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, 2018/2019

End-term exam | May, 30 ; 8:00 pm | Available time: 1:30

You can consult your class notes, with 2 A4 pages.
Explain, in detail, all your answers. Write down all the hand calculations that you carry out.

1. The following questions address the *transformed-based image processing techniques*.

   (a) $\{1.25\}$ State the key advantages and drawbacks of the *transformed-based image processing techniques*, as compared to the *linear spatial filtering techniques*. Provide a diagram of both techniques to illustrate your answer.

   (b) $\{1.25\}$ Let $f[m,n] = \begin{bmatrix} 1 & 1 & 1 \\ 2 & 2 & 2 \\ 1 & 1 & 1 \end{bmatrix}$ and its DCT $F[u,v] = \begin{bmatrix} ? & 0 & 0 \\ 0 & 0 & 0 \\ -\sqrt{2} & 0 & 0 \end{bmatrix}$, from which we do not know the value of one coefficient. State the value of the unknown coefficient of $F[u,v]$.

   (c) $\{1.25\}$ Let m_f be the average intensity of $f[m,n]$ and $g[m,n] = f[m,n] - m_f$. Compute $G[u,v] = DCT[g[m,n]]$.

   (d) $\{1.25\}$ Consider the following algorithm applied on monochrome images.

   ```
   Input:  Monochrome image, f[m,n].
   Output: Monochrome image, g[m,n].
   1. F = DCT(f);
     2. F[0,0]= 2*F[0,0];
   3. g = IDCT[F];
   ```

   State the functionality of the algorithm. State the result obtained by the algorithm when applied to the $f[m,n]$ image given in (b).

   The definition of the *Discrete Cosine Transform* (DCT) for $M \times N$ images is:

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

   The definition of the *Inverse Discrete Cosine Transform* (IDCT) for $M \times N$ images is:

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

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

2. The monochrome image $f[m,n]$, with depth $n = 8$ bit/pixel, has the histogram shown in the table.

Pixel Value	0	100	200	210	220	230	240
Pixel Ocurrences	4000	4000	4000	100	100	100	100

   (a) $\{1.5\}$ Suppose you need to colorize the $f[m,n]$ image with the *intensity slicing* technique, so that each gray level of the image corresponds to a different *Web Safe Color*. Please state how you would do this.

   (b) $\{1.5\}$ Display the intensity transformation functions to perform the coloring of the $f[m,n]$ image with the intensity to RGB transform technique, as follows:

   (i) the intensity values 0, 100, and 200 must correspond to the three primary colors Red, Green and Blue, respectively;

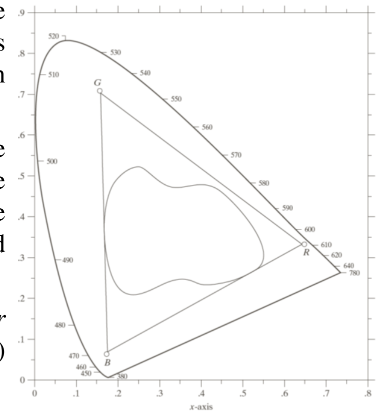
   (ii) the values of intensity above 200 should correspond to the white color.

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

   (a) {1.5} The acquisition and display of color images is typically performed in the RGB color space. Indicate: (i) the main reasons for this situation; (ii) the colors represented by the codes $[120, 120, 120]$ and $[250, 0, 250]$, considering that each component is represented with $n = 8$ bit/pixel.

   (b) {1.5} Consider applying the histogram specification technique to a color image in order to make the existing colors lighter/brighter. Indicate the steps of the algorithms to be performed for this purpose considering the following: (i) the images are represented in the RGB color space; (ii) the images are represented in the HSI color space.

   (c) {1.5} Consider the diagram shown in the next figure, which is called *color gamut*. State the meaning: (i) of the triangle with vertices R, G, and B; (ii) the irregular area contained within the triangle.



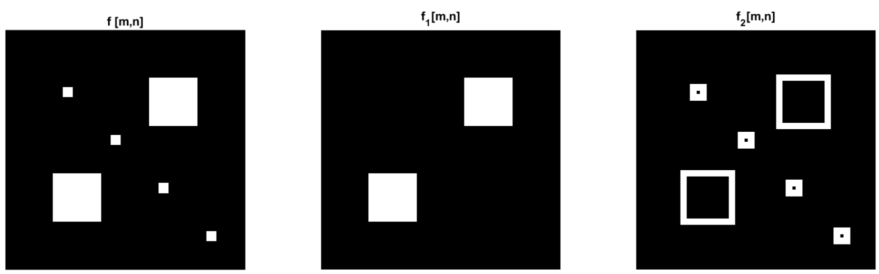
4. The following questions address the morphological processing of binary images.

   (a) {1.5} In morphological processing operations, it is necessary to define and apply a structuring element. Explain what is the structuring element and the criteria for choosing it.

   (b) {1.5} The binary image $f[m, n]$ of the figure has spatial resolution 500×500 and is composed of six squares. The smaller squares have sides equal to 20 pixel while larger ones have sides equal to 100 pixel. State how to proceed, using morphological operations, from the image $f[m, n]$ to:

      (i) remove the four smaller squares, keeping the larger ones intact, getting the image $f_1[m, n]$.

      (ii) get the $f_2[m, n]$ image, shown in the figure.



5. The following questions refer to Biometric Systems (BS).

   (i) {1.5} Consider the biometric modalities face, fingerprint, and iris. Characterize, in a comparative way, these modalities regarding the following indicators: uniqueness, permanence, and performance.

   (ii) {1.5} State the meaning of the *failure to enroll* (FTE) indicator. Give an example of a situation where a case of *failure to enroll* happens, when using the biometric modality *face*.

   (iii) {1.5} The figure shows a graph with the goal of evaluating the performance of a BS. What actions do you need to perform the chart? The chart refers to to user registration actions or does it refer to verification actions? Choosing the value of $t = 0.6$, the system will present greater number of false positives or false negatives?