

Tutorial 6

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COMP435p
Biometrics Authentication

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- Problem 1: Answer The Questions
- Problem 2: Singular Points
- Problem 3: Fingerprint Patterns
- Problem 4: Global and Local Fingerprint Features
- Problem 5: Minutiae Matching



Outline

1 Problems

- Problem 1: Answer The Questions
- Problem 2: Singular Points
- Problem 3: Fingerprint Patterns
- Problem 4: Global and Local Fingerprint Features
- Problem 5: Minutiae Matching



Problem 1.1 Two Stages

Understand two stages (Enrollment and Authentication) in a fingerprint system. (P6:11)



Problem 1.1 Two Stages

Biometrics Research Centre (BRC)

Enrollment stages

- **Image acquisition** : Inked based scanning & Live based scanning
- **Fingerprint extraction** : identifying and specifying small details found in finger images
- **Storing** : recording the result of extraction on the database



Authentication stages

- **Capture**
- **Extraction**
 - Preprocessing
 - Detect minutia
- **System search for similarities** (matching process)



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Problem 1.1 Two Stages

- Enrollment stage
 - Image acquisition
 - Fingerprint extraction
 - Storing
- Authentication stage
 - Capture
 - Extraction
 - Matching





Problem 1.2 Pre-processing

In the pre-processing stage, what should be done? (P7:14-16)



Problem 1.2 Pre-processing

Biometrics Research Centre (BRC)

System Overview: Pre-processing

- ◆ Important stage before feature extraction
- ◆ Poor quality of fingerprint images due to noise
- ◆ Enhancement, segmentation and thinning

Enhancement

- ◆ Noise removal
- ◆ Enhance quality of fingerprint image
- ◆ Low-pass filter, FFT-based technique, oriented filters

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Problem 1.2 Pre-processing

Biometrics Research Centre (BRC)

System Overview: Pre-processing

Segmentation

- ❑ Decomposition to foreground & background
- ❑ Foreground – fingertip image
- ❑ Background – Noisy area outside fingertip

Binarization & Thinning

- ❑ Binarization by a thresholding operation
- ❑ Thinning to reduce the width of ridge to a single pixel

Original Image	Binarized Image
Thinning Image	Line Extraction

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Problem 1.2 Pre-processing

Biometrics Research Centre (BRC)

Fingerprint Preprocessing

Fingerprint

The figure illustrates the three steps of fingerprint preprocessing:

- Original image:** A grayscale image showing a clear fingerprint pattern.
- Binary image:** A binary (black and white) representation of the fingerprint, where the ridges are solid black and the valleys are white.
- Thinning image:** A binary image where each ridge is reduced to a single, continuous black line, representing the skeleton of the fingerprint.

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Problem 1.2 Pre-processing

- Enhancement
 - Noise removal
 - Enhance quality of images
 - Low-pass filter, FFT-based technique, oriented filters
- Segmentation
 - Foreground
 - Background
- Binarization & Thinning
 - Binarization by a thresholding operation
 - Thinning to reduce the width of ridge to a single pixel





Problem 1.3 Fingerprint sensing

Understand the two primary methods for fingerprint sensing: inked and live scan and compare the different live-scan fingerprint technologies. (P7:19-25)



Problem 1.3 Fingerprint sensing

Biometrics Research Centre (BRC)

Fingerprint Sensing

□ Two primary methods: **inked** (off-line) and **live scan** (ink-less)

(a) an inked fingerprint image;
(b) a livescan fingerprint imaged from a optical sensor;
(c) rolled fingerprints are images depicting nail-to-nail area of a finger;
(d) fingerprints captured using solid state sensors;
(e) a latent fingerprint from a scene of crime.

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(a) belongs to inked, others belong to live-scan



Problem 1.3 Fingerprint sensing

Biometrics Research Centre (BRC)

Fingerprint Sensing

- ❑ An **inked fingerprint** image is typically acquired by a trained professional obtains an impression of an inked finger on a paper and the impression is then scanned using a flat bed document scanner.
- ❑ The **live scan fingerprint** is a collective term for a fingerprint image directly obtained from the finger without the intermediate step of getting an impression on a paper.
- ❑ The most popular live-scan fingerprint technology is based on optical frustrated total internal reflection (FTIR) concept.
- ❑ When a finger is placed on one side of a glass platen (prism), ridges of the finger are in contact with the platen, while the valleys of the finger are not in contact with the platen.

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Three main kinds.



Problem 1.3 Fingerprint sensing

Biometrics Research Centre (BRC)

Fingerprint Input Devices

The diagram illustrates two methods for fingerprint sensing:

CCD Device: A light source emits light that passes through a prism. The light reflects off a finger and is captured by an image pickup element.

VLSI Device: A cross-sectional diagram shows the skin surface with ridges and valleys. Below the skin is a sensor chip with capacitor plates. The distance from the skin surface to a valley is labeled "Distance to valley", and the distance to a ridge is labeled "Distance to ridge".

Leading methods in finger scan technologies:
Optical, Silicon and Ultrasound, Thermal, etc.

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Problem 1.3 Fingerprint sensing

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Optical Technology

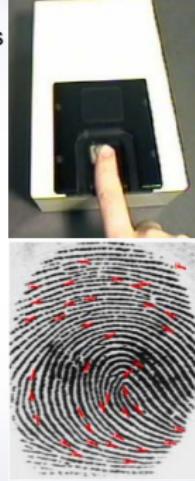
- User places finger on platen (glass)
- Camera acquired the image, where digitized ridges and valleys appear as black, gray and white lines
- Underlying software assesses fingerprint quality
- Generates template for enrollment or verification

Strengths

- Proven reliable over time
- Resistant to electrostatic discharge
- Fairly inexpensive
- Can provide resolutions up to 500 dpi (high-quality fingerprint images)

Weaknesses

- Platen size must have sufficient surface area and depth to capture quality images
- Tendency to show latent prints as actual fingerprints
- Susceptibility to fake fingers



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Problem 1.3 Fingerprint sensing

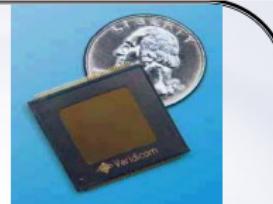
Biometrics Research Centre (BRC)

Silicon Technology

- Silicon chip is used as the platen
- Produces better image quality with less surface area than optical devices

Strengths

- High image quality (approaching that of the "better" optical devices)
- Modest size requirements (allowing technology to be integrated into small, lower power devices)
- Potentially lower cost (large number of platens can be manufactured from a single wafer)



Weaknesses

- Durability is subject to question
- Some silicon technology have been susceptible to electrostatic damage
- Performance in challenging conditions is unproven



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Problem 1.3 Fingerprint sensing

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Ultrasound Technology

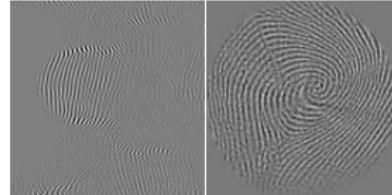
- Least frequently used of the three
- Considered the most accurate
- Ultrasonic beam is scanned across the fingerprint surface
- Echo signal is captured at the receiver
- Measures range, thus ridge depth

Strengths

- High quality fingerprint images
- Capable of penetrating dirt and residue

Weaknesses

- Larger acquisition device due to the machinery involved in ultrasound imaging



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Problem 1.3 Fingerprint sensing

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Fingerprint Sensors

The collage includes:

- A hand holding a black card with a blue sensor area, labeled www.idtek.com.
- A close-up of a green sensor chip integrated into a fingerprint pattern, labeled www.fingertip.de.
- A Siemens mobile phone with a fingerprint sensor on its keypad, labeled www.siemens.de.
- A hand holding a grey cylindrical device with a sensor, labeled www.tcs.thomson-csf.com.
- A small square sensor chip next to a coin, labeled www.veridicom.com.
- A hand using a computer mouse with a sensor, labeled www.elgentica.com.
- A hand holding a smartphone with a sensor, labeled www.cherrybiometric.com.
- A hand holding a keyboard with a sensor, labeled www.cherrybiometric.com.
- A hand holding a small blue device with a sensor, labeled www.tcs.thomson-csf.com.

Fingerprint

One Line Sensor

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Problem 1.4 Global and Local Features

Please understand the feature definitions in both P7:27-29 (Global feature) and P7: 34-35 (Local feature).



Problem 1.4 Global and Local Features

Biometrics Research Centre (BRC)

Global Feature Characteristics

A fingerprint is a pattern of flowing line structure consisting of ridges and valleys OR curving line structures (ridges) and skin with a higher profile than its surroundings (valleys)

- Pattern Area
- Core Point
- Type Lines
- Delta
- Ridge Count
- Basic Ridge Patterns
 - ◆ Loop
 - ◆ Arch
 - ◆ Whorl



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Global features.



Problem 1.4 Global and Local Features

Pattern Area

- ❑ Area of the fingerprint that contains all the global features
- ❑ Can be read and classified based on the information in the pattern area



Core Point

- ❑ Located at the approximate center of the finger impression
- ❑ Used as a referenced point for reading and classifying the print



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Problem 1.4 Global and Local Features

Biometrics Research Centre (BRC)

Type Lines

- Two innermost ridges that start parallel, diverge, and surround or tend to surround the pattern area



Delta

- It is a definite fixed point used to facilitate ridge counting and tracing



Ridge Count

- The number of ridges between the delta and the core

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Problem 1.4 Global and Local Features

Biometrics Research Centre (BRC)

Local Representation

- ❑ Major representations of the local information in fingerprints are based on **finger ridges**, pores on the ridges, or salient features derived from the ridges.
- ❑ The most widely used **local features** are based on minute details (**minutiae**) of the ridges. It forms a valid representation of the fingerprint.
- ❑ This representation is compact, and captures a significant component of individual information in fingerprints.
- ❑ Compared to other representations, **minutiae extraction is relatively more robust to various sources of fingerprint degradation.**



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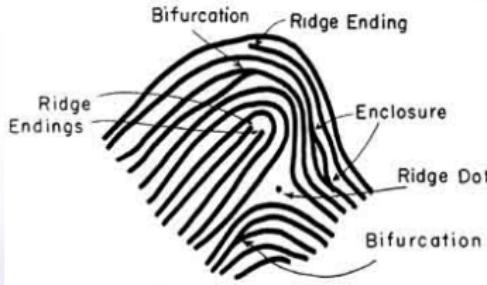


Problem 1.4 Global and Local Features

Biometrics Research Centre (BRC)

Local Feature Characteristics

- ❑ Known as minutia points which ridges end, fork and change
 - ❑ Tiny, unique characteristics of fingerprint ridges that are used for positive identification
 - ❑ Possible for one or more individuals to have identical global features but still have different and unique fingerprints because of the minutia points
- ❑ Types
- ◆ Ridge ending
 - ◆ Ridge bifurcation
 - ◆ Ridge divergence
 - ◆ Dot or Island
 - ◆ Enclosure
 - ◆ Short Ridge



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Local features.



Problem 1.4 Global and Local Features

- Global features

- Pattern Area
- Core Point
- Type Lines
- Delta
- Ridge Count
- Basic Ridge Patterns: Loop, Arch, Whorl

- Local features

- Ridge ending
- Ridge bifurcation
- Ridge divergence
- Dot or island
- Enclosure
- Short ridge





Problem 1.5 Matching Strategies

*How many strategies can be used for fingerprint matching?
Please compare their difference. (P7:49-52)*



Problem 1.5 Matching Strategies

Biometrics Research Centre (BRC)

Matching Strategies

- A number of strategies have been employed in the literature to solve the alignment problem.
- Typically, it is assumed that the alignment of the test and template fingerprints involve an overall displacement (translation) and rotation.
- The scale variations, shear transformations, local elastic deformations are often overlooked in the alignment stage.
- In **image based representations**, the alignment of the prints may be obtained by optimizing their image correlation.
- In **ridge representations** of the fingerprints, portions of ridges may be used to align the prints
- In **minutiae based representations**, typically, the alignment process uses predominantly minutia positions; minutia angles are not significantly involved because they are vulnerable to image noise/distortion.

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Three kinds of matching strategies based on three different representation of the fingerprint.



Problem 1.5 Matching Strategies

Matching Strategies

- ❑ In image based representation, the correlation coefficient generated during the alignment can serve as a matching score.
- ❑ The elastic deformation, shear transformation, and scale variations may impose severe limitations on the utility of image correlation and image based representations.
- ❑ In an *elastic* minutia based matching, the test minutia are searched in a square region centered (bounding box) around each template minutia in the aligned representation.
- ❑ The elastic matchers account for small local elastic deformations.

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Problem 1.5 Matching Strategies

Biometrics Research Centre (BRC)

Matching Strategies

- There are several approaches to converting minutia correspondence information to a matching score. One straightforward approach for computing the score S is:

$$S = \frac{100 M_{PQ} M_{PQ}}{M_P M_Q} \quad (1)$$

where M_{PQ} is the number of corresponding minutiae and M_P, M_Q , are the total number of minutiae in template and test fingerprints.

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a Simple way to compute the matching score



Problem 1.5 Matching Strategies

Biometrics Research Centre (BRC)

Matching Strategies

- In some matchers, the total number of minutiae (M_P and M_Q in Eq. (1)) is not used. After the correspondence is determined, an *overall* bounding box only for corresponding test and template minutia is computed. The matching score S_B is then computed as:

$$S_B = \frac{100 M_{PQ} M_{PQ}}{M_{Pb} M_{Qb}} \quad (2)$$

where M_{PQ} is the number of corresponding minutiae and M_{Pb} , M_{Qb} are the number of minutia in the overall bounding boxes computed for template and test fingerprints, respectively.

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a General way to compute the matching score





Outline

1 Problems

- Problem 1: Answer The Questions
- **Problem 2: Singular Points**
- Problem 3: Fingerprint Patterns
- Problem 4: Global and Local Fingerprint Features
- Problem 5: Minutiae Matching



Problem 2: Singular Points

Singular points consist of Core point and Delta point. In P7:30 we can use the directional map to find them (one Core point and two Delta points). Please think about how to make an algorithm to do so.



Problem 2: Singular Points

Biometrics Research Centre (BRC)

Fingerprint Singular Points (Core/Delta) Extraction

Original image Direction image

(1: Core point; 2: Delta point)

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Problem 2: Singular Points

- ① Find the most compact circle of the point
 - ② Turn the direction value around the circle into direction vectors
 - ③ sum up all the direction vectors^a ^b
 - ④ The sum of core points and delta points should be almost zero.
- .

^aKalle Karu, Anil K. Jain, Fingerprint classification, Pattern Recognition, Volume 29, Issue 3, March 1996, Pages 389-404, ISSN 0031-3203, 10.1016/0031-3203(95)00106-9.

^bThien Hoang Van; Hoang Thai Le; , "An Efficient Algorithm for Fingerprint Reference-Point Detection," Computing and Communication Technologies, 2009. RIVF '09. International Conference on , vol., no., pp.1-7, 13-17 July 2009



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Problem 3: Fingerprint Patterns

In P7:33 six major classes of the overall fingerprint patterns are given. Please compare them and try to classify the other all fingerprint samples in P7:3, 8-9, 12, 14-19, 24, 27, 31.

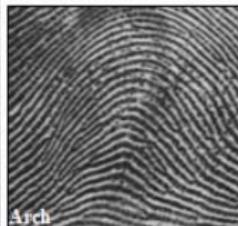


Problem 3: Fingerprint Patterns

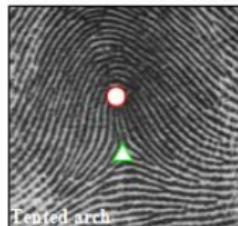
Biometrics Research Centre (BRC)

Fingerprint Classification

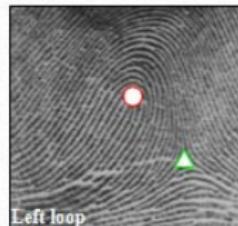
- One of the significant global features used for fingerprints is its class or type. The overall fingerprint pattern is typically categorized as six major classes



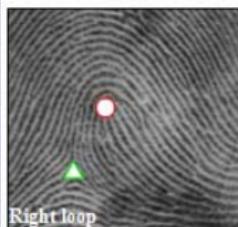
Arch



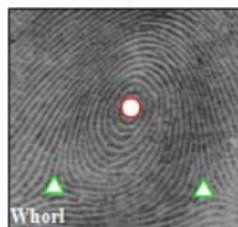
Tented arch



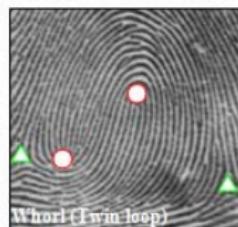
Left loop



Right loop



Whorl



Whorl (Twin loop)

Arch, Tented arch, Left loop, Right loop, Whorl, Whorl(Twin loop)



Problem 3: Fingerprint Patterns

Biometrics Research Centre (BRC)

Why Fingerprint?

- ❑ Fingerprint identification
 - ◆ a trustworthy means of personal identification
 - ◆ cannot be stolen, duplicated, shared
 - ◆ other personal characteristics change but fingerprint do not
- ❑ Best known biometric technology
- ❑ Used as a method of identification for over 100 years
- ❑ Huge databases are now available for instant searches



Lecture 7 - 3 -

Whorl



Problem 3: Fingerprint Patterns

Biometrics Research Centre (BRC)

Fingerprint Images: Different Resolution

The figure displays four fingerprint images side-by-side, each labeled with its source and resolution:

- A rolled inked fingerprint**: Shows a thumbprint with the label "6. L. THUMB" and a small number "7" at the bottom right.
- Digital Biometrics sensor (508x480)**: Shows a high-resolution circular fingerprint pattern.
- Fidelica sensor (256x256)**: Shows a low-resolution circular fingerprint pattern.
- Veridicom sensor (300x300)**: Shows a medium-resolution circular fingerprint pattern.

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Left loop, Whorl, Whorl, Whorl



Problem 3: Fingerprint Patterns

Biometrics Research Centre (BRC)

Fingerprint Images

(a) High quality (b) Poor quality

Different Quality

Inked image on-line image

Different Capture

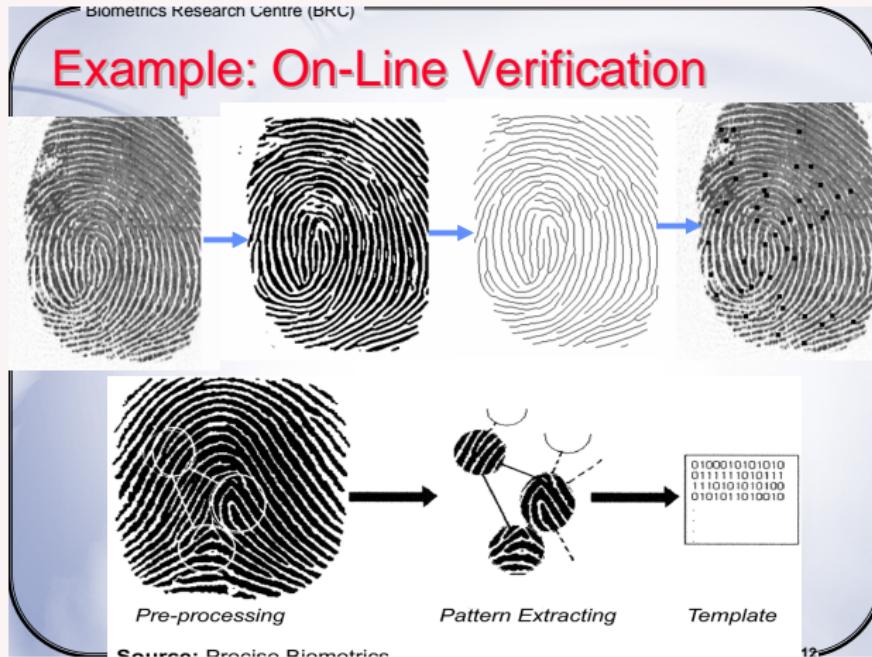
Lecture 7 - 9

The slide shows two rows of fingerprint images. The top row, labeled '(a) High quality' and '(b) Poor quality', demonstrates the effect of image quality on fingerprint visibility. The bottom row, labeled 'Inked image' and 'on-line image', shows the difference in appearance between a physical inked print and a digital scan. The slide is framed by a thick black border.

Whorl, Arch, Whorl, Right loop



Problem 3: Fingerprint Patterns



Whorl, Tented arch



Problem 3: Fingerprint Patterns

Biometrics Research Centre (BRC)

System Overview: Pre-processing

- ◆ Important stage before feature extraction
- ◆ Poor quality of fingerprint images due to noise
- ◆ Enhancement, segmentation and thinning

Enhancement

- ◆ Noise removal
- ◆ Enhance quality of fingerprint image
- ◆ Low-pass filter, FFT-based technique, oriented filters

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Left loop



Problem 3: Fingerprint Patterns

Biometrics Research Centre (BRC)

System Overview: Pre-processing

Segmentation

- ❑ Decomposition to foreground & background
- ❑ Foreground – fingertip image
- ❑ Background – Noisy area outside fingertip

Binarization & Thinning

- ❑ Binarization by a thresholding operation
- ❑ Thinning to reduce the width of ridge to a single pixel

Original Image	Binarized Image
Thinning Image	Line Extraction

Lecture 7 - 15

Arch



Problem 3: Fingerprint Patterns

Biometrics Research Centre (BRC)

Fingerprint Preprocessing

Fingerprint

The diagram shows three stages of fingerprint processing:

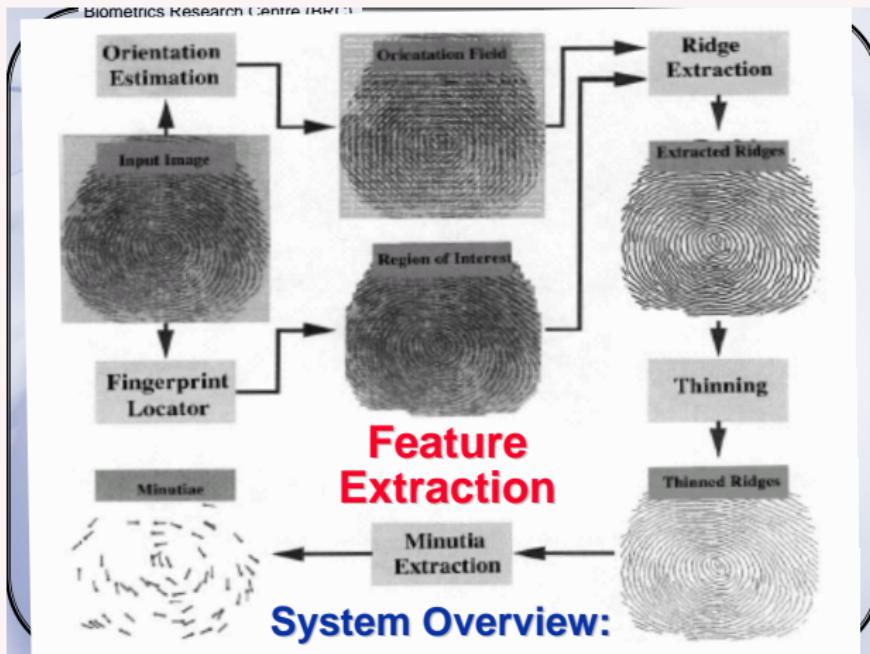
- Original image:** A grayscale image of a whorl fingerprint.
- Binary image:** A binary (black and white) representation of the same fingerprint, where the ridges are solid black and the valleys are white.
- Thinning image:** A binary image where the ridges have been reduced to a single pixel width, creating a skeletal representation of the fingerprint.

Lecture 7 - 16

Whorl



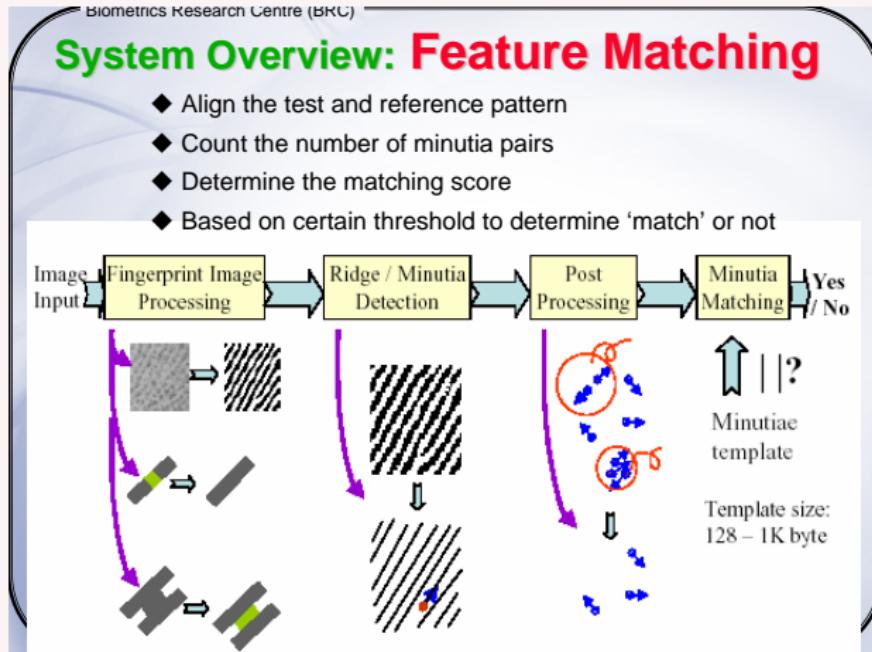
Problem 3: Fingerprint Patterns



Whorl



Problem 3: Fingerprint Patterns



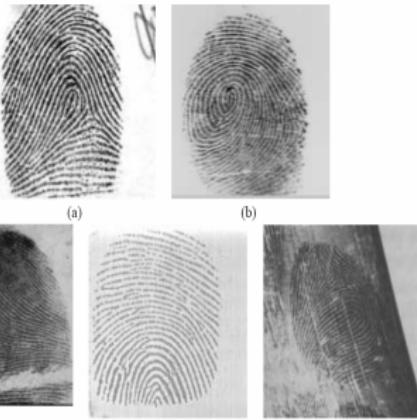


Problem 3: Fingerprint Patterns

Biometrics Research Centre (BRC)

Fingerprint Sensing

□ Two primary methods: **inked** (off-line) and **live scan** (ink-less)



(a) an inked fingerprint image;
(b) a livescan fingerprint imaged from a optical sensor;
(c) rolled fingerprints are images depicting nail-to-nail area of a finger;
(d) fingerprints captured using solid state sensors;
(e) a latent fingerprint from a scene of crime.

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Left loop, Whorl, Right loop, Whorl, Whorl(Twin loop)



Problem 3: Fingerprint Patterns

Biometrics Research Centre (BRC)

Ultrasound Technology

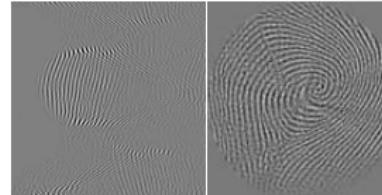
- Least frequently used of the three
- Considered the most accurate
- Ultrasonic beam is scanned across the fingerprint surface
- Echo signal is captured at the receiver
- Measures range, thus ridge depth

Strengths

- High quality fingerprint images
- Capable of penetrating dirt and residue

Weaknesses

- Larger acquisition device due to the machinery involved in ultrasound imaging



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Whorl, Whorl



Problem 3: Fingerprint Patterns

Biometrics Research Centre (BRC)

Global Feature Characteristics

A fingerprint is a pattern of flowing line structure consisting of ridges and valleys OR curving line structures (ridges) and skin with a higher profile than its surroundings (valleys)

- Pattern Area
- Core Point
- Type Lines
- Delta
- Ridge Count
- Basic Ridge Patterns
 - ◆ Loop
 - ◆ Arch
 - ◆ Whorl



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Whorl



Problem 3: Fingerprint Patterns

Basic Ridge Patterns

Arch – ridges enter from one side, rise to a ridge in the center and exit out the opposite side (has no delta)



ARCH



ARCHES

Loop – one or more ridges make a loop and then exit the same side they entered (has only one delta)



WHORL

Whorl – at least one ridge makes a 360 degree circle in the center of the print (has two deltas)

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Arch, Left loop, Whorl





Outline

1 Problems

- Problem 1: Answer The Questions
- Problem 2: Singular Points
- Problem 3: Fingerprint Patterns
- **Problem 4: Global and Local Fingerprint Features**
- Problem 5: Minutiae Matching



Problem 4: Global and Local Fingerprint Features

Which features are used as global and local features, respectively? Could you find them in the given fingerprint image (P7:35)?



Problem 4: Global and Local Fingerprint Features

- Global features

- Pattern Area
- Core Point
- Type Lines
- Delta
- Ridge Count
- Basic Ridge Patterns: Loop, Arch, Whorl

- Local features

- Ridge ending
- Ridge bifurcation
- Ridge divergence
- Dot or island
- Enclosure
- Short ridge



Problem 4: Global and Local Fingerprint Features

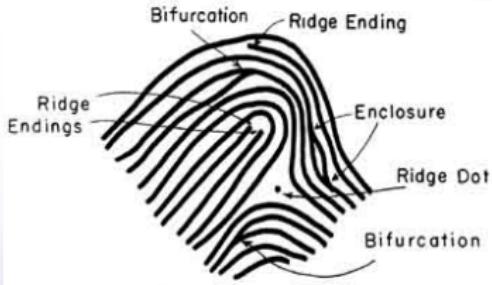
Biometrics Research Centre (BRC)

Local Feature Characteristics

- ❑ Known as minutia points which ridges end, fork and change
- ❑ Tiny, unique characteristics of fingerprint ridges that are used for positive identification
- ❑ Possible for one or more individuals to have identical global features but still have different and unique fingerprints because of the minutia points

❑ Types

- ◆ Ridge ending
- ◆ Ridge bifurcation
- ◆ Ridge divergence
- ◆ Dot or Island
- ◆ Enclosure
- ◆ Short Ridge



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(Left Loop, Delta point: 1 Bifurcation: 4 and Ending: 3)





Outline

1 Problems

- Problem 1: Answer The Questions
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- **Problem 5: Minutiae Matching**



Problem 5: Minutiae Matching

Please check the Minutiae matching in P7:46 and compute the matching score according to the Eq.(1) in P7:51.



Problem 5: Minutiae Matching

Biometrics Research Centre (BRC)

Matching Strategies

- There are several approaches to converting minutia correspondence information to a matching score. One straightforward approach for computing the score S is:

$$S = \frac{100 M_{PQ} M_{PQ}}{M_P M_Q} \quad (1)$$

where M_{PQ} is the number of corresponding minutiae and M_P, M_Q , are the total number of minutia in template and test fingerprints.

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Problem 5: Minutiae Matching

Biometrics Research Centre (BRC)

Matching Methods

Two different impressions of the same finger using a Digital Biometrics scanner.

Direct matching

Minutiae matching

For minutiae matching: Relative configuration of ridge endings and branching between two impressions of the same finger.

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$$S = \frac{100M_{PQ}M_{PO}}{M_P M_Q} = \frac{100 \times 8 \times 8}{14 \times 17} = 26.9$$



Q & A

Any questions?