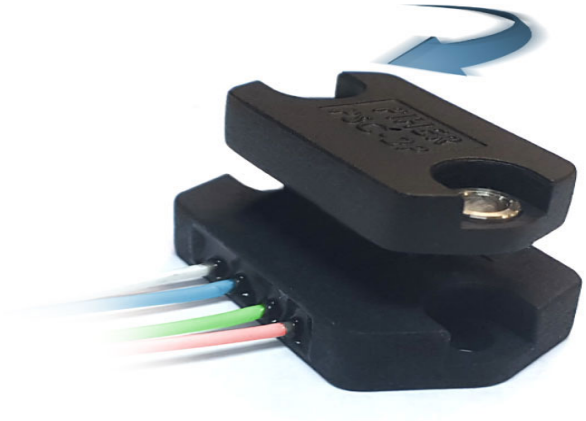


(a) (b) (c)

(C.W.G. Tsai)

Methods of acquisition

Thermal sensor cont.



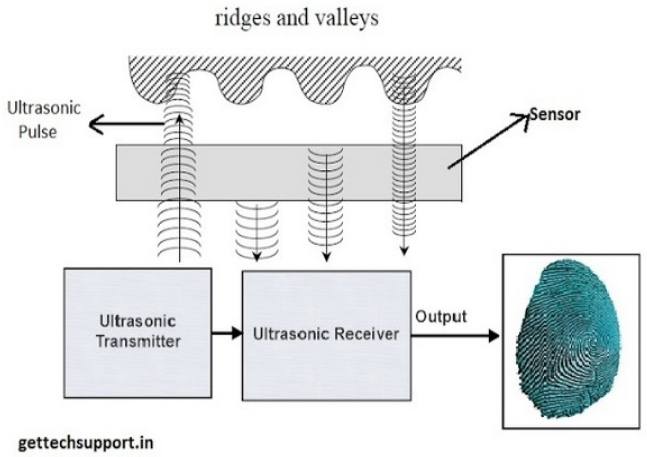


PIHER single finger touchless scanner and Morpho touchless scanner.
Resolution 300–1200dpi.

Methods of acquisition

Ultrasound sensor





Measures the sound scatter and reflections. Quick response time after collecting all impulses by the transducer. The most costly method, yet allowing detection through certain materials and detecting liveness by verifying skin properties. Resolution up to 400dpi.

Representation

The data may be kept in several forms:

- Raw image compliant with ISO/IEC 19794-4
- JPEG compressed image of the scan
- WSQ compressed scan
- Skeletal data of ridges pattern compliant with ISO/IEC 19794-8
- List of features (or xml-file containing list of hierarchical features) compliant with ISO/IEC 19794-2
- Spectral data after DCT, FFT, wavelet or Gabor transform, compliant with ISO/IEC 19794-3

Challanges

- Noise and blurred image
- Incorrectly aligned image parts before merging or errors during 3D to 2D projection
- Improperly performed measurement (lack of contact, various level of pressure, impurities)
- Transitions and rotations on a sensor
- Moist, dirty or dry finger
- Sensor restrictions
- Latent fingerprints or smudges left on the sensor

Challanges



Normal skin | Dry skin | Wet skin

D. Maltoni et al.: Handbook of Fingerprint Recognition

Preprocessing

- Noise removal – texture analysis and spectral analysis (DCT, FFT, Gabor, . . .)
- Illumination normalization – CLAHE, Retinex, Laplacian of Gaussian
- Contrast enhancement – sharpening, clastrization
- Energy reduction – thresholding, Local Fourier spectrum

Singular points

- In order to detect singular points we can use Poincare index.
- We add up 'total' rotation on a gradient field.
- Similarly to HoG calculation, we $\nabla(x_i, y_i) = [\nabla_x(x_i, y_i); \nabla_y(x_i, y_i)]$, omit the direction and normalize on larger patches.



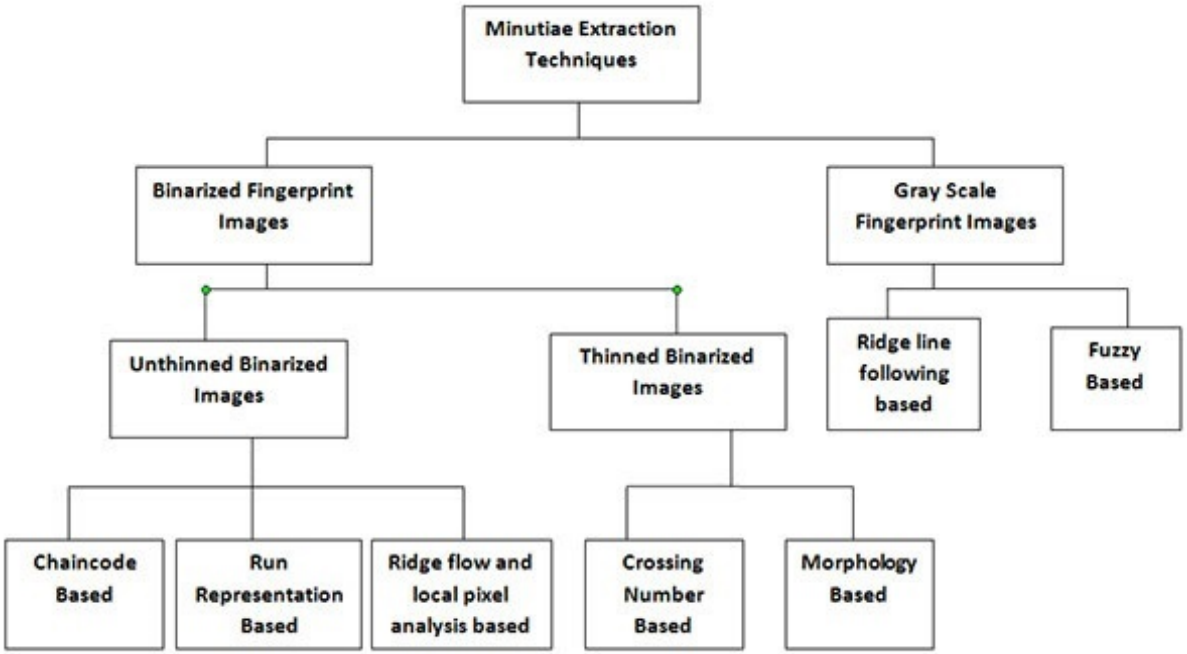
Singular points

- For a given pixel, we assign to each of its neighbors a direction based on the original pixel 2-neighborhood.
- We normalize the directions by lowering angle resolution.
- Walking along the curve, we sum the directions:
  - if the sum is equal to $-180°$ we found a delta
  - if the sum is equal to $180°$ we found a loop
  - if the sum is equal to $360°$ we found a whorl
  - otherwise no singular point is detected

Additional features may be calculated, e.g., ridge irregularity coefficient, assigning relative position of singular points on a single finger.

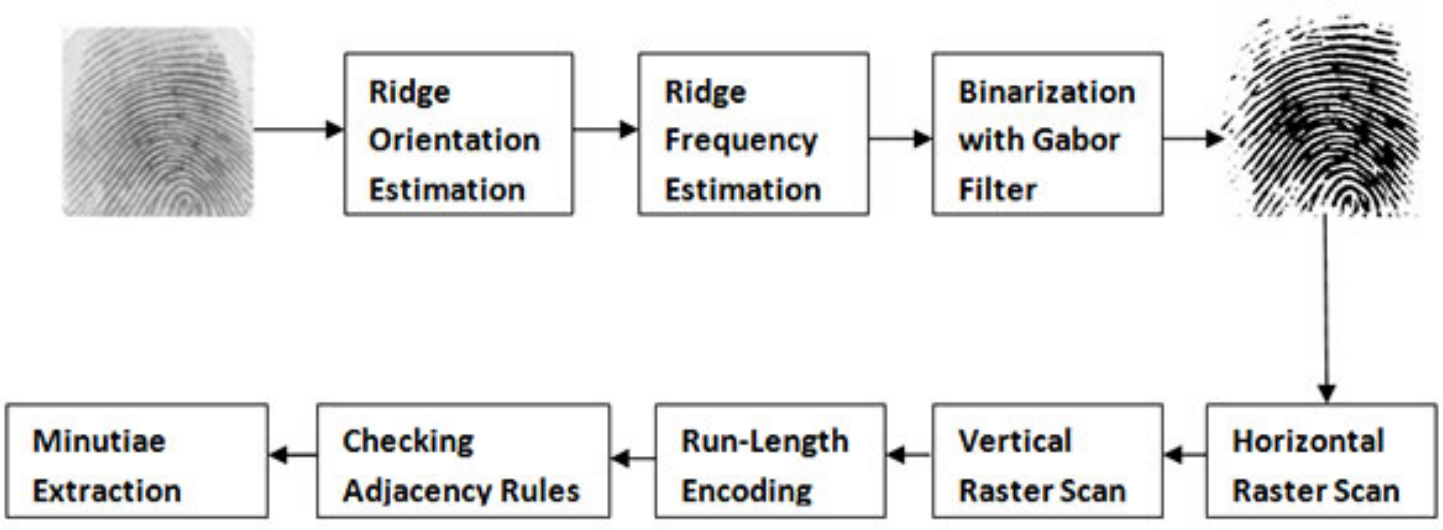
Minutiae

Detection method classification



Minutiae

Example of detection method



Minutiae

Simple detection algorithm

- We binarize the image using adaptive binarization threshold.
- We perform morphological thinning and skeletonize the image.
- We simplify the image by removing short ridges and joints, and removing short ridges breaks by morphological opening and closure.
- For each black pixel batch we analyze the neighborhood – if 1 pixel is black we have ridge ending, if 2 the ridge continues and we have no minutiae, if we have more than 2 we have a bifurcation (right neighbors) or opposed bifurcation or a bridge (otherwise).
- In post processing we remove the false positive matches according to heuristics and minutiae map.

Minutiae matching

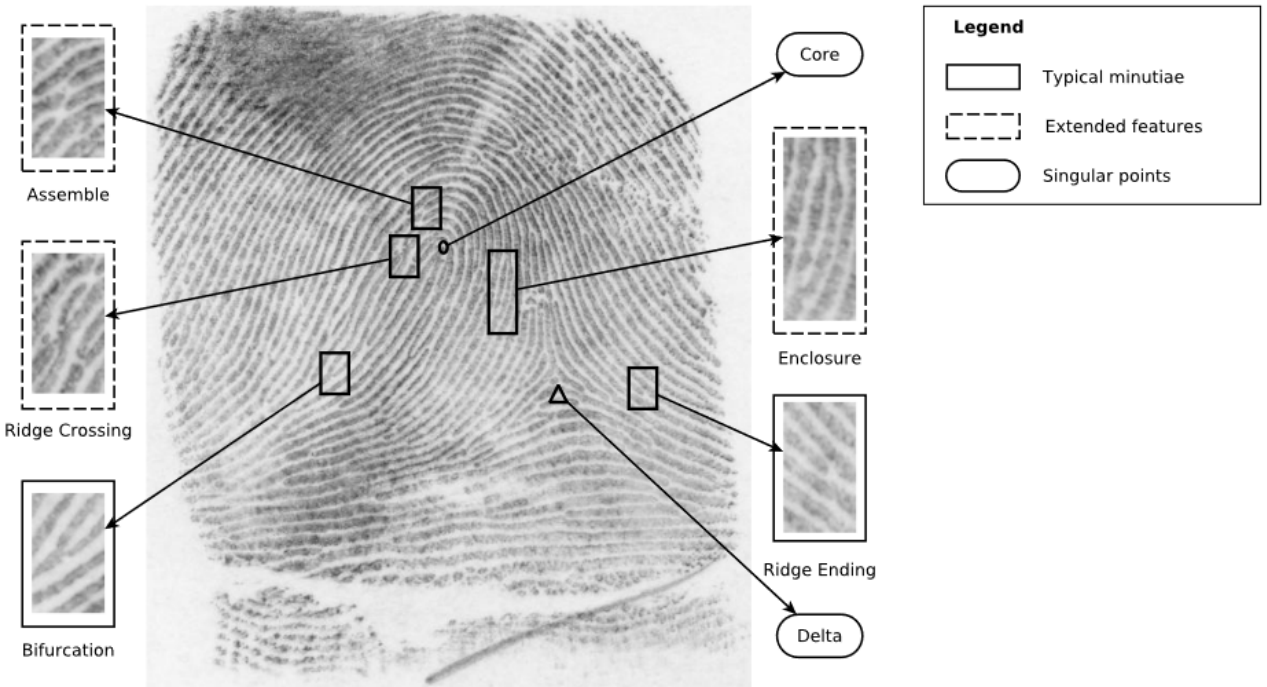
- Let us assume that we have a sample of minutiae to identificate $M = \{m_1, m_2, \ldots, m_N\}$ with all $m_i = \langle t, x_i, y_i, \theta_i \rangle$ representing the type, position and the angle of the feature.
- For a pair of minutiae from different samples, we denote a match (set $p = 1$) if both inequalities hold for thresholds R and Θ:
  $\sqrt{(x'_j - x_i)^2 + (y'_j - y_i)^2} \leq R$ and
  $\min(\left|\theta'_j - \theta_i\right|, 360 - \left|\theta'_j - \theta_i\right|) \leq \Theta$.
- In order to compare the sets we need to compensate for possibly different position of the scanned finger, noise, linear deformations and scale.
- We need to find an affine mapping (a rigid transform) from one set to the other.
- We optimize $\max_{\Delta x, \Delta y, \theta, c} \sum_{i=1}^{N} [\![p = 1]\!] f_{\Delta x, \Delta y, \theta}(m'_{c(i)}, m_i)$, where f is the affine transform between the minutiae and $c(\cdot)$ denotes the correspondence of the feature indexes.

Partial Latent Fingerprint Identification with Extended Minutiae

R.P. Krish et al.: *Improving Automated Latent Fingerprint Identification using Extended Minutia Types*

- Introducing a method of coping with partial fingerprints or matching distorted biometric samples.
- Utilizing adjusted weights for additional (rare) minutiae and taking into account that not all features may be present on a sample to perform a match (reducing weights).
- Adding rare features allows the authors to improve the identification by 12–90% (not perc. pts) depending on the dataset.
- Tests on 3 datasets showed that after threshold based modification, the method achieves nearly 75% acuracy on Bozoroth3, 77% on VeriFinger set and 96% on MCC set.

Partial Latent Fingerprint Identification with Extended Minutiae



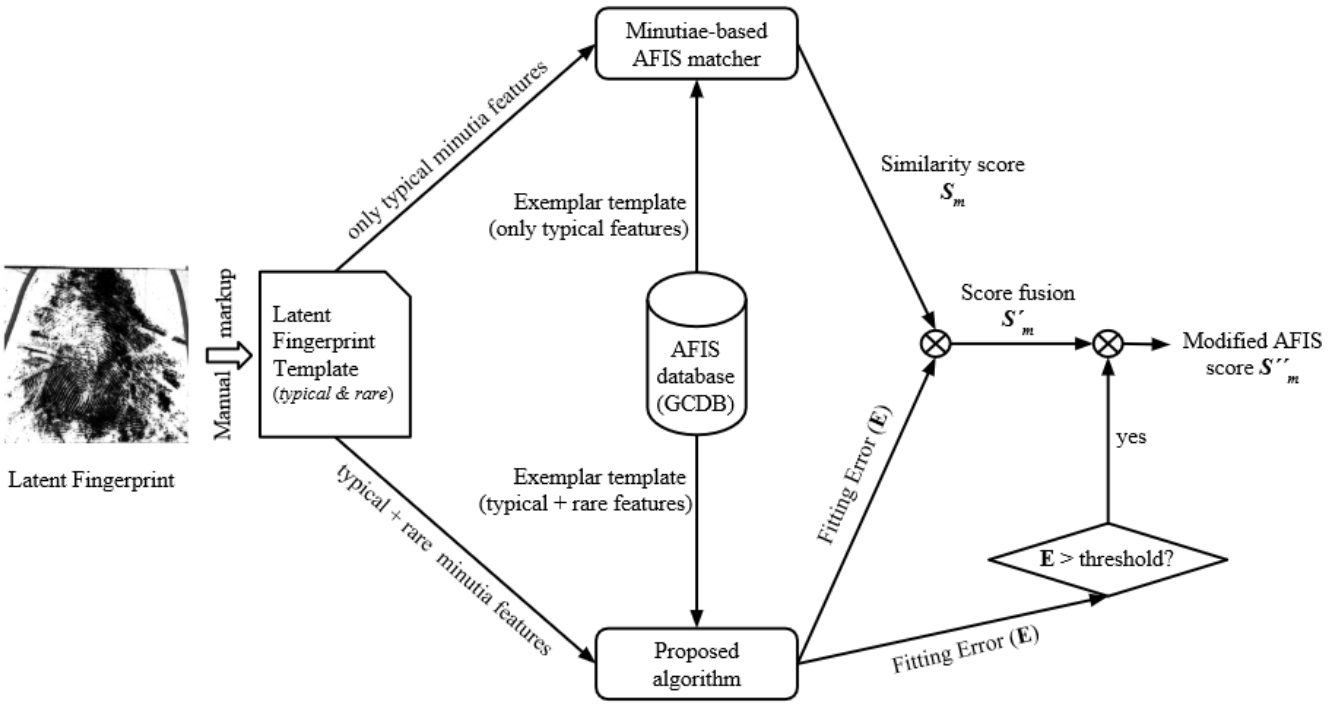
Partial Latent Fingerprint Identification with Extended Minutiae

- The algorithm is based on the previous minutiae matcher.
- First step represents set-to-set correspondence between the samples, by selecting the set of minutiae with equal type and corresponding relative positions in the set M_s.
- We superimpose one of the rare minutiae from one set to the other in order to find a base-point for rigid transform mapping.
- We superimpose the other minutiae from the obtained set and check their correspondence by calculating Euclidean distance between the pairs.
- Rotation in the range $[-45°, 45°]$ is performed with step of a single degree.
- The optimal rotation is the one for which the average sum of distances between closest pairs is minimal.
- All the minutiae pairs that where matched are treated as corresponding obtaining sets $\hat{M}_s$ and $\hat{M}'$.

Partial Latent Fingerprint Identification with Extended Minutiae

- LSE affine transform A between the corresponding sets is found $\hat{M}_s \approx A\hat{M}' + \tau$, where τ is translation matrix for each of the minutiae matched.
- Fitting error is calculated $E = \frac{1}{N}\sum_{i=1}^{N} \left\| \hat{m}'_i - A\hat{m}_i - \tau_i \right\|_2^2$.
- Standard minutiae matcher S_m score is calculated and readjusted for the error $S'_m = \frac{S_m + 1 - E}{2}$.
- Given error threshold E_t a threshold-adjusted score is calculated $S''_m = \alpha S'_m$ if $E < E_T$ and $S''_m = \beta S'_m$ otherwise, where α and β are reward and penalize constants.
- The threshold and the constants were determined empirically, with respect to the sample distortion rate.

Partial Latent Fingerprint Identification with Extended Minutiae



Useful articles

- D. Maltoni et al.: Handbook of Fingerprint Recognition
- R. Capelli: SFinGe: an Approach to Synthetic Fingerprint Generation
- J. Galbally et al.: Fake fingertip generation from a minutiae template
- A. Belmonte Hernandez et al.: SWiBluX: Multi-Sensor Deep Learning Fingerprint for Precise Real-Time Indoor Tracking
- F. Lemic et al.: Regression-Based Estimation of Individual Errors in Fingerprinting Localization
- D. Valdes-Ramirez et al.: A Review of Fingerprint Feature Representations and Their Applications for Latent Fingerprint Identification:Trends and Evaluation
- NIST Database
- VeriFinger and FingerCell