EEE-6561 Fundamentals of Biometric Identification

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Lecture #10: Fingerprint Recognition (Part 1)

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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

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1. Introduction

- The skin on the palms and soles:
  - ridges and valleys, not smooth;
  - contains no hair and oil glands.

Smooth skin

ridged skin

1. Introduction

- The papillary ridges on the finger, called friction ridges.
- The value of friction ridges:
  - Increase the friction between the volar and the contact surface;
  - Person recognition.
- The pattern of friction ridges on each finger:
  - unique
  - immutable

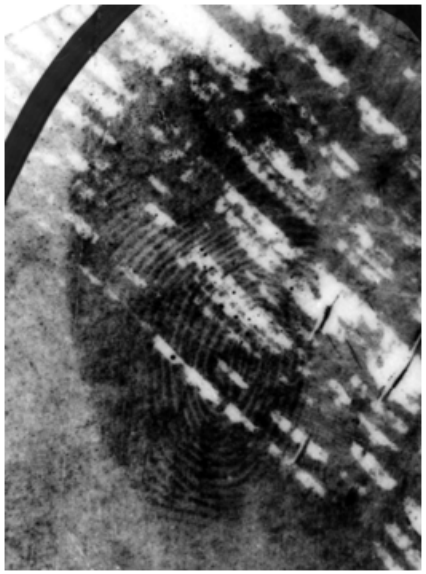
1. Introduction

- Systematically used in forensic applications in early 20th century.
- Two major uses:
  - identify repeat offenders using 10 fingers;
  - establish the identity of a suspect based on partial fingerprints left at a crime scene.

1. Introduction

- 3 types of fingerprint impressions:
  - rolled fingerprint
  - plain fingerprint
  - latent fingerprint





1. Introduction

- Automated Fingerprint Identification System (AFIS):
  - time: 1970s;
  - purpose: to improve efficiency and accuracy.
- Non-forensic applications:
  - homeland security
  - consumer fraud
- Synonym of biometric recognition because of its success.

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2. Friction Ridge Pattern

- Fingerprint recognition is mainly feature-based (as opposed to image-based).
- Next, we will introduce:
  - different types of features
  - formation of fingerprint

2.1 Friction Ridge Pattern: Features

- The details in a fingerprint can be categorized into 3 different levels (level 1, 2, & 3) ranging from coarse to fine.

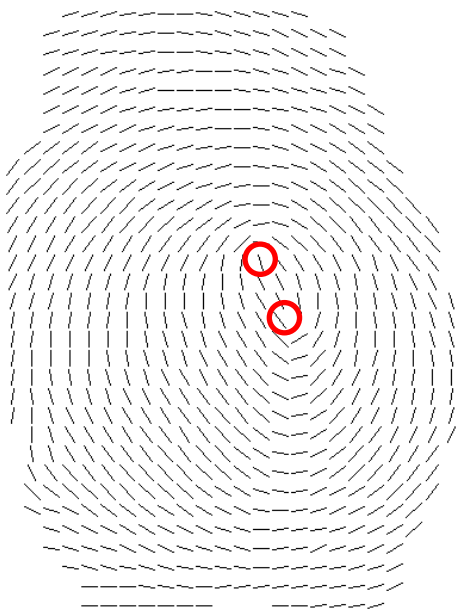
2.1 Friction Ridge Pattern: Features

- First (coarsest) level:
  - ridge orientation map (orientation field, flow map, direction map/field);
  - ridge frequency map.
- Second (middle) level:
  - ridge skeleton image (one-pixel wide);
  - minutiae.
- Third (finest) level:
  - inner holes of ridges (sweat pores);
  - outer contours of ridges (edges).

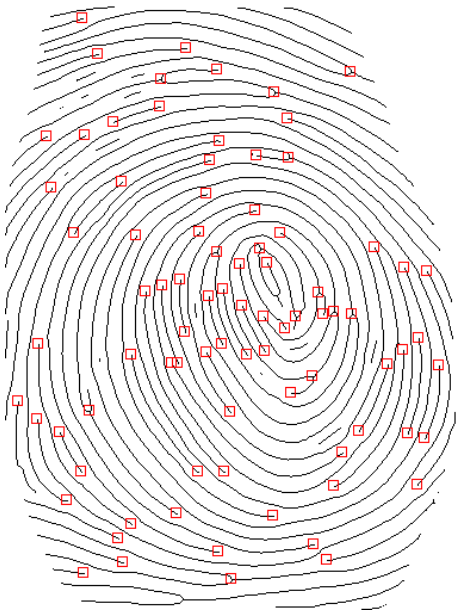
2.1 Friction Ridge Pattern: Features

Fingerprint features at 3 different levels

Fingerprint image



Level 1



Level 2

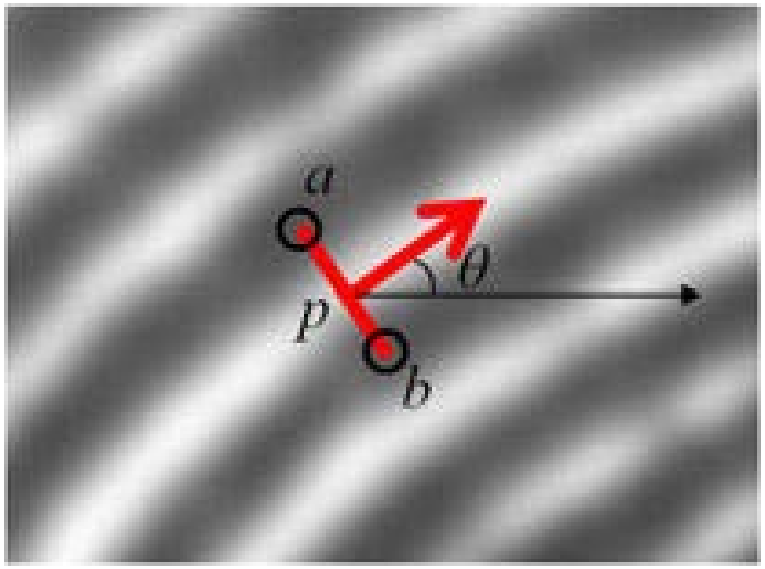
Level 3

2.1.1 Friction Ridge Pattern: Level 1 feature

- Minimum image resolution: 250 ppi.
- Local ridge orientation at (x, y):
  - the tangential direction;
  - in the range $[0, \pi)$.
- Local ridge frequency at (x, y):
  - the average number of ridges per unit length along a normal line segment centered at (x, y).

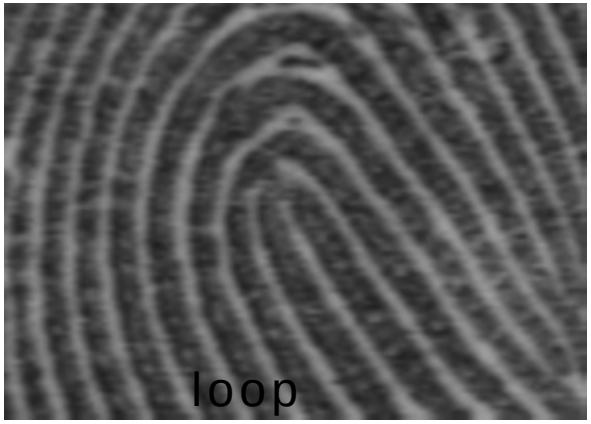
2.1.1 Friction Ridge Pattern: Level 1 feature

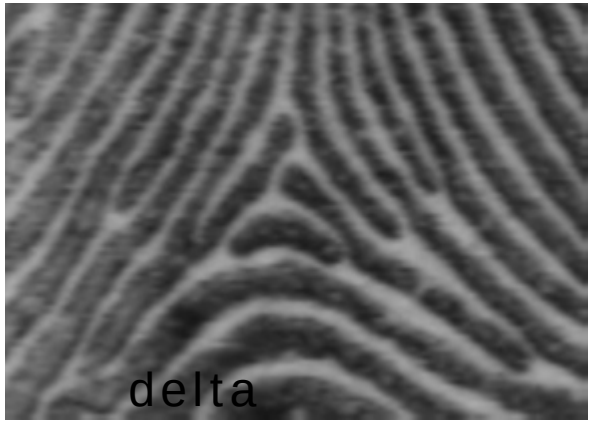
- Local ridge orientation and local ridge frequency ($\frac{1}{ab}$)



2.1.1 Friction Ridge Pattern: Level 1 feature

- A ridge orientation map typically contains some singular points where the ridge orientations change abruptly.
- Two basic types of singular points: loop & delta.



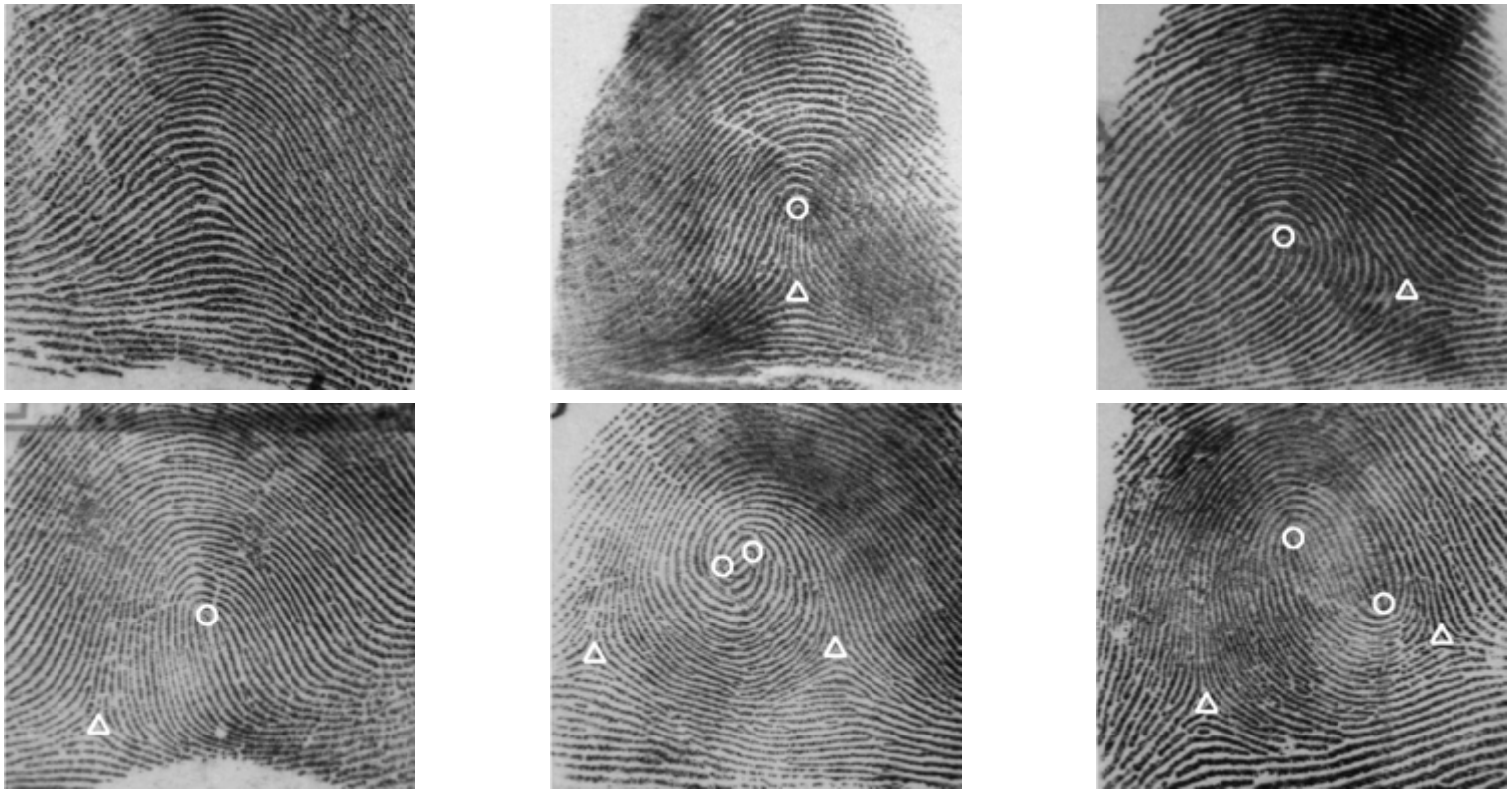


2.1.1 Friction Ridge Pattern: Level 1 feature

- A loop-type singularity:
  - a local area where a set of ridges enters from one direction and exits in the same direction.
  - can be used as a landmark point to align the fingerprint.
- A delta-type singularity indicates a local area where three ridge systems meet.

2.1.1 Friction Ridge Pattern: Level 1 feature

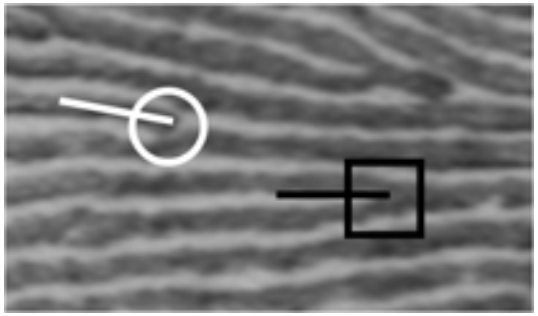
- Six major fingerprint pattern types (arch, tented arch, left loop, right loop, whorl, twin loop)



2.1.1 Friction Ridge Pattern: Level 1 feature

- Singularities are observed to satisfy the following constraints:
  - the numbers of loops and deltas in a full fingerprint are the same, in other words, loops and deltas appear in pairs;
  - the total number of singular points are either 0 (plain arch), 2 (tended arch, left/right loop), or 4 (whorl, twin loop).

2.1.2 Friction Ridge Pattern: Level 2 feature



- Resolution: 500 ppi.
- Two types of minutiae
  - Ridge ending;
  - Ridge bifurcation.
- The properties of a minutia:
  - Location
  - Direction: along the local ridge orientation
  - Type: ending or bifurcation

2.1.2 Friction Ridge Pattern: Level 2 feature

- A minutia can be characterized by
  - its location
  - its direction
  - its type (not reliable)
- A minutiae set:
  - contains all the minutiae in a fingerprint;
  - captures most of the discriminative information at Level 2.

2.1.2 Friction Ridge Pattern: Level 2 feature

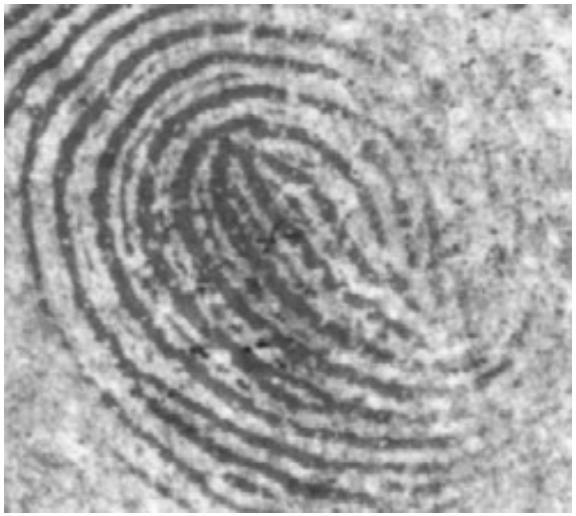
- Minutiae-based representations are extensively used because
  - minutiae capture much of the discriminative information;
  - minutiae-based representations are storage efficient;
  - minutiae extraction is reasonably robust to various sources of degradation.

2.1.3 Friction Ridge Pattern: Level 3 feature

- Resolution: 1000 ppi.
- Major level 3 features:
  - Sweat pores
  - Ridge edges
  - Incipient ridges: thinner ridges containing no sweat pores;
  - Dots: short ridges containing only a single ridge unit.
- Level 3 features are important in matching latent fingerprints.

2.1.3 Friction Ridge Pattern: Level 3 feature

- Incipient ridges in a latent and its mated rolled fingerprint.



2.1.4 Friction Ridge Pattern: Additional features

- Fingerprints often have other features:
  - creases;
  - cuts;
  - scars and the like.
- These features are
  - not stable;
  - not universal, limiting the utility.
- In fact, such abnormalities are often the source of matching errors.

2.2 Friction Ridge Pattern: Formation

- The exact process is not fully known.
- Embryology research has shown:
  - epidermal ridges: sixth week;
  - friction ridges: fourth month;
  - the ridges are elevated: eighteenth week;
  - minutiae are formed as ridges separate and create space for forming new ridges.

2.2 Friction Ridge Pattern: Formation

- The ridge flow on the boundary runs parallel to the fingernail furrow and the finger crease.
- The ridge flow pattern in the central area is governed by the shape, size, and placement of volar pads;
  - higher/flatter and symmetric volar pads tend to generate whorls/arches;
  - asymmetric volar pads tend to generate loops.

2.2 Friction Ridge Pattern: Formation

- Friction ridge patterns are influenced by:
  - genetic factors;
  - random physical stresses;
  - tensions during fetal development.
- These random effects during the morphogenesis of fingerprints are believed to impart uniqueness to the fingerprint.

Questions?