**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**

Mid-term exam April, 27 ; 3:30 pm Available time: 1:30

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**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 monochrome image $I$ with 16 gray levels was decomposed into bitplanes. The binary images corresponding to the Most Significant Bitplane (MSB) and to the Least Significant Bitplane (LSB) are

$$I_{MSB} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \end{bmatrix} \quad \text{and} \quad I_{LSB} = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \end{bmatrix}.$$

   (a) $\{1.0\}$ Under these settings, regarding image $I$, state: the total number of distinct bitplanes that compose the image; the spatial resolution; the total number of bits that the image occupies; the minimum value for its energy.

   (b) $\{1.0\}$ Assume that $I$ has average intensity $m_I = 8$. Consider that image $I_2$ is computed from $I$, by setting its LSB bitplane, $I_{LSB}$ to zero. Compute the average intensity of the $I_2$ image.

2. The monochrome images $I_1$ and $I_2$, with depth $n = 4$ bit/pixel, are defined as

$$I_1 = \begin{bmatrix} 10 & 1 & 10 & 1 \\ 5 & 1 & 1 & 5 \\ 4 & 1 & 1 & 4 \end{bmatrix} \quad \text{and} \quad I_2 = \begin{bmatrix} 12 & 10 & 8 & 7 & 6 \\ 12 & 10 & 8 & 7 & 6 \\ 12 & 10 & 8 & 7 & 6 \end{bmatrix}.$$

   (a) $\{1.5\}$ Draw the histogram of each image. Which one of these images has higher brightness? Which one has higher contrast? Show the brightness and contrast indicators that you have considered.

   (b) $\{1.5\}$ Let $I_3 = \text{NOT}[I_1]$ and $I_4 = 2 \times I_2 - 5$. Show the $I_3$ and $I_4$ images, as well as their corresponding histograms.

   (c) $\{1.5\}$ Sketch the intensity transformation $T_1$ that yields the negative version of $I_1$. Explain how the lookup table that performs this transformation is composed. Show the image that results from applying $T_1$ to $I_1$.

   (d) $\{1.5\}$ Sketch the intensity transformation $T_2$ that performs histogram equalization on $I_1$. Show the image that results from applying $T_2$ to $I_1$.

3. The following questions address Digital Image Processing (DIP) techniques.

   (i) $\{1.5\}$ The monochrome images $I_1$ and $I_2$ shown in the figure below have the properties reported in the table. Suppose you want to mix both images, yielding image $I_3$. State, with all the details, how one should proceed in order to compute the $I_3$ image.

| | $I_1$ | $I_2$ |
|---|---|---|
| Spatial Resolution | $512 \times 512$ | $256 \times 256$ |
| Depth Resolution | 8 bit/pixel | 16 bit/pixel |

(ii) $\{1.5\}$ State two examples of DIP problems, such that one has to resort to spatial or frequency filtering techniques, given that the use of intensity transformations is not enough/adequate.

(iii) $\{1.5\}$ On a given software module of a monochrome digital camera, we want to add the brightness control capability. This feature consists of detecting if the image under acquisition has excessive high brightness or excessive low brightness. The goal is to prevent the user from taken a picture which is not of good quality. State, in detail, how would you proceed to implement this capability.

(iv) $\{1.5\}$ On the following algorithm, the `linear_spatial_filtering` function performs linear spatial filtering, with the masks defined by parameters `a` and `b`.

```
-------------------------------------------------------------------------------------
Input:  Monochrome image f[m,n], Mask a, Mask b, Boolean flag.
Output: Monochrome image g[m,n].
-------------------------------------------------------------------------------------
1. f1 = linear_spatial_filtering( f, a ).
2. f2 = linear_spatial_filtering( f, b ).
3. if (flag==1)
4.  g = abs(f1) + abs(f2).
5. else
6.  g = f1 - f2.
-------------------------------------------------------------------------------------
```

State the type of operation/technique that this algorithm performs as well as the relationship between the $f[m,n]$ and the $g[m,n]$ images, with:

$$(1) \qquad a = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad , \quad b = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \quad \text{and} \quad \text{flag=0.}$$

$$(2) \qquad a = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \quad , \quad b = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad \text{and} \quad \text{flag=1.}$$

4. The $f[m,n]$ image has spectrum $F[u,v] = \begin{bmatrix} 15 & 2-j & 5 & 2+j \\ -1 & -2-j & -3 & -2+j \\ -5 & -2-j & 1 & -2+j \\ -1 & -2-j & -3 & -2+j \end{bmatrix}$.

   (a) $\{1.5\}$ State the average intensity value and the spatial resolution of $f[m,n]$.

   (b) $\{1.5\}$ Compute $|F[u,v]|$ and arg[F[u,v]], on the centered format.

5. The following questions address image filtering techniques.

   (a) $\{1.5\}$ On a given digital image processing problem, one wonders regarding the choice of spatial filtering techniques or frequency filtering techniques. State the advantages and disadvantages of frequency filtering techniques, as compared to spatial filtering. Show one example of a case, in which we should chose a spatial filtering technique. Show another example, in which we should chose a frequency filtering technique.

   (b) $\{1.5\}$ Show as an image sketch, the frequency response of the following filters:

      (1) Ideal high-pass filter, with cutoff frequency $D_o = 40$, for $256 \times 256$ images;

      (2) Filter that removes the image DC component, while keeping all the other frequency components, for $512 \times 512$ images;

      (3) Band-Reject Filter, for the bandwidth between $D_a = 30$ and $D_b = 50$, for $1024 \times 512$ images.