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

Mid-term exam | April, 17 ; 6:30 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.

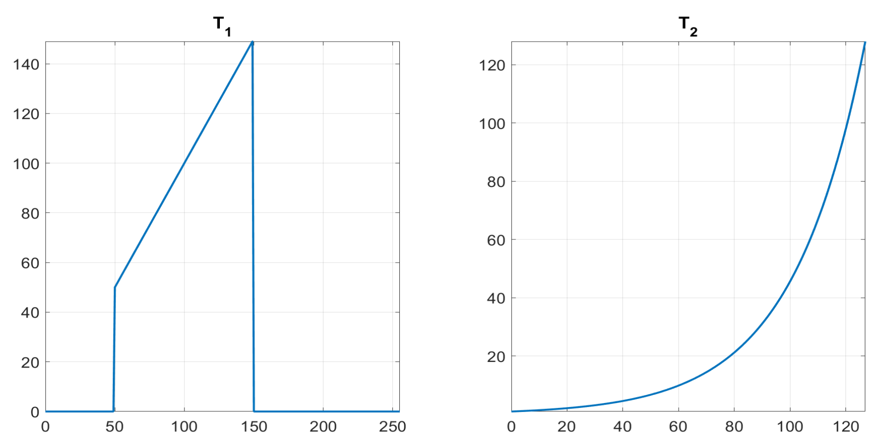
1. The square monochrome image I has 128 grayscale levels and occupies a total of 28672 bits of storage space.
   (a) $\{1.25\}$ Regarding I, state: its spatial resolution; its depth resolution; the range of values (the minimum and maximum values) taken by the energy, power, and entropy indicators.
   (b) $\{1.25\}$ Assume now that the sum of all the pixels of I is 40960. Using all the available information, is it possible to conclude about the brightness and contrast of this image? If it is possible, state if these indicators have low, medium or high values. Otherwise, state why it is not possible to conclude on this.
   (c) $\{1.25\}$ Let I_n be the negative version of I. Sketch the intensity transformation that computes I_n from I.

2. The monochrome images I_1 and I_2 have a depth of $n = 3$ bit/pixel, are defined as

$$I_1 = \begin{bmatrix} 3 & 4 & 4 & 2 & 1 \\ 1 & 3 & 2 & 1 & 0 \\ 1 & 1 & 1 & 6 & 5 \end{bmatrix} \quad \text{and} \quad I_2 = \begin{bmatrix} 4 & 3 & 4 & 2 & 1 \\ 1 & 2 & 3 & 1 & 0 \\ 3 & 3 & 3 & 3 & 3 \end{bmatrix}.$$

   (a) $\{1.25\}$ Sketch the histogram of I_1. Compute the entropy of this image.
   (b) $\{1.25\}$ Compute and present the I_3 and I_4 images, that result from the following operations: $I_3 = I_1$ AND I_2; $I_4 = I_1 + I_2$.

3. The intensity transformations T_1 and T_2 are depicted in the following figure.



   (a) $\{1.25\}$ For each intensity transformations, state: its functionality/usage; the depth resolution of the input image; how would you proceed to compute its corresponding lookup table; the number of entries on this table.
   (b) $\{1.25\}$ State two examples of images I_1 and I_2, with spatial resolution 3×4 and without repeated pixel values, such that:
      (i) the use of T_1 on I_1 does not change the contents of I_1;
      (ii) the use of T_1 on I_2 produces/outputs a null image.

4. The following table shows the histogram of I_1 and I_2 images, both with 128 colums, with minimum and maximum intensity 0 and 255, respectively.

Pixel value	0	10	20	30	40	120	180	200	255
Ocurrences, I_1	4000	4000	4000	4000	84	75	75	75	75
Ocurrences, I_2	168	150	150	150	150	8000	8000	8000	8000

(a) $\{1.25\}$ For the I_1 and I_2 images, state the number of rows. Compute the average intensity of I_1.

(b) $\{1.25\}$ For I_1, sketch the intensity transformation function T_{HE} that performs histogram equalization.

(c) $\{1.25\}$ Suppose you apply the histogram specification technique on I_1, with I_2 as the reference image, resulting in the output image I_3. State the key differencces between I_1 and I_3.

5. The following questions address the spatial filtering technqiues.

(a) $\{1.25\}$ The spatial filtering mask w is defined as $w = \begin{bmatrix} a & d & g \\ b & e & h \\ c & f & i \end{bmatrix}$. State the values for the coeffientes a to i, such that w is a mask that performs:

(i) a smoothing operation;

(ii) a gradient operation;

(iii) a Laplacian operation.

(b) $\{1.25\}$ The I image has depth resolution of $n = 8$ bit/pixel defined as $I = \begin{bmatrix} 120 & 0 & 120 & 118 & 122 \\ 118 & 120 & 122 & 255 & 120 \\ 116 & 120 & 0 & 118 & 118 \\ 118 & 118 & 255 & 118 & 0 \end{bmatrix}$, being contaminated with *salt & pepper* noise. Identify the pixels that appear to be contaminated with noise. State, in detail, all the steps of an adequate technique to remove this noise.

6. The following questions address frequency-based filtering techniques. With $D[u,v] = \sqrt{(u - P/2)^2 + (v - Q/2)^2}$, we have the following filters on the frequency domain:

$$H_1[u,v] = \exp\left(-\frac{D^2[u,v]}{2D_o^2}\right) \quad \text{and} \quad H_2[u,v] = \frac{1}{1 + \left(\frac{D_o}{D[u,v]}\right)^{2n}}.$$

(a) $\{1.25\}$ For each filter: identify the algorithm/technique that leads to this definition; the filtering type. Explain the meaning of the D_o and n parameters.

(b) $\{1.25\}$ Sketch as an image the frequency response of the following filters:

(i) $H_a[u,v]$, ideal low-pass filter for input images with spatial resolution of 256×256;

(ii) $H_b[u,v]$, notch band-pass filter, for input images with spatial resolution of 512×256.

7. The $f[m,n]$ image has spectrum $F[u,v] = \begin{bmatrix} 13 & -1 & 5 & -1 \\ -j & j & -j & j \\ -5 & 1 & 3 & 1 \\ j & -j & j & -j \end{bmatrix}$.

(a) $\{1.25\}$ Regarding $f[m,n]$ state: the average intensity; the power.

(b) $\{1.25\}$ Display $|F[u,v]|$ and arg[F[u,v]], on the centered spectrum form.