Fingerprint recognition system

Fingerprint recognition

- Fingerprint identification is the oldest of the biometric sciences.
- Fingerprint comparisons have been based on "minutiae", i.e., individual unique characteristics within the fingerprint pattern.
- Within a typical fingerprint image obtained by a live scan device, there is an average of 30-40 minutiae. The Federal Bureau of Investigation (FBI) has shown that no two individuals can have more than 8 common minutiae.
- The U.S. Court system has consistently allowed testimony based on 12 matching minutiae; in some courts, a lower number of matching minutiae have been allowed.

Fingerprint recognition

- In the early 1970's, the U.S. government commissioned a study by Scandia Labs to compare various biometric identifiers; the conclusion of this report was that fingerprint technology had the greatest potential to produce the highest accuracy rate for identification purposes.
- The Scandia study is dated but the impact of the study was to shift focus onto fingerprint technology. Because of this early emphasis on fingerprint technology, the years since 1970 have produced a large body of research and development in fingerprint identification algorithms and integrated systems.

Strengths of Fingerprint recognition

- It is a mature and proven core technology, capable of high levels of accuracy.
- It can be deployed in a range of environments.
- It employs ergonomic, easy-to-use devices.
- The ability to enroll multiple fingers can increase system accuracy and flexibility.

Weaknesses of Fingerprint recognition

- Most devices are unable to enroll some small percentage of users.
- Performance can deteriorate over time.
- It is associated with forensic applications.

Finger-scan technology

- Image acquisition
- Image preprocessing
- Feature extraction
- Template creation
- Template matching

Image acquisition

- Biometric sample acquisition is the process of capturing information about a biological attribute of the subject, as it exists within a specific time frame.
- The objective is to measure data that can be used to derive unique properties of the subject that are stable and repeatable over time and over variations in acquisition conditions.

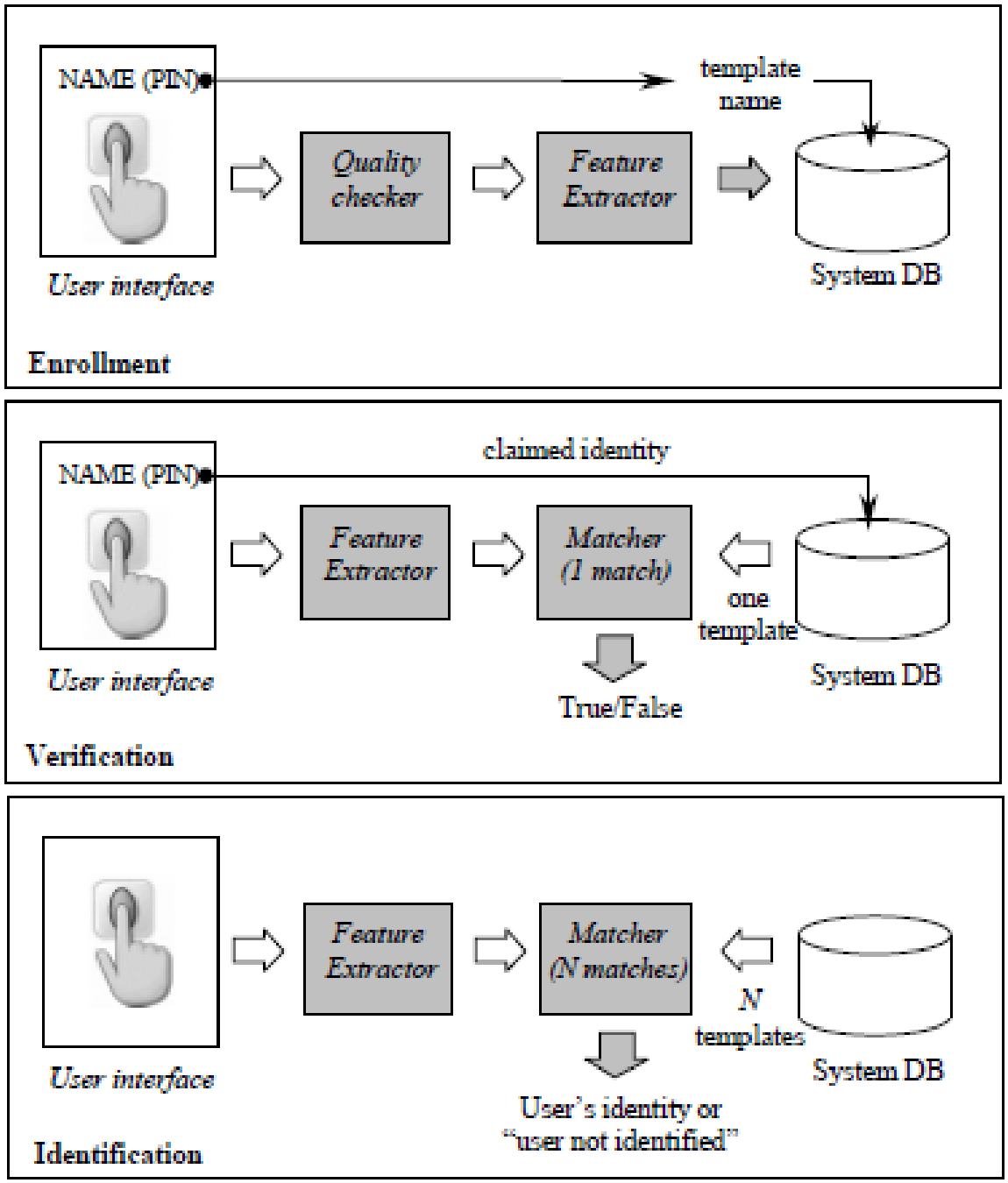


Figure 1.1. Block diagrams of enrollment, verification, and identification tasks.

Image acquisition

- Historically, in law enforcement applications, the acquisition of fingerprint images was performed by using the so-called “ink-technique”: the subject’s fingers were smeared with black ink and pressed or rolled on a paper card; the card was then scanned by using a general purpose scanner, producing a digital image.
- This kind of acquisition process is referred to as *off-LINE. Particular* case of off-line sensing is the acquisition of latent fingerprints from crime scenes.

Fingerprint Representation and Feature Extraction

- The problem of representation is to determine a measurement (feature) space in which the fingerprint images belonging to the same finger form a compact cluster and those belonging to different fingers occupy different portions of the space (low *intra-class variation and high inter-class variations).*

The fingerprint pattern, when analyzed at different scales, exhibits different types of features – Level-1, Level-2, Level-3 features.

Features at global level (Level-1)

- *Singular points, called loop and delta (denoted as squares and* triangles, respectively in Figure), are a sort of control points around which the ridge lines are “wrapped”, but their distinctiveness is not sufficient for accurate matching.
- External fingerprint shape, orientation image, and frequency image also belong to the set of features that can be detected at the global level.
- Singular points and coarse ridge line shape are useful for fingerprint classification and indexing

Features at global level

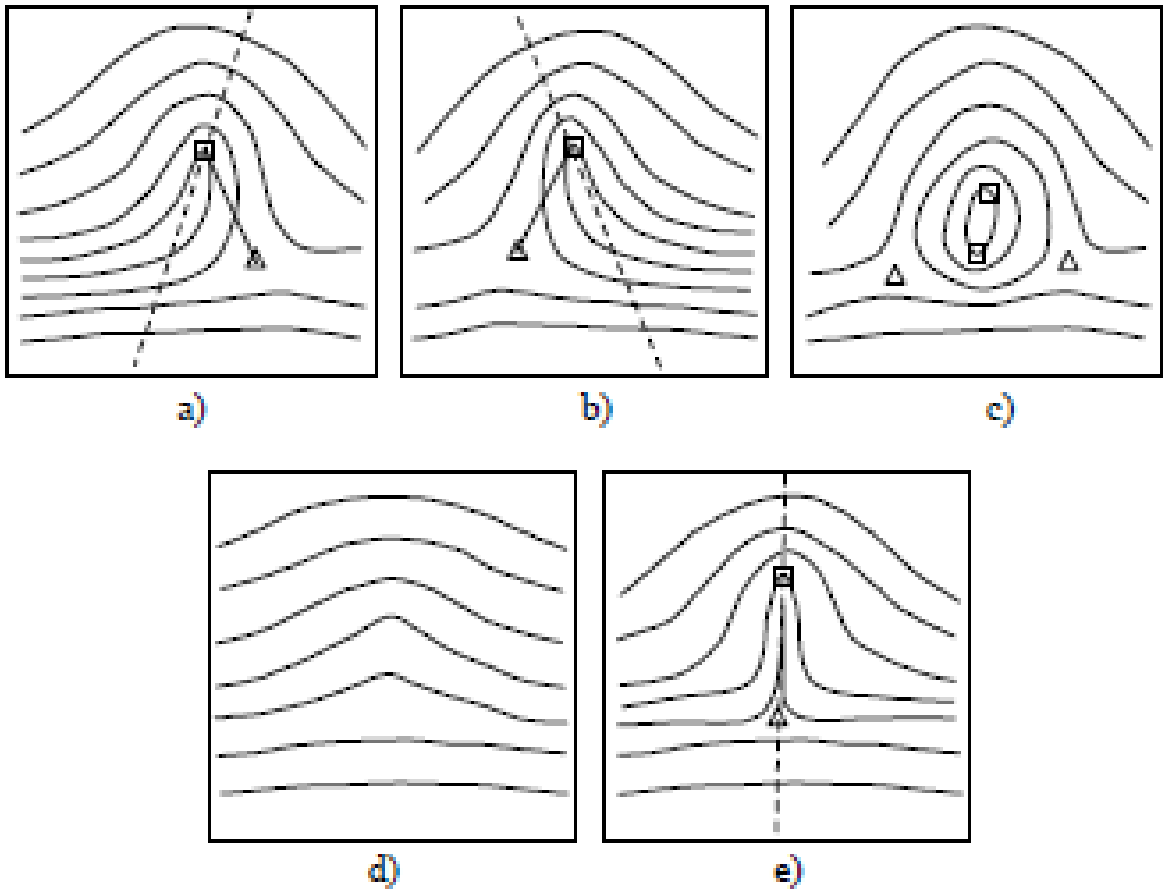
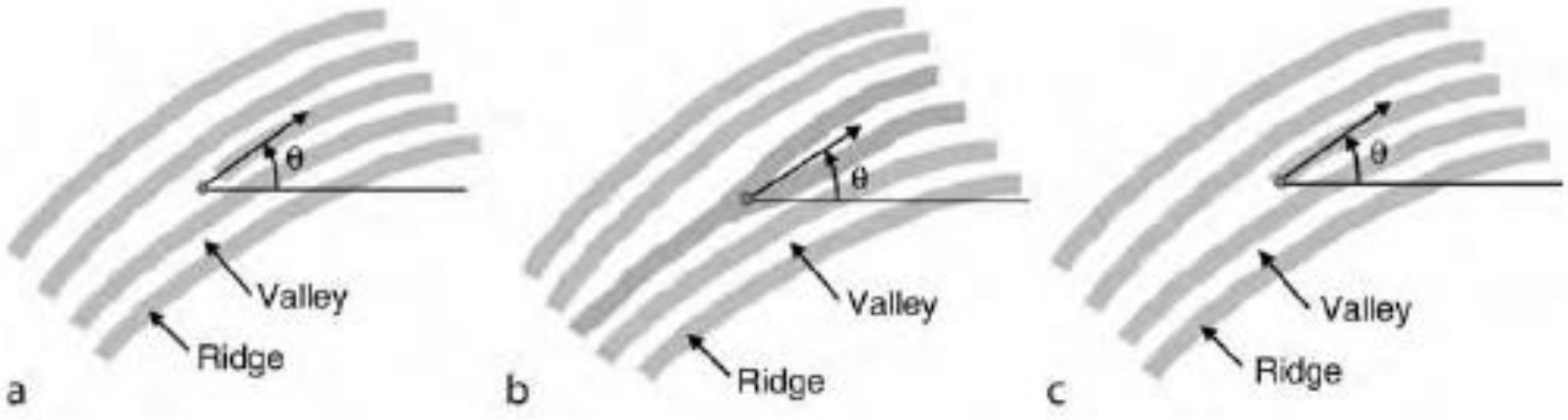


Figure 1.12. Fingerprint patterns as they appear at a coarse level: a) left loop; b) right loop; c) whorl; d) arch; and e) tented arch; squares denote loop-type singular points, and triangles delta-type singular points.

Features at local level (Level-2)

- A total of 150 different local ridge characteristics, called *minute details.*
- The two most prominent ridge characteristics, called *minutiae are: ridge termination* and *ridge bifurcation.*
- A ridge ending is defined as the ridge point where a ridge ends abruptly.
- A ridge bifurcation is defined as the ridge point where a ridge forks or diverges into branch ridges.

Features at local level



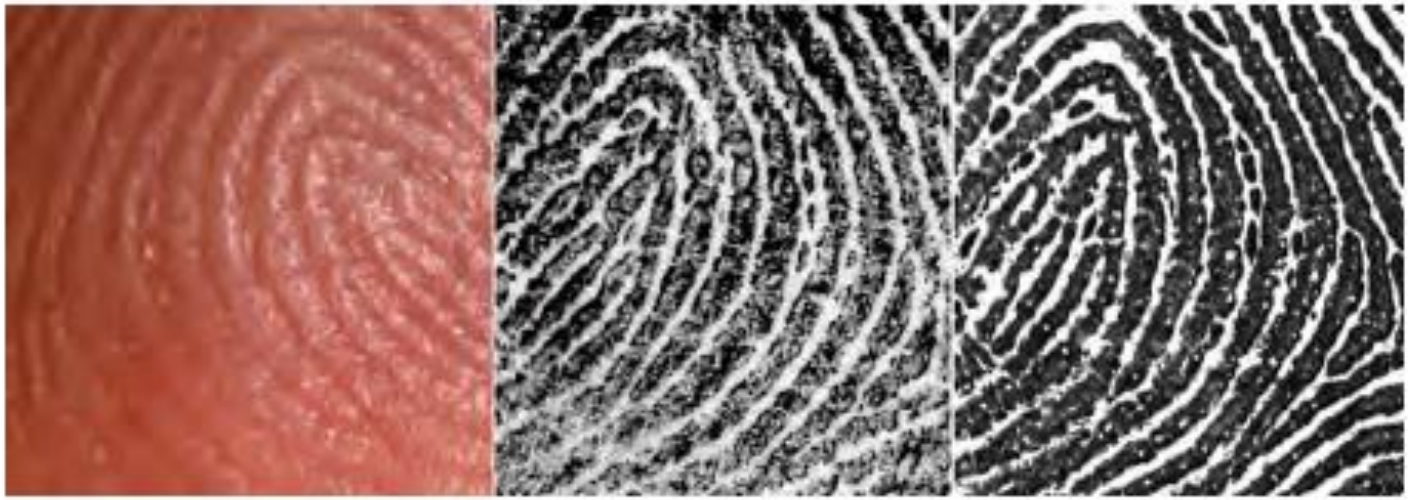
Level 3 Features

- At the very-fine level, intra-ridge details can be detected. These are essentially the finger *sweat pores whose position and shape are considered highly* distinctive.
- However, extracting pores is feasible only in high-resolution fingerprint images (e.g., 1000 dpi) of good quality and therefore this kind of representation is not practical for most applications.

Level 3 Features

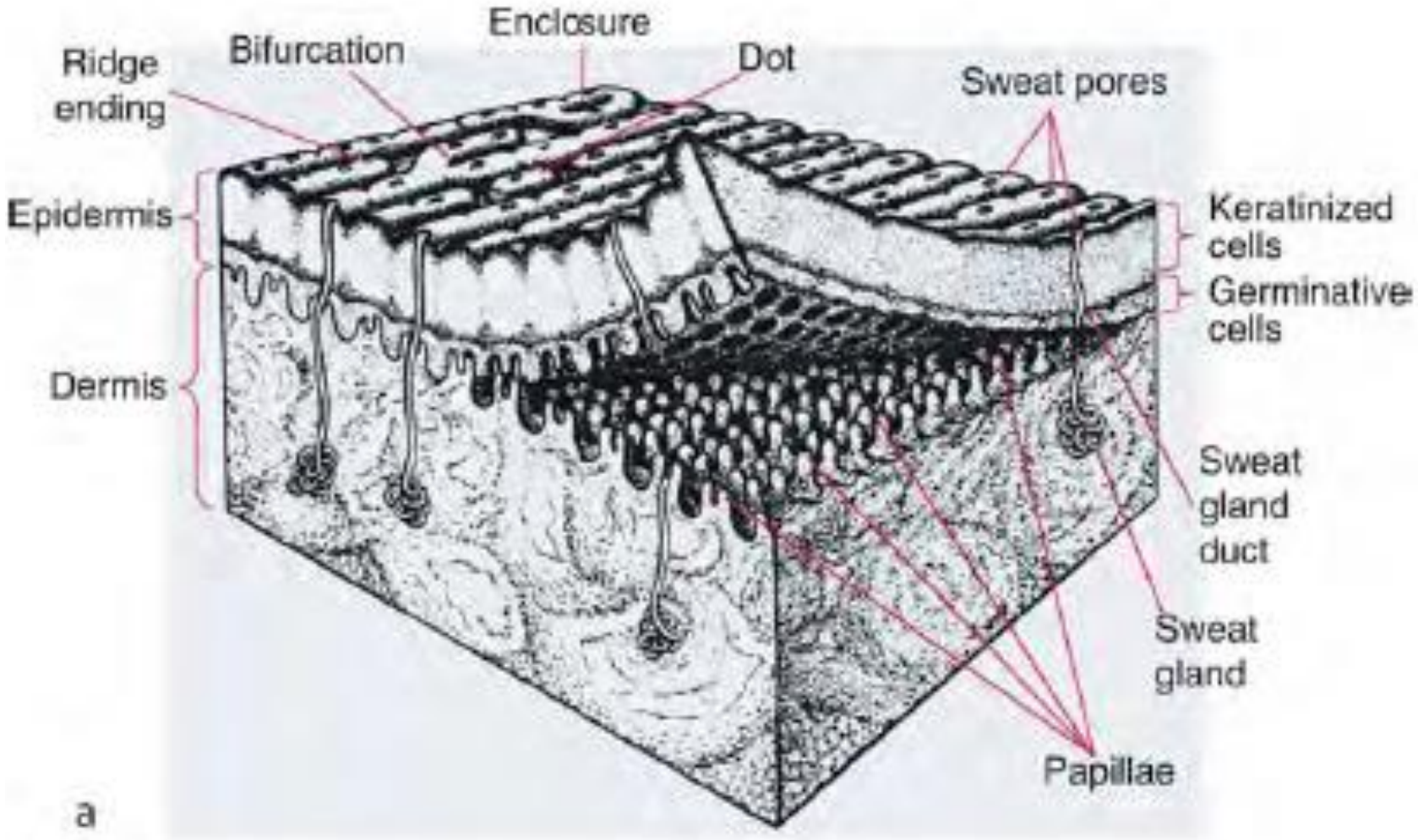
- Friction ridge skin is differentiated from thin skin not just by the presence of raised papillary ridges, but also by epidermis that is much thicker and structurally more complex, by increased sensory abilities, by the absence of hair, and by the absence of sebaceous glands.
- Skin throughout the body is composed of three basic layers: the hypodermis, dermis, and epidermis.

Level 3 Features



Anatomy of Friction Ridge Skin. Figure 2 Friction ridge skin with corresponding inked and optical live scan fingerprint impressions. Note the variation in appearance of details, especially the incipient ridges. The pores are clearly visible in the rightmost image.

Level 3 Features



Structure of friction ridge

Level 3 Features

Examples of friction ridge features

Level 3 Features

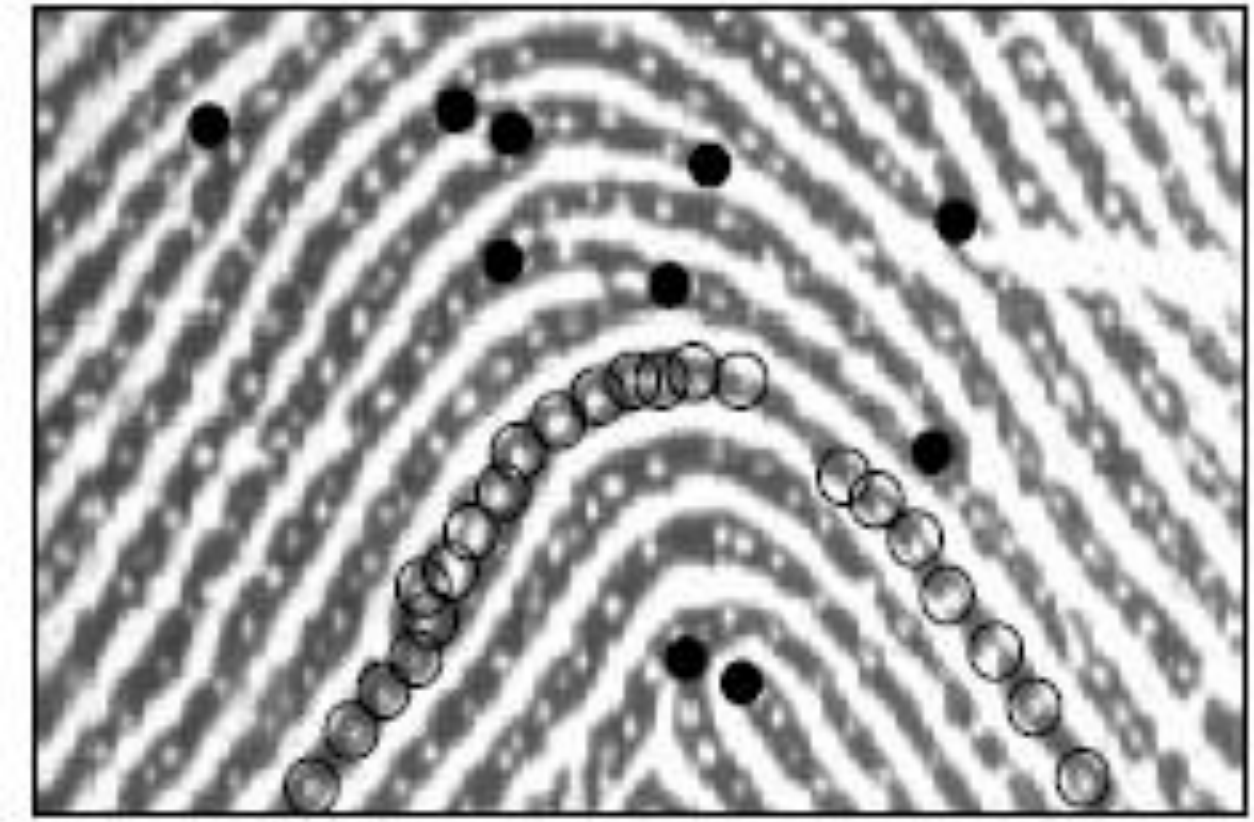


Figure: Sweat pores (empty circles) on ridge line

Template Creation

Biometric features are encoded into a template, a (proprietary or standards-conforming) compact digital representation of the essential features of the sample image. One common claim is that, since template creation is a one-way function, it is impossible or infeasible to regenerate the image from the templates; however, it has been shown that it is generally possible to regenerate versions of biometric sample images from templates.

Fingerprint Matching

- A matching algorithm compares the features extracted from the query with the stored templates in the database to produce scores that represent the (dis)similarity between the input and template.
- Matching must provide a decision, either in the form of validating a claimed identity or providing a ranking of the enrolled templates to perform identification.
- The biometric matching algorithms range from simple nearest neighbor algorithms, to sophisticated methods such as support vector machines.

Fingerprint Matching

- Thresholding techniques are used to decide if the distance of the claimed identity (in verification) or first rank (in identification) is sufficient for authentication.
- The main factors responsible for the intra-class variations are: displacement, rotation, partial overlap, non-linear distortion, variable pressure, changing skin condition, noise, and feature extraction errors.

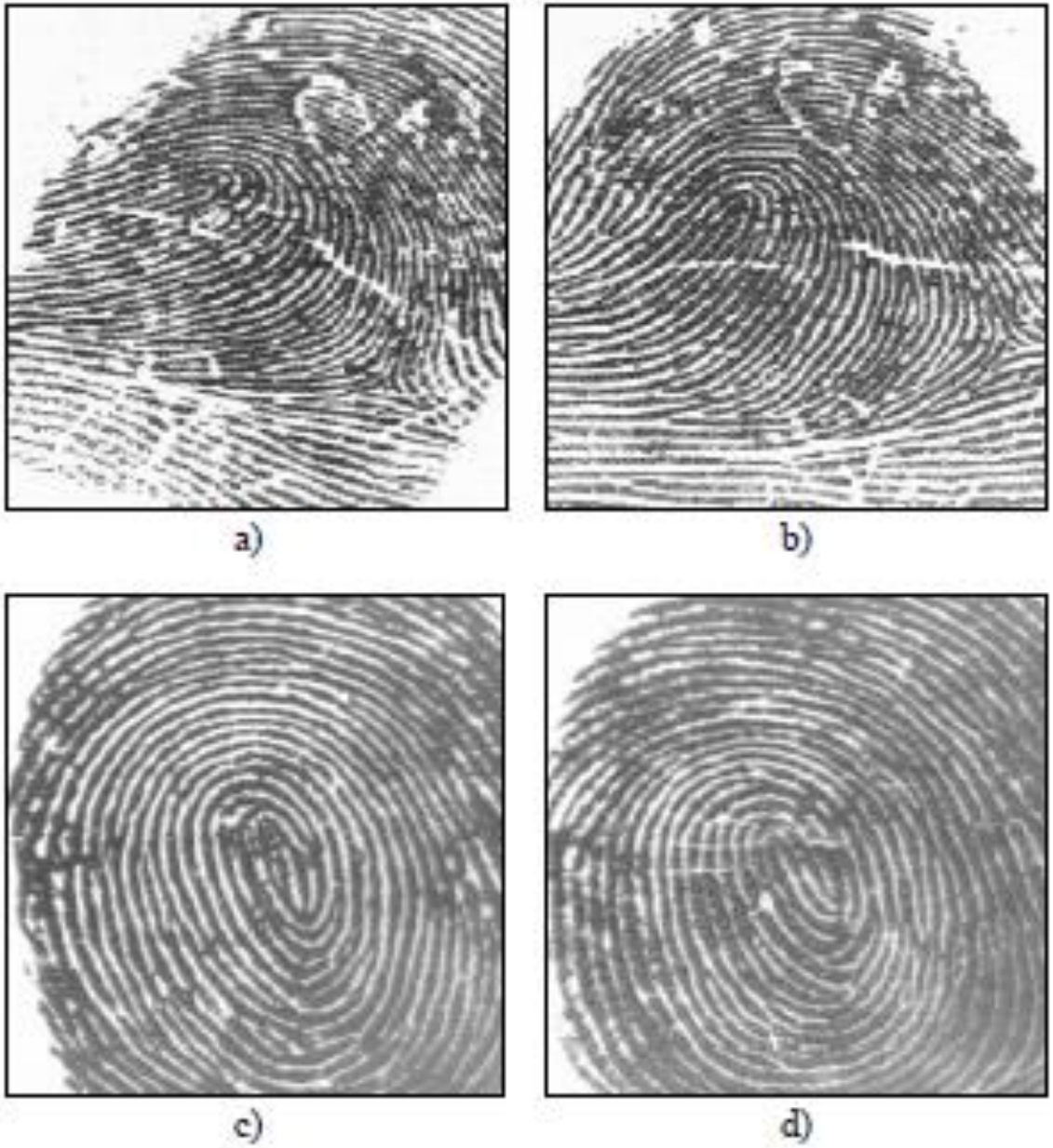


Figure 1.14. Difficulty in fingerprint matching. Fingerprint images in a) and b) look different to an untrained eye but they are impressions of the same finger. Fingerprint images in c) and d) look similar to an untrained eye but they are from different fingers.

Fingerprint Matching

- ***Correlation-based matching:*** *two fingerprint images are superimposed and the correlation* (at the intensity level) between corresponding pixels is computed for different alignments (e.g., various displacements and rotations);
- **M*inutiae-based matching:*** *minutiae are extracted from the two fingerprints and stored* as sets of points in the two-dimensional plane. Minutiae matching essentially consists of finding the alignment between the template and the input minutiae sets that results in the maximum number of minutiae pairings;

Fingerprint Matching

- **R*idge feature-based matching:***
  Minutiae extraction is difficult in very low-quality fingerprint images, whereas other features of the fingerprint ridge pattern (e.g., local orientation and frequency, ridge shape, texture information) may be extracted more reliably than minutiae, even though their distinctiveness is generally lower. The approaches belonging to this family compare fingerprints in term of features extracted from the ridge pattern.