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

2nd semester, 2017/2018

Exam 2 — July, 3 ; 2:00 pm — Available time: 2:30

You can consult your class notes, with four A4 pages.
Explain, in detail, all your answers. Write down all the hand calculations that you carry out.

1. Let I be the monochrome image $I = \begin{bmatrix} 10 & 13 & 12 & 32 \\ 11 & 14 & 20 & 35 \\ 14 & 0 & 4 & 6 \end{bmatrix}$.

   (a) $\{1.0\}$ Regarding I, state: its spatial resolution; its minimum pixel depth in bit/pixel; its energy; its average intensity. Classify I regarding its brightness and contrast (low/medium/high).

   (b) $\{1.0\}$ Suppose you want to compute image I_2 with similar visual content to I, but with twice the spatial resolution on both vertical and horizontal directions. State a possible image I_2 as well as the procedure that you have taken to compute I_2.

   (c) $\{1.0\}$ Compute the images given by:

   (i) I_A, such that $I_A = (I + 1)$ AND $\begin{bmatrix} 8 & 8 & 8 & 8 \\ 7 & 7 & 7 & 7 \\ 6 & 6 & 6 & 6 \end{bmatrix}$.

   (ii) I_B, such that $I_B = I - 15$.

   (iii) I_C, such that its has four times the power of image I.

2. The intensity transformation T, is defined on the following lookup table.

Input pixel, x_i	**Output pixel**, y_i
$\{0, \ldots, 100\}$	$2x_i$
$\{101, \ldots, 200\}$	x_i
$\{201, \ldots, 255\}$	255

   (a) $\{1.0\}$ Draw a sketch of T. State the changes that this function performs over:

   (i) an image with all its grayscale values located on the range 10 to 80;

   (ii) an image with all its grayscale values located on the range 110 to 192.

   (b) $\{1.0\}$ Draw a sketch of the intensity transformation T_2, such that:

   (i) it significantly increases the contrast on the range 110 to 140;

   (ii) the minimum and maximum intensity values of the image, after T_2 is applied, are 8 and 252, respectively.

3. Let the spatial masks

$$w_1 = A \begin{bmatrix} 1 & 2 & 1 \\ 2 & B & 2 \\ 1 & 2 & 1 \end{bmatrix} \quad \text{and} \quad w_2 = \frac{4}{C+1} \begin{bmatrix} C/4 & (1-C)/4 & C/4 \\ (1-C)/4 & -1 & (1-C)/4 \\ C/4 & (1-C)/4 & C/4 \end{bmatrix}.$$

   (a) $\{1.0\}$ Compute the values of A and B, such that w_1 is an operator that performs: i) *smoothing*; ii) *sharpening*.

   (b) $\{1.0\}$ With $C = 0$, identify the operator performed by the w_2 mask. Compute the adequate range of values for the C parameter.

   (c) $\{1.0\}$ Let I be a monochrome image with spatial resolution 512×512, such that its first 256 rows are 12 and the remaining 256 rows are 40. Describe the contents of images I_1 and I_2, resulting from spatial filtering of I:

   (i) with w_1, setting $A = 1$ and $B = 2$.

   (ii) with w_2, setting $C = 0$.

4. The *Inverse Discrete Cosine Transform* (IDCT) for $M \times N$ images is defined as.

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

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

(a) $\{1.0\}$ With $F[u,v] = \begin{bmatrix} 12 & 0 \\ 0 & 0 \end{bmatrix}$, compute $f[m,n] = \text{IDCT}[F[u,v]]$. Try to do the smallest number of computations as possible.

(b) $\{1.0\}$ Let $D[u,v] = \text{DCT}[I[m,n]]$, with I being a monochrome $M \times N$ image. Let I' be the negative version of I, as well as $D'[u,v] = \text{DCT}[I'[m,n]]$. What is the relationship between $D[u,v]$ and $D'[u,v]$?

5. Consider the image frequency filtering algorithm. After the *zero padding* step, the *padded* image has $P = 2M$ rows and $Q = 2N$ columns. Given that $D[u,v] = \sqrt{(u - P/2)^2 + (v - Q/2)^2}$, we define the following filters:

$$H_A[u,v] = D[u,v], \quad H_B[u,v] = \exp\left(-\frac{D^2[u,v]}{2D_o^2}\right), \quad H_C[u,v] = \frac{1}{1 + \left(\frac{D[u,v]}{D_o}\right)^{2n}} \quad \text{and} \quad H_D[u,v] = 1 - H_B[u,v].$$

(a) $\{1.0\}$ For each one of the four filters, state the type of filtering.

(b) $\{1.0\}$ For $H_B[u,v]$ state the functionality of the D_o parameter. For $H_C[u,v]$ state the functionality of the D_o and n parameters.

(c) $\{1.0\}$ What is a *notch filter*? Show an example and state in which cases it should be applied.

6. Take into account color image representation on the RGB and HSI color spaces.

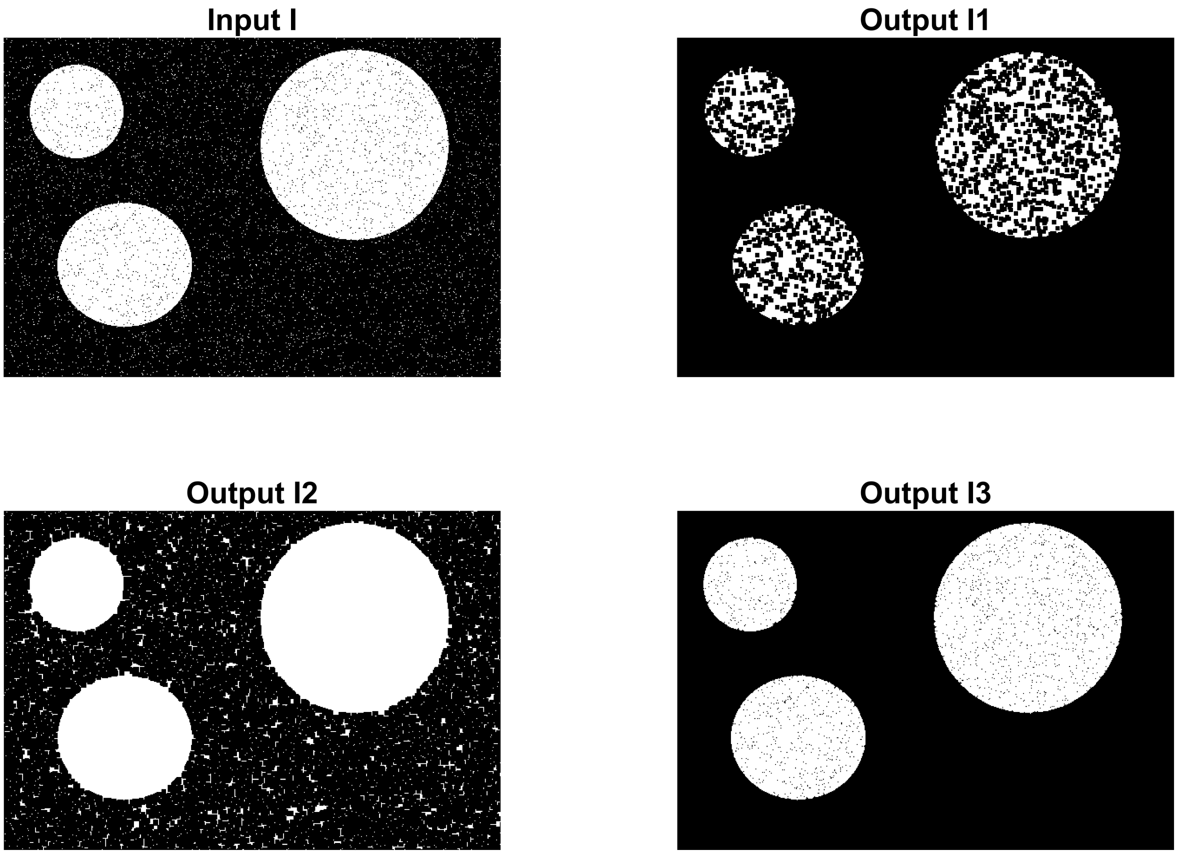
(a) $\{1.0\}$ The color image I is represented on both color spaces RGB and HSI, with $n = 5$ bit/pixel, on each band. For both color spaces, draw a sketch of the intensity transformation functions that yield the color complement ("negative").

(b) $\{1.0\}$ The monochrome image M has 256 gray levels. From M, we compute the color images, represented on the RGB or HSI color space, given by

$$I_1 : \begin{cases} R_1 = & M/2 \\ G_1 = & M/2 \\ B_1 = & M/2 \end{cases}, \qquad I_2 : \begin{cases} R_2 = & M \\ G_2 = & M \\ B_2 = & 0 \end{cases} \quad \text{and} \quad I_3 : \begin{cases} H_3 = & 0 \\ S_3 = & 128 \\ I_3 = & M \end{cases}.$$

Identify the type of technique applied on image M. Provide a description of the visual contents of the color images I_1, I_2 and I_3 and its relationship with the visual contents of M.

7. The following figure shows the output of three different morphologic procedures over the binary image I, in an attempt to remove the noise from the image, while preserving the circles.



   (a) $\{1.0\}$ Identify the morphologic operations that produced: I_1 from I; I_2 from I; I_3 from I.

   (b) $\{1.0\}$ Propose another technique that effectively removes the noise, while keeping the circles intact without any noise.

8. The following questions address pattern recognition and biometric systems.

   (a) $\{1.0\}$ The biometric traits are evaluated by different properties such as *universality*, *unicity*, *permanence*, and *performance*. State the meaning of each one of these properties. Show a comparison of the *fingerprint* and *face* biometric traits, regarding these properties.

   (b) $\{1.0\}$ On the use of biometric systems we have the existence of *false positives* and *false negatives*. Explain: the meaning of these indicators (for identification and authentication tasks); how one must proceed to set their values to an adequate range.

   (c) $\{1.0\}$ Regarding the *decision tree* classifier, state: how the training/learning process is done; how the classifier decides the class label to assign to a pattern, after training. The feature located at the root of the tree is the most or the less relevant?