UNIVERSITY
OF
JOHANNESBURG

FACULTY OF SCIENCE
ACADEMY OF COMPUTER SCIENCE AND SOFTWARE ENGINEERING

MODULE	IT28X07: BIOMETRICS
CAMPUS	AUCKLAND PARK CAMPUS (APK)
ASSESSMENT	JUNE 2021 **MEMO**

DATE: 2021-06   **SESSION:** 08:30 - 10:30

ASSESOR(S):   PROF D.T. VAN DER HAAR

EXTERNAL MODERATOR: DR D. BROWN (RU)

DURATION: 120 MINUTES   **MARKS:** 85

Please read the following instructions carefully:

1. You must complete this assignment yourself within the prescribed time limits.

2. You are bound by all university regulations please special note of those regarding assessment, plagiarism, and ethical conduct.

3. You must complete and submit the *"Honesty Declaration : Online Assessment"* document along with your submission to EVE. No submissions without an accompanying declaration will be marked.

4. Your answers together with the declaration must be submitted in the following format. STUDENTNUMBER_SURNAME_INITIALS_SUBJECTCODE_ASSESSMENT e.g. *202012345_SURNAME_IAM_IT28X07_EXAM.pdf*

5. No communication concerning this test is permissible during the assessment session except with Academy staff members. The invigilator is available via email (dvanderhaar@uj.ac.za) and on the "UJ Biometrics" Discord server throughout the assessment (https://discord.gg/A6NQwemFqb).

6. This paper consists of 12 pages excluding the cover page.

SECTION A - SHORT QUESTIONS

QUESTION 1

General Biometric Systems

(a) Provide a score (low, medium or high) for **retina recognition** against the Collectability, Acceptance and Circumvention (more is good) **biometric requirements** for 2021 (i.e. as it stands today).   (3)

> **Solution:**
>
> 1. Universality - medium (COVID makes it lower)
>
> 2. Collectability - Low/Mediuum
>
> 3. Acceptance - Medium
>
> 4. Circumvention - Medium/High (some of them switched this around)

(b) Analyse the following image for the same system and answer the questions that follow: (3)

(a)   (b)
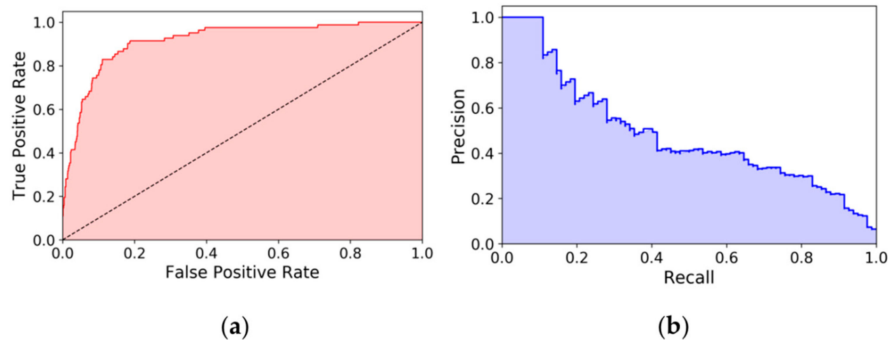
1. What does the above overall image depict? (1)
2. Describe a potential issue found when analysing the image (2)

> **Solution:**
>
> 1. A ROC curve and precision recall curve
>
> 2. The system has good accuracy as sown in a) but the precision recall curve is not as good as shown in b.

Total: 6

QUESTION 2

(a) Provide the coordinates, in the format CR where C the column and R depicts the row (e.g. J0), for **four** examples of **ridge ends** in the fingerprint binary image below (where 1 depicts a ridge and 0 a valley):   (4)

	A	B	C	D	E	F	G	H	I	J
0	1	1	0	0	0	0	0	0	1	0
1	1	1	0	1	1	0	1	1	0	0
2	1	0	0	1	1	1	1	0	1	0
3	0	0	1	0	1	1	1	1	1	1
4	0	1	1	0	1	0	1	0	1	1
5	0	0	1	1	0	1	0	0	0	1
6	1	0	0	0	0	1	1	0	0	0
7	1	0	1	0	1	1	0	0	1	1
8	1	1	0	1	1	1	0	1	1	0
9	1	1	1	1	0	0	0	0	1	0

Solution:

1. C7

2. B4

3. A6

4. H8

5. D1

6. I0 (if ends count)

(b) Can you find any **anomalies** in the above fingerprint? If so, what are they?   (2)

Solution:
Yes:

1. It does not have a normal tessellation pattern

2.

Total: 6

QUESTION 3
Face Recognition

(a) Consider the "Fisherfaces" approach to face recognition and answer the questions that follow: (4)

1. What are the **features** that the algorithm extracts, and how does it compute them?
2. What are the **weaknesses** of the approach?

Solution:

1. similar to Eigenfaces

    2. uses LDA

    3. spatial dimensional reduction

    4. Expressions, rotations and lighting are problematic

(b) Briefly define a Gabor **wavelets** and their relation to Gabor **filters**.   (2)
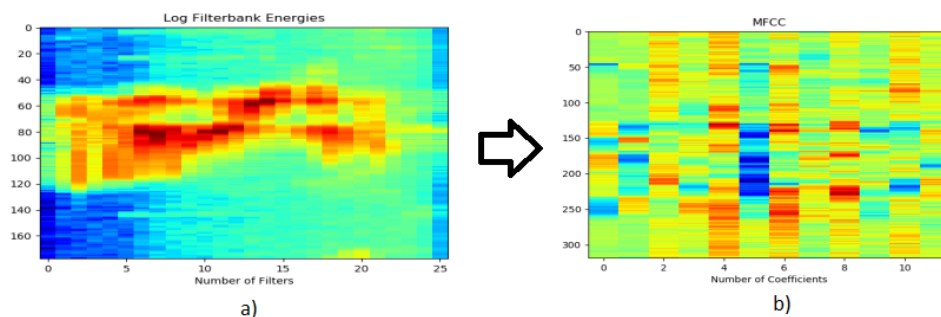
Solution:

1. It minimises the product of its standard deviations in the time and frequency domain (i.e. it minimises its uncertainty). Since they are non-orthogonal decomposition is computationally inefficient, but Gabor filters focus on specific number dilations and rotations with various scales to make it more efficient.

Total: 6

QUESTION 4

(a) Analyse the following images relevant to speaker recognition and answer the questions that follow: (3)

a)   b)

1. What does the above overall image depict (be sure to make reference to a and b)? (2)
2. Briefly describe the computation taking place (1)

Solution:

1. (a) Logarithmic computation on initial filterbank energies. (b) 12 MFCCs.

2. It is a logarithmic transformation being applied (a channel normalization technique through cepstral mean subtraction) and then deriving the MFCC coefficients

(b) What does the equation below represent and what **role** does it play in   (3)
speaker recognition?

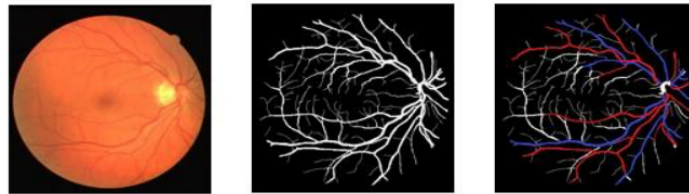$$x_n = \frac{1}{N} \sum_{k=0}^{N-1} X_k \cdot e^{2\pi i k n / N}$$

Solution:

It represents a discrete cosine transform (2) and it is used to convert
an audio signal from time to frequency domain

Total: 6

QUESTION 5

Ocular Biometrics

Analyse the image below and answer the questions that follow.

(a) Discuss the ocular technology being shown and the process taking place.   (4)

> **Solution:**
>
> 1. Retina
>
> 2. Capture binary vessel mapping and major artery mapping

(b) Describe two (2) eye **ailments or diseases** that affects conjunctiva biometrics systems, along **why** it impacts it.   (2)

> **Solution:**
>
> 1. Diabetes - vascular disruptions
>
> 2. Conjunctivitis - burst vessels on the eye

Total: 6

QUESTION 6

For the grayscaled 4x4 pixels below derive the **local binary pattern** matrix (starting off at the top left corner with radius=1 in a clockwise direction):

$$\begin{bmatrix} 91 & 90 & 27 & 87 \\ 39 & 167 & 59 & 114 \\ 6 & 245 & 148 & 119 \\ 91 & 179 & 172 & 178 \end{bmatrix}$$

Solution:

0.5 marks per value
$$\begin{bmatrix} 00001000 & 00000101 & 00011111 & 00000100 \\ 01111000 & 00000100 & 10111111 & 00000110 \\ 01111100 & 00000000 & 10001111 & 00000111 \\ 00110000 & 01000000 & 10010001 & 00000000 \end{bmatrix} \begin{bmatrix} 8 & 5 & 31 & 4 \\ 120 & 4 & 191 & 6 \\ 124 & 0 & 143 & 7 \\ 48 & 64 & 145 & 0 \end{bmatrix}$$

Total: 8

QUESTION 7

Fingerprint-vein multimodal recognition-based biometric systems have have been gaining success in the east. One of the reasons behind this can be attributed to the maturity of finger vein sensors in Japan. Discuss how you would implement a fingerprint and vein multimodal biometric system, the **types** of sensors, along with various **steps** required to capture, process, match and fuse the samples. For each step in your discussion be sure to elaborate on the following aspects:

- The different sensors that can be used to capture a sample.
- A brief description of the steps followed to process, match and fuse a sample.
- The algorithms used at each step (if necessary).

Solution:

Types of fingerprint sensors (2):

- optical (using CCD and LED)
- Capacitive (Solid state)
- thermal
- ultrasonic (transducer type)

Capture(1):

- User presents finger
- It captures the sample

Preprocessing(1):

- Greyscaling
- Histogram equilisation

- CLAHE

- Gaussian Blur

- Gabor filters

Feature Extraction(2):

- Level 1: Holistic view, ridge count and orientation

- Level 2: According to minutia and on the Cartesian axis

- Level 3: Ridge edge shape and pores

- *Level 4: fingerprint molecular identification (FMID)*

Matching(1):

- RANSAC (for feature selection)

- (Euclidean, Manhattan, Mahanalobis) Distance measure

- Hough transform

- Support Vector Machine (SVM)

feature fusion is preferred (1)

Total: 8

QUESTION 8

Biometric Trends and Esoteric Biometrics

(a) Discuss **human heart rate recognition-based authentication**, along a brief description on **how** you would implement such a system.　(4)

> **Solution:**
> An ear classification system where certain parts are taken into account:
>
> 1. ECG
>
> 2. Sinus rhythm
>
> 3. Pan Tomkins (phase detection)
>
> 4. fiducial (QRS complex, etc.) or non-fiducial based
>
> 5. classification (any ML would suffice)
>
> Any valid implementation decision should suffice

(b) What sensor is used in **odour** recognition systems?　(2)

> **Solution:**
> Any electronic nose sensors:
>
> 1. MOSFET (most popular)
>
> 2. Conducting polymers
>
> 3. quartz crystal microbalance
>
> 4. surface acoustic wave

Total: 6

QUESTION 9

Vulnerabilities and Countermeasures
Draw an **attack tree** that highlights the **weaknesses** that will typically be found for a **voice assistant** system such as Amazon Alexa, Google Assistant or Apple Siri **WHERE** the attacker is not allowed to be in the same room as the listening device **ALONG** with two ways to **safeguard** against them.

> **Solution:**
>
> Any attack tree that depicts common attacks (and their subsequent conditions that need to be met for that respective attack).
> Drawing (2)

Root attack such as certain PAD attacks (2)
Conditions for attack (2)
Safeguards include (any two) (2):

- Spoof detection

- Watermarking

- Human Verification

- Multimodal Biometrics

- Passive and Active Biometrics

- Mitigating Weak Users

- Biometric Encryption

- Revocable Biometrics

Total: 8

SECTION B - LONG QUESTIONS

QUESTION 10

A recent study by Penn State University (https://bit.ly/33ZIt2B) shows when the AI system recognises the person's uniqueness that patients considers the "AI doctor" to be intrusive and less likely to follow its medical advice. It highlights key concerns about AI in society related to bias and user acceptance, which affect the ultimate roll out of biometric applications. Write a report that pays special attention to the following:

- Bias in biometric applications.
- User acceptance and usability in biometrics.
- The ethical aspects and your opinion on the case study.

Solution:

Anything discussed on bias that is relevant(3):

- Prejudice in the population

- Discrimination in the use

- All negatively impacts user acceptance

Ethical considerations(3):

- Privacy

- Cultural

- Safety

- etc.

Ethical impact (3)

- Risk of an incorrect decision

- Impact of a decision has far reaching consequences

- Little bed side manner negates care

Their opinion on the case (2) (it is publicly available information?)

Total: 10

QUESTION 11

A soft wearable sensor developed by Northwestern University can measure the itchiness suffered by a person (https://bit.ly/3ohx1sm). The sensor gauges both low-frequency motion and high-frequency vibrations from the hand to improve accuracy compared to wrist watch tools. Comprehensively discuss the design and implementation of an alternative way to achieve the same task (scratch detection because of itchiness). It should include which **biometric attribute** you would use, the **sensor(s)** and **algorithms** you would use and how you would **evaluate** the system. The report should pay special attention to the following:

- The biometric attribute you would use, along with the associated sensor(s)
- The algorithms you would use to implement it.
- Advantages and disadvantages of your selected biometric technology.
- The metrics that should be used to evaluate biometric systems.

Solution:

Appropriate biometric attribute with the right sensors (2)

Algorithms for(5):

- Preprocessing

- Feature Extraction

- Classification

Advantages and disadvantages if biometric technology(4)

- Any biometric

- The appropriate advantages and disadvantages

Test metrics(4):
Match accuracy: Type 1 error (FRR), Type 2 error (FAR)
Match threshold relationship - Improvement of one at the cost of the other
Failure to enrol rate (FTER)
Failure to acquire rate (FTAR)
User throughput
Matching algorithm throughput
Retrial rate (RR)
Cumulative Match Rate (CMR)

Total: 15

— End of paper —