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 1 June, 19 ; 2:00 pm

- R1 - Mid-term (repetition), 1h30, exercises **1, 2, 3, 4, and 5**.
- R2 - End-term (repetition), 1h30, exercises **6, 7, 8, 9, and 10**.
- GE - Global Exam, 2h30, exercises **2, 3, 5, 6, 7, 8, and 9**.

You can consult your class notes, with 2 A4 pages (R1 or R2) or 4 A4 pages (GE).
Explain, in detail, all your answers. Write down all the hand calculations that you carry out.

1. $\{$R1$\}$ Let I_1 and I_2 be two monochrome images with depth of $n = 4$ bit/pixel.

$$I_1 = \begin{bmatrix} 14 & 12 & 12 & 12 & 12 \\ 12 & 13 & 14 & 2 & 2 \\ 8 & 6 & 5 & 3 & 4 \end{bmatrix} \quad \text{and} \quad I_2 = \begin{bmatrix} 10 & 10 & 10 & 10 & 10 \\ 12 & 12 & 12 & 15 & 15 \\ 8 & 8 & 8 & 6 & 6 \end{bmatrix}.$$

   (a) $\{1.25\}$ For image I_1, compute: the most significant bitplane, I_{MSB}; the least significant bitplane, I_{LSB}; the histogram; the total number of bits that the image occupies.

   (b) $\{1.25\}$ State the average intensity value, the power and the energy of I_2. Classify I_2 regarding its brightness and contrast (low/medium/high).

   (c) $\{1.25\}$ Compute the following images:

      (i) I_A, such that $I_A = I_1 + I_2$.

      (ii) I_B, such that I_B is computed from I_1, setting its most significant bitplane I_{MSB} to 1.

   (d) $\{1.25\}$ Compute the negative version of I_1, named I_n. Show image I_n as well as its histogram.

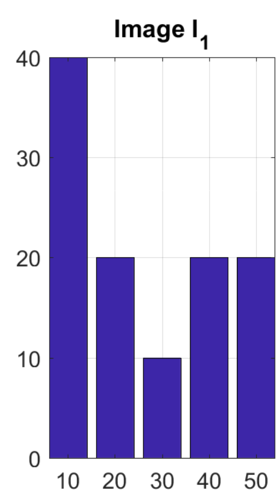
2. $\{$R1||GE$\}$ The following histograms refer to images I_1 and I_2, with depth of $n = 6$ bit/pixel.

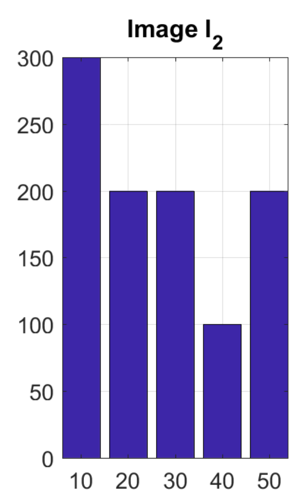
   (a) $\{1.25||1.0\}$ For image I_1, state: its average intensity; its energy; its power; a possible value for its spatial resolution.

   (b) $\{1.25||1.0\}$ Suppose we want to perform histogram equalization on I_2. Sketch the corresponding intensity transformation function to perform this operation, as well as the histogram of the resulting image.

   (c) $\{1.25||1.0\}$ Suppose we want to increase the contrast of I_1, using the histogram specification technique, with the function/class method Iout=HistogramSpecification(Iin,Iref). State all the steps that are necessary to perform to accomplish this goal.

   (d) $\{1.25||1.0\}$ Let $I_3 = I_1 + 30$. Sketch the histogram of I_3. Suppose you want to perform the operation given by $I_4 = I_1 + I_2$. Is it possible? In the affirmative case, show the result. If it is not possible, state the reason for this impossibility.





3. {R1||GE} The following questions refer to Digital Image Processing (DIP) techniques.

(i) {1.25||1.0} For each one of the following situations, state one example of a problem of DIP, such that it is adequate:

(1) to use a frequency filtering technique, since spatial filtering is inadequate;

(2) to use a spatial filtering technique, instead of a frequency filtering technique;

(3) to use an intensity transformation, instead of a (spatial or frequency) filtering technique.

(ii) {1.25||1.0} The *global histogram equalization* and the *local histogram equalization* are two related techniques. State: how these techniques work; the goals of these techniques; in which case should we apply each one of these techniques.

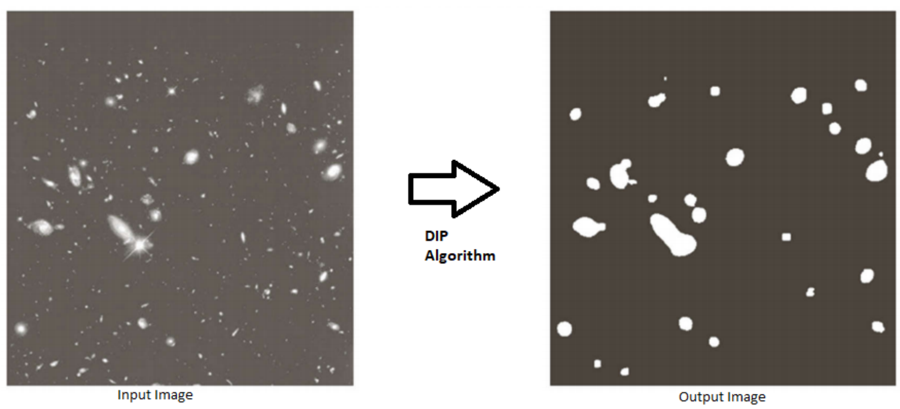
(iii) {1.5||1.0} The monochrome image I has spatial resolution 512×512, such that its first 256 columns are equal to 100 and the remaining 256 columns are 120.

(1) Suppose we perform spatial filtering of I, with 3×3 average filter. State the total number of multiplications and sums. Describe the contents of the filtered image, I_1.

(2) Suppose we apply the 1×5 median filter on I. Describe the filtered image, I_2.

(3) Suppose we apply the 1×4 median filter on I. Describe the filtered image, I_3.

(iv) {1.5||1.0} The following figure shows the output of a DIP algorithm on a given input image. State the goal of the algorithm and present a possible set of actions taken by this algorithm.



4. {R1} The $f[m,n]$ image has centered spectrum $F[u,v] = \begin{bmatrix} 0 & 0 & -12.5000 - j4.0615 & 0 & 0 \\ 0 & 0 & -12.5000 - j17.2048 & 0 & 0 \\ 0 & 0 & 75 & 0 & 0 \\ 0 & 0 & -12.5000 + j17.2048 & 0 & 0 \\ 0 & 0 & -12.5000 + j4.0615 & 0 & 0 \end{bmatrix}$.

(a) {1.5} Compute $|F[u,v]|$ and arg[F[u,v]]. In a generic sense: what is the information contained in the module of the spectrum of an image? what is the information contained in the argument of the spectrum of an image?

(b) {1.5} Regarding $f[m,n]$ state: its spatial resolution; its average value; its energy.

5. {R1||GE} {1.5||1.0} Consider the 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:

$$H_A[u,v] = \begin{cases} 1, & \text{if} \quad D[u,v] \leq 50 \\ 0{,}5, & \text{if} \quad 51 \leq D[u,v] \leq 90 \\ 0, & \text{if} \quad D[u,v] \geq 91 \end{cases} \quad \text{and} \quad H_B[u,v] = \begin{cases} 0, & \text{if} \quad D[u,v] \leq 50 \\ 1, & \text{if} \quad D[u,v] > 50. \end{cases}$$

For the $H_A[u,v]$, $H_B[u,v]$, $H_C[u,v] = H_A[u,v] + H_B[u,v]$ and $H_D[u,v] = H_A[u,v] \times H_B[u,v]$ filters, state the filtering type and sketch each filter as an image.

6. {R2||GE} The DCT for $M \times N$ images is defined as

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

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

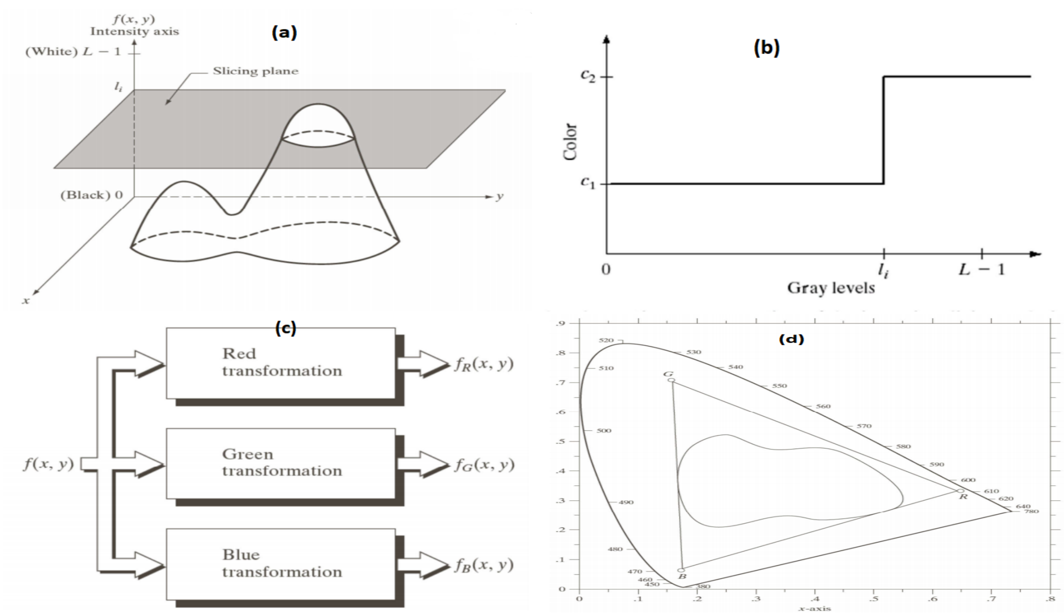
Let $f[m,n] = \begin{bmatrix} 1 & 0 \\ 0 & 2 \end{bmatrix}$.

(a) {1.5||1.0} Let $F[u,v] = DCT[f[m,n]]$, with $F[0,1] =$ -0.5 and $F[1,1] = 1.5$. Compute $F[0,0]$ and $F[1,0]$.

(b) {1.5||1.0} Let m_f be the average intensity of $f[m,n]$. Let $g[m,n] = f[m,n] - m_f$ and without explicit computation of the DCT of $g[m,n]$, state the contents of $G[u,v]$, with $G[u,v] = DCT[g[m,n]]$.

(c) {1.5||1.0} In a generic sense, what are the key properties of the DCT that make its usage adequate for different digital image processing problems? In this framework, show one example of the use of the DCT.

7. {R2||GE} The following figure depicts several properties and/or techniques that are related to color representation and processing.



(a) {1.5||1.0} Identify the properties/techniques depicted by figures (a), (b), (c), and (d). For each property/technique, state one example of its usage.

(b) {1.5||1.0} The technique described on the diagram of figure (c) is applied over an input image with 512×512 spatial resolution and 128 gray levels. Show a sketch of the contents of the *Red transformation*, *Green transformation*, and *Blue transformation* blocks. State the criterion that you have followed in the definition of these blocks.

8. {R2||GE} The following questions refer to color image processing techniques.

   (i) {1.5||1.0} State the main advantages and disadvantages of color image processing, with the color represented on the HSI color space, as compared to the RGB color space. State the connection between these color spaces and the human perception (by the human visual system) and the human written/spoken description of the color.

   (ii) {1.5||1,0} The RGB image I_1 has depth of $n = 24$ bit/pixel. This image was processed trough an algorithm that has changed the depth to $n = 18$ bit/pixel, resulting in image I_2. State: a possible approach for the implementation of this algorithm; the maximum number of distinct colors for I_1 and I_2; the maximum number of gray levels for I_1 and I_2.

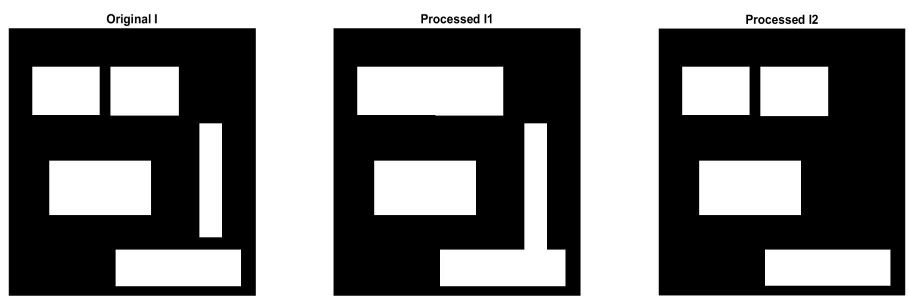
   (iii) {1.5||1.0} A given RGB image has low contrast. Moreover, the image shows impulsive *salt & pepper* noise on the R and B bands, with a larger noise density on the R band. State how you would proceed to: remove the noise from the image; adjust the contrast, after noise removal.

   (iv) {1.5||1.0} Show a sketch of an algorithm such that, on the input color RGB image, counts the total number of pixels that have a *safe color*. Establish the set of input and output parameters of the algorithm stating their meaning and contents.

9. {R2||GE} The following questions refer to morphologic image processing techniques.

   (i) {1.5||1.0} In which cases, we should consider the use of morphologic operations, instead of other techniques? What are the criteria to chose the morphologic operation and the structuring element? We can apply morphologic processing techniques to what type of images?

   (ii) {1.25||1.0} The following figure shows the output of two different morphologic procedures over the binary image I. Identify the morphologic operations that produced: I_1 from I; I_2 from I.



10. {R2} The following questions address pattern recognition and biometric systems.

    (i) {1.25} Show the generic block diagrams of pattern recognition and biometric systems. State the goals of each block. State how we should proceed to choose, implement, and to evaluate each block.

    (ii) {1.25} The confusion matrix C reports the result of a test on a given classifier. State: the number of classes; the number of patterns of the test; the error percentage per class; the global error percentage; the class which seems the most difficult to predict correctly.

$$C = \begin{bmatrix} 14 & 2 & 2 \\ 0 & 13 & 4 \\ 2 & 0 & 16 \end{bmatrix}.$$

    (iii) {1.25} Regarding the *k nearest neighbors* classifier, state: how the training process is done; how the classifier decides the class label to assign to a pattern, after training.