Homework 2

CSE 402: Biometrics and Pattern Recognition Instructor: Dr. Arun Ross

Due Date: October 17, 2022 (11:00 pm)

Total Points: 60

Note:

- **You are permitted to discuss the following questions with others in the class.**
- **However, you *must* write up your *own* answers to these questions. Any indication to the contrary will be considered an act of academic dishonesty.**
- **A neatly typed report with detailed answers is expected. The report must be uploaded in D2L in PDF format.**
- **All outputs, such as graphs and images, must be included in the report.**
- **Any code developed as part of the assignment must be (a) included as an appendix in the report, as well as (b) archived in a single zip file and uploaded in D2L.**
- **Include a bibliography at the end of the report indicating the resources that you used (e.g., URL, scientific articles, books, etc.) to complete this homework.**
- **Please submit the report (PDF) and the code (Zip file) as two separate files in D2L.**

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1. [10 points] Consider a scenario wherein a fingerprint-based biometric system is installed in a grocery store in East Lansing. Assume that shoppers have the option of enrolling into the system. This would allow them to render payment at the checkout register by merely placing their index finger on a fingerprint sensor and typing in a 4-digit PIN. After successfully verifying the shopper's identity, the system would then connect to their bank account and debit the amount of the purchase. Based on the terminology developed in class, explain how you would characterize this biometric system (see Section 1.5.1 in the textbook). You must justify your answer with a **detailed** explanation.

Ans) The characteristics of this biometric system are as follows:

I. **Cooperative users:** Cooperation refers to the behavior of the user when interacting with the system. In the given system the genuine users need to cooperate with the system to be accepted as a valid user.

II. **Overt deployment:** If the user is aware that he is being subjected to biometric recognition, the application is categorized as overt. In the given system the users have the option to enroll in the biometric system making them aware that they are subjected to biometric recognition.

III. **Habituated users:** If the enrolled users interact with the biometric system quite frequently, they tend to get habituated in providing their biometric data. In the given system the users must access the system quite frequently since there will be numerous numbers of repeated shoppers every day and as they start to use this system, they will get habituated to it.

IV. **Attended enrollment & Unattended operation:** In the given system at the time of enrollment there are supervisors to help you get to know about the system and assist you in using it but, afterwards there will be many people at the billing counter and the supervisors can't help everyone. So, in this case habituated users use the system without any supervision making it an unattended operation.

V. **Controlled operation:** In a controlled environment, ambient environmental conditions such as temperature, pressure, moisture, lighting conditions, etc. The given system is installed in a grocery store which is an indoor setting, so all the ambient environmental conditions are maintained making the biometric system a controlled operation.

VI. **Closed system:** There is no collection of biometric template or use of these templates across multiple platforms in this system.

2. [10 points] (a) What is the main difference between closed-set identification and open-set identification? (b) Consider a watch-list application in an airport where a passenger's biometric data is used to determine if they are present in a watch-list or not. Is this an example of open-set or closed-set identification? Justify your answer.

Ans)

a) The main difference between an open-set identification and a closed-set identification is that in an open set the database may or may not have the correct identity of the probe whereas in closed-set identification the database contains the correct identity of the probe.

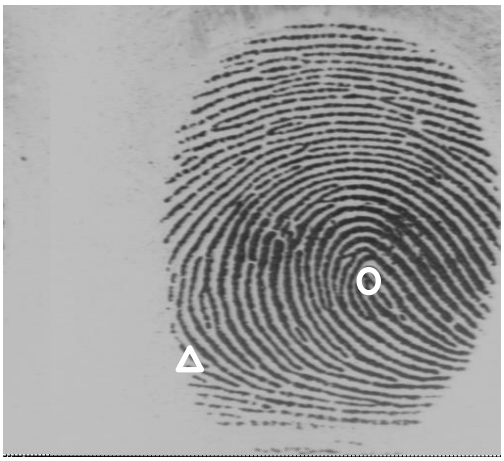
b) The watch-list application in an airport is an example of open-set identification because in an open-set identification a biometric sample of a passenger is compared with the database and if it matches with another identity then only the result is given so, basically it means that the identification process must confirm that the given biometric sample exists in the database.

3. [10 points] A set of 10 fingerprint images may be accessed here. Based on visual examination, determine the class of each of the 10 fingerprints. **Justify your answer.** (For each fingerprint, include the image along with a clear annotation explaining how the class was determined.)

Ans) O: Loop

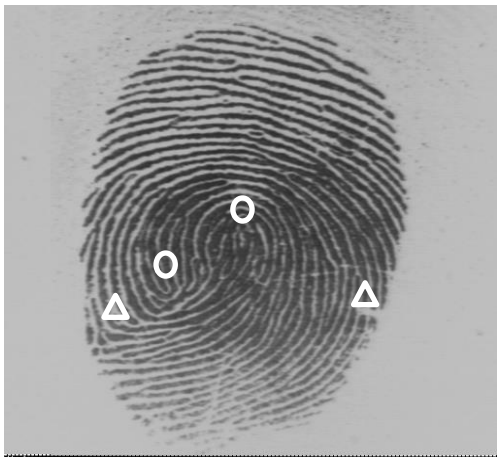
Δ: Delta

user001



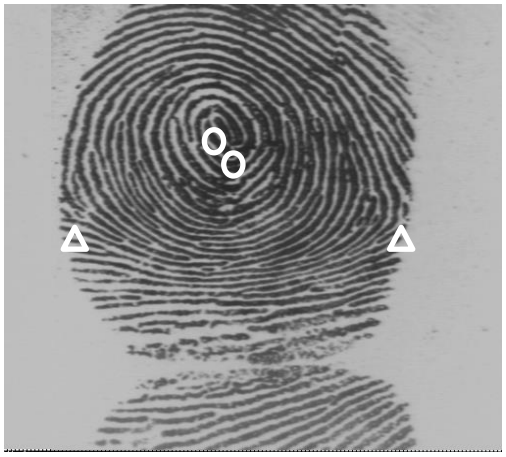
The classification of the above fingerprint is a right loop because it has one loop towards the right side of the delta (which is in the left side).

user002



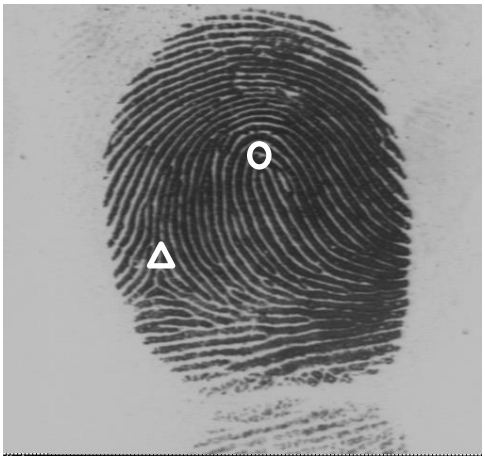
The classification of the above fingerprint is a twin loop because it contains two loops and deltas and ridge orientation field around the loops is not in a circular orbit.

user003



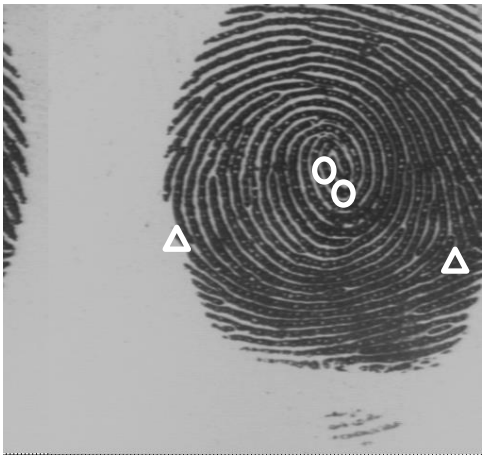
The classification of the above fingerprint is a whorl because it contains two loops in the center and two deltas one to the left and the other to the right and the ridge orientation field around the loops is in a circular orbit.

user004



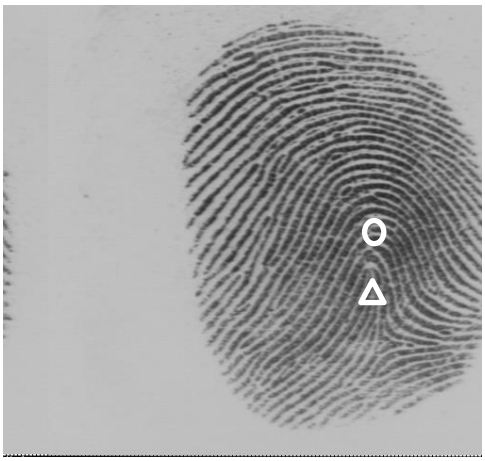
The classification of the above fingerprint is a right loop because it has one loop towards the right side of the delta (which is on the left side).

user005



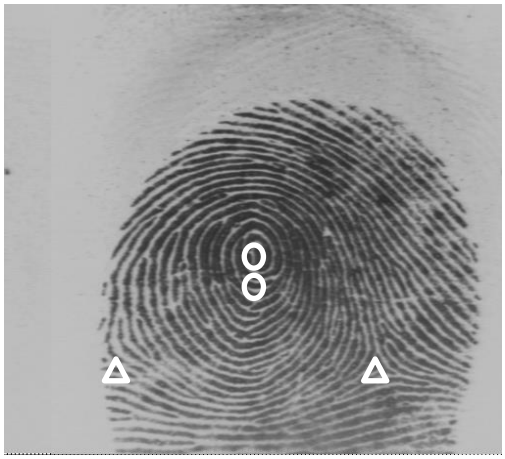
The classification of the above fingerprint is a whorl because it contains two loops in the center and two deltas one to the left and the other to the right and the ridge orientation field around the loops is in a circular orbit.

user006



The classification of the above fingerprint is a tented arch because it has one loop directed towards delta.

user007



The classification of the above fingerprint is a whorl because it contains two loops in the center and two deltas one to the left and the other to the right and the ridge orientation field around the loops is in a circular orbit.

user008

The classification of the above fingerprint is plain arch because it has zero singular points which means there are no loops and deltas.

user009

The classification of the above fingerprint is a tented arch because it has one loop directed towards delta.

user010

The classification of the above fingerprint is a left loop because it has one loop towards the left side of the delta (which is on the right side).

4. [10 points] Briefly describe the following terms: (a) Latent Fingerprints; (b) Volar Pads; (c) Orientation Field; (d) Level 3 Features; (e) Delta

Ans)

a) Latent Fingerprints:

- The partial fingerprints found at a crime scene are called latent prints.
- When compared to rolled and plain fingerprints latent fingerprints have poor image quality.
- Latent fingerprints when extracted from a surface have less minutiae points when compared to other types of fingerprints.
- They have very small finger area.

b) Volar Pads:

- They are fingerprints that are formed in the sixth week of fetal development.
- The central or pattern area of the finger is governed by the shape, size, and placement of the volar pads:

1. higher and symmetric volar pads tend to generate whorls.
2. flatter and symmetric volar pads tend to generate arches.
3. asymmetric volar pads tend to generate loops.

c) Orientation Field:

- At the first (coarsest) level, a fingerprint is represented as a ridge orientation map.
- The fingerprint orientation in the ridge orientation map is known as Orientation field.
- This ridge orientation map records the local ridge orientation at each location of the fingerprint, and a ridge frequency map.
- This ridge frequency map records the local ridge frequency at each location in the fingerprint.
- Ridge orientation is defined in the range $[0,\Pi)$.
- A ridge orientation map typically contains some salient locations where the ridges orientations change abruptly – such. Locations are termed as singular points.

d) Level 3 Features:

- In level 3 (finest level) a fingerprint is represented using both the inner holes which are also known as sweat pores and outer contours known as edges of the ridges.
- These ridges contain information which is observed in detail.
- Incipient ridges belong to immature ridges, which are thinner when compared to mature ridges and these type ridges don't contain any sweat pores.
- A sensor with 1000ppi scanning capability is required to measure the level 3 details in a fingerprint.
- Level 3 features play an important role in matching latent fingerprints.

e) Delta:

- In a ridge orientation map, there are certain locations where the ridge orientations change abruptly these locations are known as singular points which are of two types of singular points-loop and delta.
- At a delta-type singularity location the three ridge systems appear to meet.
- The number of delta points and number of loops help in determining orientation map.

5. [10 points] According to the article *Fingerprint MATCHING* by Jain et al., describe some of the challenges that exist in fingerprint recognition. **You must explain each challenge in detail.**

Ans) **New sensors**:

The physical shape of the fingers makes it difficult to obtain a complete fingerprint pattern using touch-based sensors this is the reason behind taking multiple impressions of the same finger to get good quality images in law enforcement offices. Since it is a touch-based sensor it directly measures the finger surface. These touch-base sensors face difficulty when the biometric sample is tampered by external sources.

Small overlapping area and nonlinear distortion:

Fingerprint sensors that are installed in mobile phones, laptops, and another consumer electronic devices have a very smaller area to place fingers to scan them. This factor combined with user's improper placement of the finger on the fingerprint scanner results in overlapping of the impressions of the same finger. Which makes it difficult to tell if the two fingerprints are from the same finger.

Latent fingerprints:

These types of fingerprints usually are of low image quality, small overlapping area and nonlinear distortion they also contain the presence of a complex background.

Altered/fake fingerprints:

Some people try to alter their fingerprints to imitate another person's fingerprints this can happen for many reasons like to get access to a mobile phone or a computer or a locker or even entry into some confidential places.

Interoperability:

You might encounter interoperability in all the three major sections of a fingerprint recognition system: sensor, feature extractor, and matcher. Multiple different sensors can output images in multiple different variations in terms of resolution, size, background noise, etc. When it comes to encoders this mechanism can also extract different features or adopt varying definitions of the same feature. This diversity makes it difficult to build a fingerprint system with principal components sourced from different vendors.

System on device:

One of most important security issue in fingerprint recognition systems is tampering or modifying of the hardware or software systems and intercept the fingerprint data passing through communication channels.

Template security:

Fingerprints templates that are collected legally by law need to be stored in large enrollment databases. Any unauthorized user who gets access to this data can reverse engineer it and construct a fake fingerprint and other major issue is the unauthorized user can crossmatch across different databases to covertly track people without their consent, thereby compromising their privacy. These fingerprint templates can't be revoked like passwords or ID cards.

6. [10 points] Collect a few fingerprint images using your smartphone *CAMERA* for this problem.

a) Use any image editing program (e.g., PhotoShop, Gimp, Matlab, etc.) to manually crop out and obtain one image each of the following 8 fingers: left and right index fingers, left and right middle

fingers, left and right ring fingers, and left and right pinky fingers.

Ans) **Left hand fingers**:

Right Hand fingers:

b) Use any image editing program to improve the “quality" of each image so that the ridges and valleys are clearly discernible (e.g., you can perform histogram equalization, change image contrast and brightness, apply gamma correction, etc.). Note: You do not have to write a program to enhance quality - the adjustment can be done using existing image editing tools. But you are also allowed to write a program to improve the quality.

Ans) **<u>Left Hand fingerprints</u>**:

Right Hand fingerprints:

c) What type of image processing operations did you conduct to improve the quality of each image?

Ans)

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
```

```
img_left_index_fingerprint = cv2.imread('IMG_LIF.jpg',0)
img_left_middle_fingerprint = cv2.imread('IMG_LMF.jpg',0)
img_left_ring_fingerprint = cv2.imread('IMG_LRF.jpg',0)
img_left_pinky_fingerprint = cv2.imread('IMG_LPF.jpg',0)
img_right_index_fingerprint = cv2.imread('IMG_RIF.jpg',0)
img_right_middle_fingerprint = cv2.imread('IMG_RMF.jpg',0)
img_right_ring_fingerprint = cv2.imread('IMG_RRF.jpg',0)
img_right_pinky_fingerprint = cv2.imread('IMG_RPF.jpg',0)

gamma_enhancements_1 = np.array(255*(img_left_index_fingerprint/255)**2.2, dtype = 'uint8')
gamma_enhancements_2 = np.array(255*(img_left_middle_fingerprint/255)**2.2, dtype = 'uint8')
gamma_enhancements_3 = np.array(255*(img_left_ring_fingerprint/255)**2.2, dtype = 'uint8')
gamma_enhancements_4 = np.array(255*(img_left_pinky_fingerprint/255)**2.2, dtype = 'uint8')
gamma_enhancements_5 = np.array(255*(img_right_index_fingerprint/255)**1.2, dtype = 'uint8')
gamma_enhancements_6 = np.array(255*(img_right_middle_fingerprint/255)**1.2, dtype = 'uint8')
gamma_enhancements_7 = np.array(255*(img_right_ring_fingerprint/255)**1.2, dtype = 'uint8')
gamma_enhancements_8 = np.array(255*(img_right_pinky_fingerprint/255)**1.2, dtype = 'uint8')

cv2.imshow('img_left_index_fingerprint', gamma_enhancements_1)
cv2.imshow('img_left_middle_fingerprint', gamma_enhancements_2)
cv2.imshow('img_left_ring_fingerprint', gamma_enhancements_3)
cv2.imshow('img_left_pinky_fingerprint', gamma_enhancements_4)

cv2.imshow('img_right_index_fingerprint', gamma_enhancements_5)
cv2.imshow('img_right_middle_fingerprint', gamma_enhancements_6)
cv2.imshow('img_right_ring_fingerprint', gamma_enhancements_7)
cv2.imshow('img_right_pinky_fingerprint', gamma_enhancements_8)


cv2.waitKey(0)
```

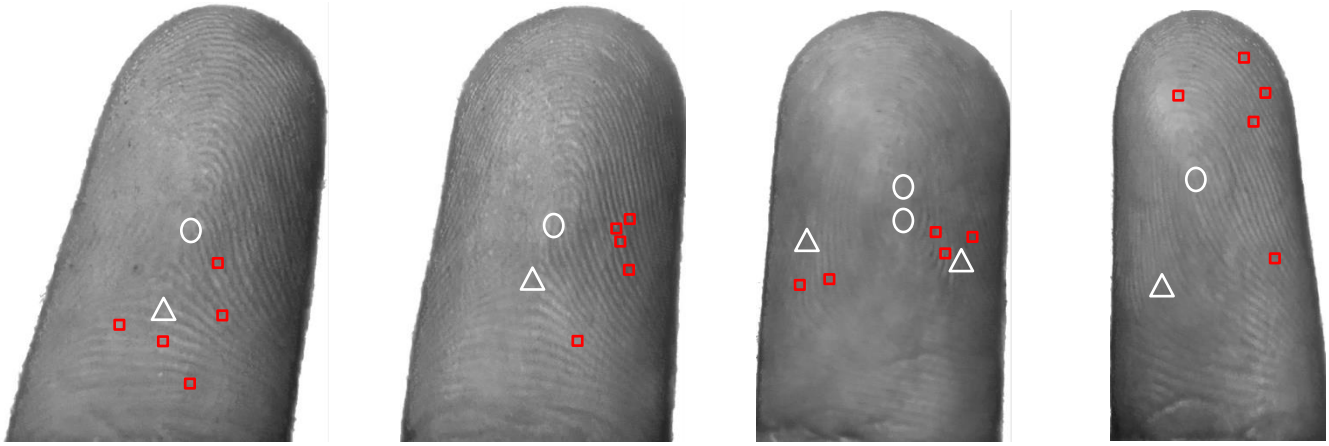
d) Manually mark at least 5 minutiae points in each of the 8 processed images. Also, mark the core and delta points if present. Include these images along with the marked points in your report.

Ans) ▫ : Minutiae points (ridge endings and bifurcations)

O : Loop

△ : Delta

Left Hand Fingers:



Right Hand Fingers: