INSTITUTO SUPERIOR DE ENGENHARIA DE LISBOA
MESTRADO EM ENGENHARIA INFORMÁTICA E DE COMPUTADORES
MESTRADO EM ENGENHARIA INFORMÁTICA E MULTIMÉDIA
IMAGE PROCESSING AND BIOMETRICS

First semester 2021/2022

Mid-term Exam | 24 November 2021, 6:30 pm | Expected duration: 1:30

You may consult 2 A4 pages with your class notes.
Present a justification for all your answers. Present all the calculations that you carry out.

1. Consider the following questions about monochrome images.

   (a) {1,25} Present images I_1 and I_2, such that they fullfill the following conditions:
   - I_1 has spatial resolution 2×3, minimum intensity $m_i = 10$, maximum intensity $m_x = 42$ and average intensity m=20.
   - I_2 has 8 *pixels*, average intensity m=100, with $n = 8$ bit/pixel, with one pixel with the minimum intensidade value, other pixel with the maximum intensity value and has no pixels with repeated values.

   (b) {1,25} For images I_1 and I_2, state: (i) the histogram; (ii) the entropy value; (iii) the total number of bits; (iv) the least significant bitplane.
   Suggestion: in case you have not answered to the previous question, please consider:

$$I_1 = \begin{bmatrix} 15 & 40 & 40 \\ 40 & 40 & 20 \\ 15 & 15 & 15 \end{bmatrix} \quad \text{and} \quad I_2 = \begin{bmatrix} 10 & 12 & 14 \\ 9 & 11 & 13 \end{bmatrix}.$$

2. The figures represent actions related to the functioning of biometric systems.

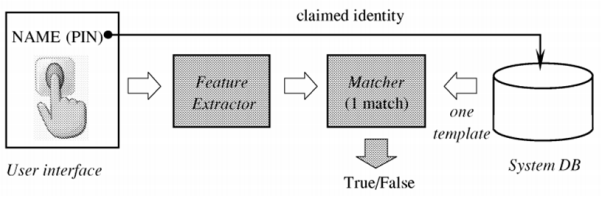


Figure (a)

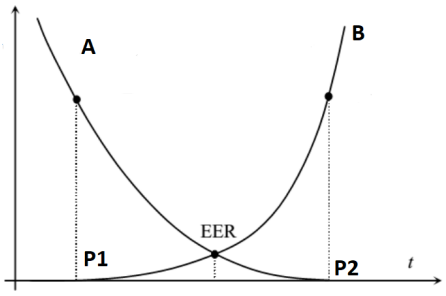


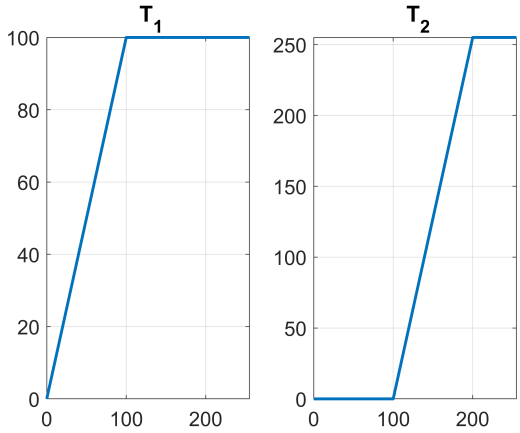
Figure (b)

   (a) {1,25} With respect to Figure (a), indicate: (i) the global functionality/action to which it refers; (ii) the functionality of the *Feature Extractor* block; (iii) the meaning of *template*, in this context.

   (b) {1,25} For Figure (b), indicate: (i) the measure to which the yy axis refers; (ii) the meaning of the EER acronym; (iii) the meaning of the curves A and B; (iv) what the P_1 and P_2 points represent.

   (c) {1,25} Identify the biometric modality referred to in the figure. Present an example of its use today. Can we consider that it is one of the most used biometric modalities?

3. The figure shows the intensity transformations T_1 and T_2, defined for monochromatic images with $n = 8$ bit/pixel.



(a) {1,5} Indicate the functionality associated with each transformation. Present the sketch of the *lookup* table that performs each transformation. State the number of positions in each table.

(b) {1,5} Let $I = \begin{bmatrix} 0 & 10 & 50 \\ 140 & 230 & 200 \\ 40 & 20 & 150 \end{bmatrix}$, be a monochrome image with $n = 8$ bit/pixel. Compute the images that result from the following operations:
(i) $I_1 = \text{NOT}(I)$;
(ii) $I_2 = T_2[I]$.

4. Let the spatial filter windows be set to

$$w_1 = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}, \quad w_2 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, \quad \text{and} \quad w_3 = \text{median}\{3 \times 3\}.$$

Consider the image I of spatial resolution 256×256 and depth resolution of $n = 8$ bit/pixel, such that the first 128 lines take the value 100 and the remaining lines take the value 200.

(a) {1,25} Describe the content of the images I_1, I_2 and I_3, resulting from the application on I, of each spatial filtering window, presented above. Assume that *padding* is applied with row/column replication.

(b) {1,25} State the total number of multiplications and additions performed when calculating I_1, that is, when applying w_1 to I.

(c) {1,25} Consider the energy of the image I, designated by E_I and the energy of the image I_1, designated by E_{I1}. What is the relationship of energies that is verified? (i) $E_I = E_{I1}$; (ii) $E_I > E_{I1}$; (iii) $E_I < E_{I1}$.

5. The following questions refer to digital image processing techniques and their application.

(a) {1,5} Image I has spatial resolution of 10×10, and $n = 6$ bit/pixel. The histogram equalization technique on I was applied, obtaining the intensity transformation

$$T_{HE}[x] = \begin{cases} 0, & 0 \leq x < 20 \\ 30, & 20 \leq x < 40 \\ 50, & 40 \leq x < 50 \\ 63, & 50 \leq x \leq 63. \end{cases}$$

Present an estimate of the histogram of the I image.

(b) {1,5} Consider the following statement. *Noise removal and contour detection operations in image cannot be achieved perform using only intensity transformations, being necessary to resort to spatial filtering*. Indicate the main reason behind this statement.

(c) {1,5} For the Laplacian and the Laplacian of Gaussian (LoG) operators, indicate: (i) their key differences; (ii) which one has more complexity; (iii) under what conditions each of these operators should be used.

6. A given gradient operator, which sets the angle to $\theta = \text{atan}(I_y/I_x)$, was applied over the I image, yielding the output

$$I_x = \begin{bmatrix} 5 & 4 & -2 \\ 6 & 3 & 2 \\ 3 & 0 & 0 \end{bmatrix} \quad \text{and} \quad I_y = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ -1 & 3 & 0 \end{bmatrix}.$$

(a) {1,25} Present the resulting images of the gradient module and argument.

(b) {1,25} Display the edge map of the I image, bearing in mind that it is applied a threshold of 3.5 in binarization.