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

End-term Exam | 19 January 2022, 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 frequency domain filtering algorithm, for input images with spatial resolution 512×512.
   (a) $\{1.5\}$ Present, in the form of an image indicating its resolution, the following filters:
      (i) Ideal low-pass with unitary gain, with cutoff frequency $D_o = 20$.
      (ii) Ideal bandpass, with gain 2, for the bandwidth defined between $D_a = 30$ and $D_b = 50$.
      (iii) *Notch* bandpass filter with parameters at your choice.
   (b) $\{1.5\}$ Consider that you intend to carry out the *image enhancement* operation, using the Laplacian operator, in the frequency domain. Present the pseudo-code of the algorithm implementing this feature.
   (c) $\{1.5\}$ In the context of frequency domain filtering, consider the *zero-padding* operation. Explain what this operation consists of and what are the advantages and disadvantages of performing it.

2. Consider the definition of the *Discrete Cosine Transform* (DCT) for images with spatial resolution $M \times N$.

$$F[u,v] = \text{DCT}[f[m,n]] = C[u]C[v] \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f[m,n] \cos\left(\frac{(2m+1)u\pi}{2M}\right) \cos\left(\frac{(2n+1)v\pi}{2N}\right),$$

$$\text{with} \quad C[u] = \begin{cases} \frac{1}{\sqrt{M}}, & u = 0 \\ \sqrt{\frac{2}{M}}, & u \in \{1, \ldots, M-1\} \end{cases} \quad \text{and} \quad C[v] = \begin{cases} \frac{1}{\sqrt{N}}, & v = 0 \\ \sqrt{\frac{2}{N}}, & v \in \{1, \ldots, N-1\} \end{cases}.$$

   (a) $\{1.5\}$ Let $f[m,n] = \begin{bmatrix} 10 & 10 & 10 \\ 20 & 10 & 20 \\ 10 & 10 & 10 \end{bmatrix}$ with DCT $F[u,v] = \begin{bmatrix} A & 0 & 4,714 \\ 0 & 0 & 0 \\ -9,4281 & 0 & B \end{bmatrix}$. Compute the values of A and B.
   (b) $\{1.5\}$ The DCT of $g[m,n]$ is $G[u,v] = \begin{bmatrix} 10 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$. For the $g[m,n]$ image, state: its spatial resolution; the sum of the values of all its pixels.

3. The following table summarizes the specification of a pseudo-color technique, to be applied on the monochromatic image I, with spatial resolution 128×128 and depth resolution with $n = 8$ bit/pixel.

Grayscale ranges	0 . . . 40	41 . . . 140	141 . . . 240	241 . . . 255
Color code in RGB	[0, 0, 0]	[110, 150, 110]	[255, 0, 255]	[255, 255, 255]

   The I image has the histogram shown in the following table.

Grayscale level	20	50	130	180	190	220
Ocurrences	2000	2000	2000	4000	4000	2384

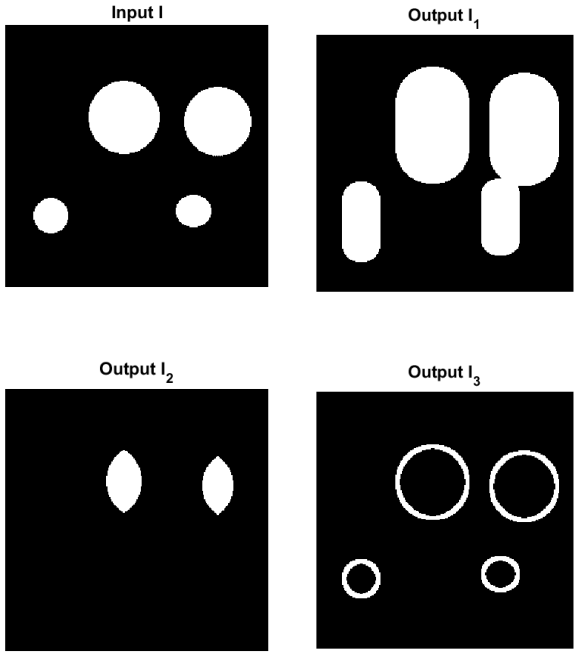
   (a) $\{1.5\}$ State: the number of bits occupied by the image resulting from the application of the pseudo-color algorithm; the number of distinct colors in the color image. Show the *lookup* tables that implement the indicated transformation.
   (b) $\{1.5\}$ Consider that we intend to apply the pseudo-color technique, through three intensity transformation functions, to obtain the R, G, and B components. Present a sketch of the intensity transformation functions.

4. The following questions address the processing of color images.

   (a) $\{1.5\}$ Assume that you have a color image contaminated with impulsive noise in the R and G color channels. It is intended to perform the segmentation operation on this image, to identify the image areas with *pixels pure red* and *pure blue*. Indicate, in detail, the procedures to be carried out to carry out this segmentation.

   (b) $\{1.5\}$ Consider that, on an RGB image, we intend to apply the *color slicing* technique on the color with code RGB=[250, 250, 20]. Present a sketch of the algorithm that performs this operation, explaining the input and output parameters. Which color is represented by this RGB code?

5. The figure shows the result of three different morphological processing on the binary image I.



   (a) $\{1.5\}$ Identify the morphological operations that transformed: I to I_1; I to I_2; I to I_3.

   (b) $\{1.5\}$ Estimate the shape and size of the structuring elements used in the morphological operations in the previous question.

6. The following questions address the implementation of biometric systems.

   (a) $\{1.75\}$ In the recognition of individuals through fingerprint, we use the detection of minutiae. Explain what the minutiae are and how they are detected. Indicate the information stored in the vectors of *templates*, which represent the individuals in the database of the biometric system.

   (b) $\{1.75\}$ In fingerprint and iris based systems, a known approach is to apply Gabor filters. What does this type of filter consist of? How is the filtered image subsequently used in the biometric system?