EEE-6561 Fundamentals of Biometric Identification

February 28th, 2018

Lecture #12: Fingerprint Recognition (Part 3)

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Outline

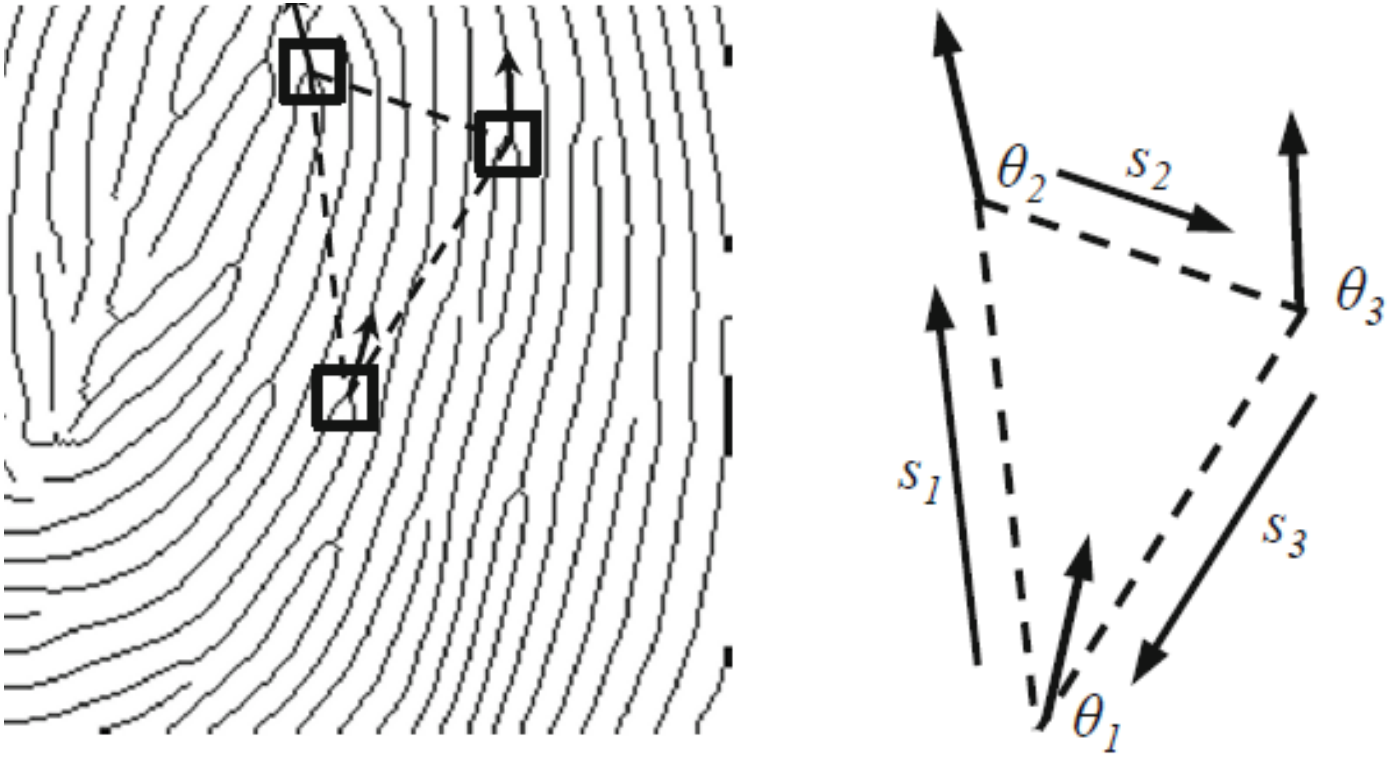
1. Introduction
2. Friction Ridge Pattern
3. Fingerprint Acquisition
4. Feature Extraction
5. Matching
6. **Fingerprint Indexing**
7. Fingerprint Synthesis
8. Palmprint
9. Summary

6. Fingerprint Indexing

- Purpose of indexing: speed-up fingerprint identification process.
- The most well-known indexing approach is based on fingerprint pattern classification.
- Another popular technique for fingerprint indexing is based on triplets of minutiae.

6. Fingerprint Indexing

- An example of a minutiae triplet.



6. Fingerprint Indexing

- Minutiae triplet is described by the geometric properties of the triangle:
  - the lengths of the sides of the triangle;
  - the ridge count between each pair of vertices;
  - the orientation of the minutiae points at the vertices encoded with respect to the longest side.

6. Fingerprint Indexing

- These features are invariant to rotation and translation.
- But, the lengths of the sides are highly sensitive to non-rigid distortions.
- The correct ordering of the features and the three angles depend on correctly identifying the longest side of the triangle.

6. Fingerprint Indexing

- The actual indexing algorithm is based on geometric hashing.
- It is mainly to calculate the similarity score between two fingerprints.
- The top N images from the database are output as possible hypotheses for further matching.

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7. Fingerprint Synthesis

- Generate artificial fingerprint images.
- Purpose:
  - generate a large database for testing fingerprint recognition algorithms (collecting real data is expensive in money and time).
  - model fingerprints and identify an appropriate set of parameters that characterize the fingerprints.

7.1 Fingerprint Synthesis: Level 1 feature synthesis

- **zero-pole model:**

$$RO(x,y) = \frac{1}{2}\sum_{i=1}^{M} t_i \arctan\left(\frac{y-y_i}{x-x_i}\right)$$

  - M: **the number of singular points;**
  - (x_i, y_i) **: the coordinates of the** i**th singularity;**
  - $t_i \in \{1,-1\}$**: the type (1 for loop and −1 for delta).**

7.1 Fingerprint Synthesis: Level 1 feature synthesis

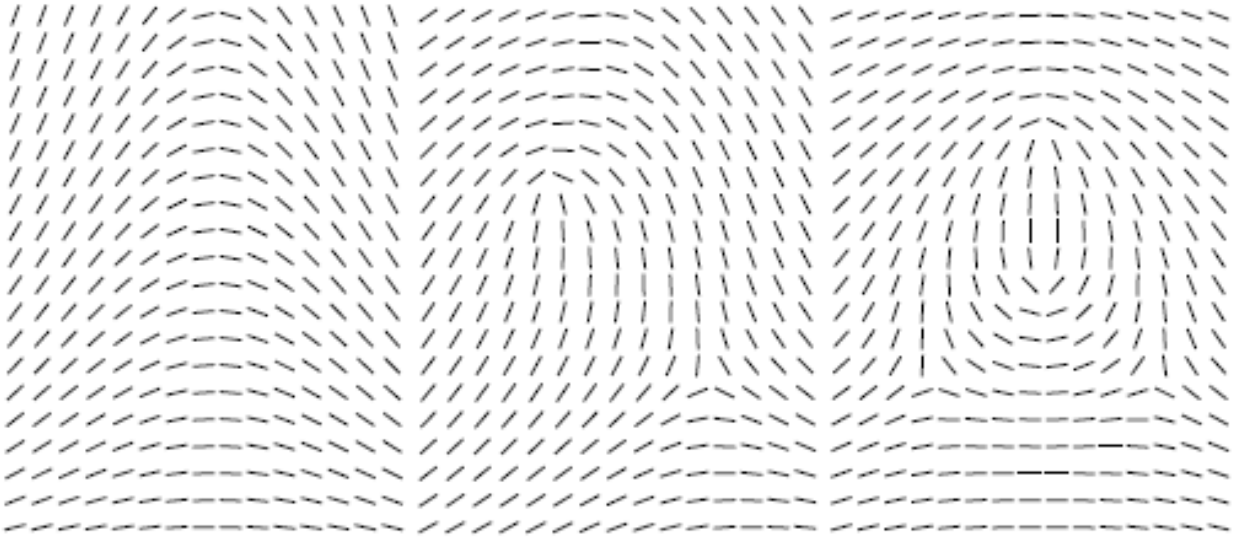
- Zero-pole model cannot correctly model the arch-type fingerprints.
- An orientation field model for arch:

$$RO_{arch}(x, y) = \arctan\left(\max\{0, (k - 3\frac{y}{H})\} \cdot \cos(\frac{x}{W}\pi)\right)$$

  - H and W denote the height and width of the image;
  - $k\ (2 < k < 5)$ controls the curvature of arch.

7.1 Fingerprint Synthesis: Level 1 feature synthesis

- **Examples of simulated fingerprint orientation fields (arch, left loop, and whorl).**

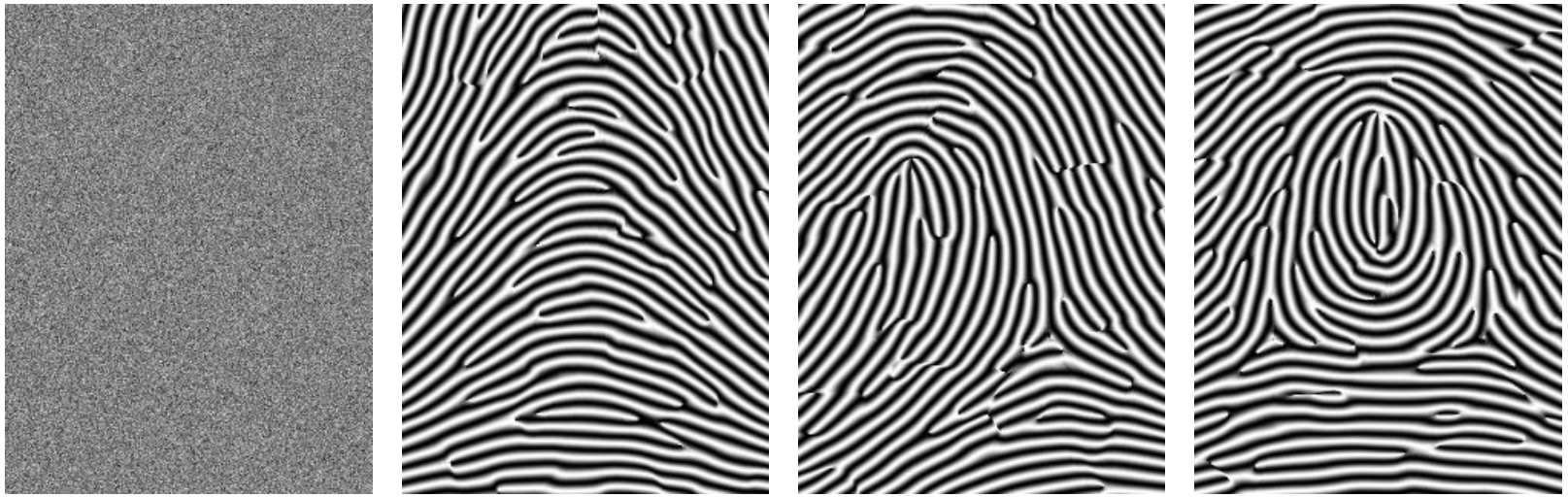


7.2 Fingerprint Synthesis: Level 2 feature synthesis

- **Ridge pattern is generated by performing Gabor filtering on an image initialized with random noise.**
- **Parameters of Gabor filters are the simulated orientation field and ridge frequency (assuming a fixed value).**
- **The noise at each pixel follows uniform distribution in the range** $[0, 255]$**.**

7.2 Fingerprint Synthesis: Level 2 feature synthesis

- Noise image and simulated fingerprint images of three types.



7.2 Fingerprint Synthesis: Level 2 feature synthesis

- Different from real fingerprint images:
  - no sweat pores;
  - the ridge contours are too straight.
- It is also necessary to simulate various intra-class variations:
  - ridge thickness and image contrast;
  - finger placement on the sensor;
  - skin distortion.

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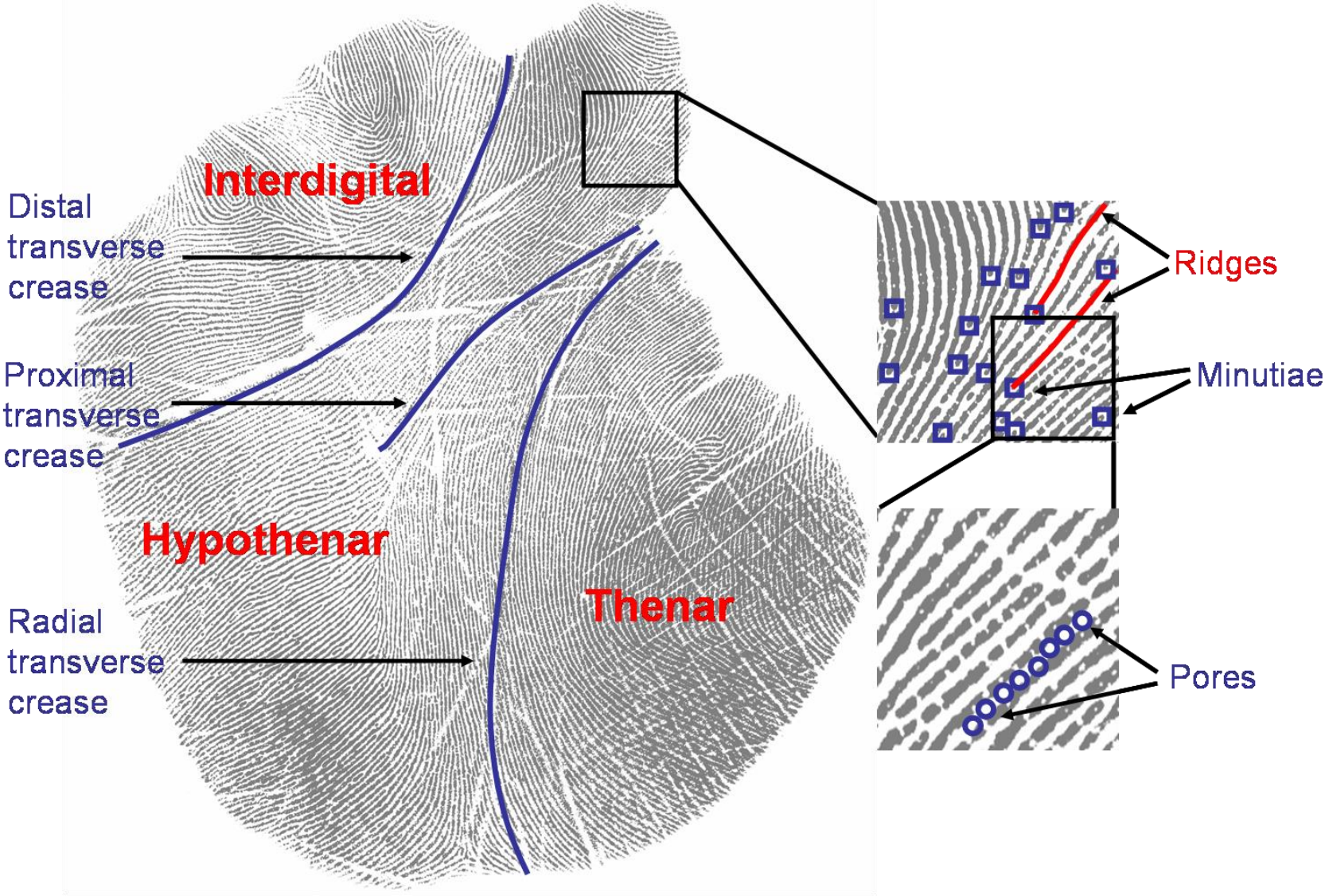
8. Palmprint

- Palmprints are unique & permanent.
- ~30% of latents at crime scenes are from palms.
- Palmprints are also friction ridge patterns; so encoding & matching algorithms are similar to fingerprints.

8.1 Palmprint: Palmprint features

- Two unique features:
  - palmar friction ridges
  - palmar flexion creases
- Three major creases:
  - distal transverse crease
  - proximal transverse crease
  - radial transverse crease
- Minimum resolutions for different features:
  - Major creases: 100 ppi
  - Thin creases & ridges: 500 ppi
  - Pores: 1000 ppi

8.1 Palmprint: Palmprint features



8.2 Palmprint: Systems for forensics

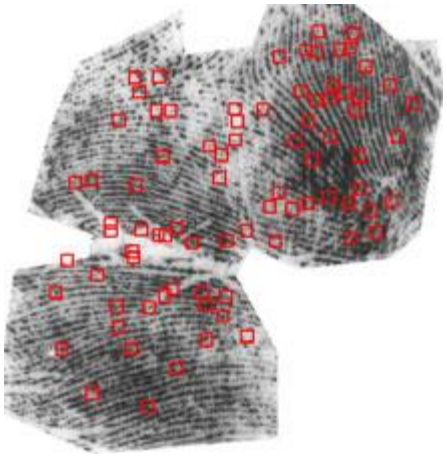
- **Minutiae** are the main features used in latent palmprint matching.
- Major difference from fingerprint: a large number of **creases**.
- Handle the creases in palmprints:
  - Detect a set of six strongest sinusoid waves in the Fourier transform of each local block (16×16 pixels) in a palmprint.

8.2 Palmprint: Systems for forensics

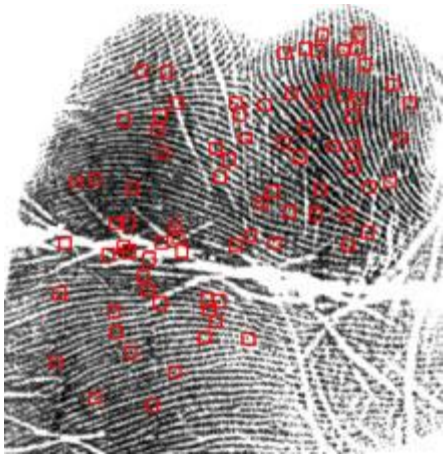
- Cluster the strongest waves that are compatible with each other into a set of seed orientation fields. Two waves in adjacent blocks are said to be compatible if their orientation and frequency are similar.
- Grow each seed orientation field by including adjacent and compatible waves.
- Select the largest seed as the final orientation field.

8.2 Palmprint: Systems for forensics

- The other fingerprint feature extraction steps can be directly used for palmprints.
- An example of successful latent palmprint matching



Latent palmprint



Corresponding region in the mated full palmprint

Mated full palmprint

8.3 Palmprint: Systems for access control

- Real-time palmprint recognition systems use low resolution images.
- Feature: flexion creases.
- Framework:
  - cropping and normalization;
  - filtering the cropped image using 2D Gabor filter with predefined direction and frequency;
  - binarize real and imaginary images.
  - compute similarity by Hamming distance.

8.3 Palmprint: Systems for access control

- Accuracies of low resolution palmprint matching systems (on databases collected in lab environment) are impressive.
- But, they have not yet shown to be competitive with respect to fingerprint matching systems for access control or other civilian applications.

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9. Summary

- Fingerprint recognition is one of the most mature biometric technologies.
- Some challenges still exist:
  - 3D & touchless fingerprint sensing
  - assure the integrity of fingerprints
  - Automated latent processing and matching
  - Privacy and security technology