Master in Computer Vision Barcelona

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Module: **M1. Introduction to human and computer vision** **Final exam**
Date: November 29th, 2021 **Time: 2h30**
Teachers: Ramon Morros, Javier Ruiz, Philippe Salembier, Javier Vázquez, Verónica Vilaplana

- Books, lecture notes, calculators, phones, etc. are not allowed.
- All sheets of paper should have your name.
- **Answer each problem in a separate sheet of paper.**
- All results should be demonstrated or justified.

Problem I Javier Vázquez (2 points)

1. Explain Color constancy. Explain the Von Kries law.
2. Explain the Color formation equation. Which two corollaries follow from this equation?
3. Explain gamma correction. How has been gamma correction modified for HDR images?
4. Explain unsharp masking.

Problem II Philippe Salembier (2 points)

1: Consider the following image which is quantized with 3 bits (form 0 to 7).

1	4	4	4
1	4	4	5
1	5	4	5
4	5	4	1

Compute the image after histogram equalization.

2: Consider the following flat structuring element SE (the underlined position indicates the m=n=0 point):

$$\begin{array}{ccccc} -\infty & -\infty & -\infty & -\infty & -\infty \\ -\infty & -\infty & 0 & -\infty & -\infty \\ -\infty & 0 & \underline{-\infty} & 0 & -\infty \\ -\infty & -\infty & 0 & -\infty & -\infty \\ -\infty & -\infty & -\infty & -\infty & -\infty \end{array}$$

Consider the operator, $\boldsymbol{\psi}$, that consists in dilating twice the image with the structuring element SE: $\boldsymbol{\psi}(.) = \boldsymbol{\delta_{SE}}(\boldsymbol{\delta_{SE}}(.))$.
Is this operator ψ increasing, idempotent and extensive? (Precisely justify your answers)

3: We construct a family of structuring element $\{SE_k\}$ based on SE defined in the previous question, with:

$$SE_k(m,n) = \begin{cases} 0 \ \ if \ \ m = \pm k, n = 0 \\ 0 \ \ if \ \ n = \pm k, m = 0 \\ \ \ -\infty \ \ otherwise \end{cases}$$

Can we compute a granulometry with the openings based on these structuring elements: $\boldsymbol{\gamma_{SE_k}}(.)$?
If yes, define the block diagram of the granulometry.

4: Consider the following operators: $\boldsymbol{\psi_1}(.) = \boldsymbol{\varphi}(\boldsymbol{\gamma}(.))$ and $\boldsymbol{\psi_2}(.) = \boldsymbol{\gamma}(\boldsymbol{\varphi}(.))$ where $\boldsymbol{\gamma}$ is an opening and $\boldsymbol{\varphi}$ a closing with a square structuring element of size 3x3.
Is the operator $\boldsymbol{\psi_2}(\boldsymbol{\psi_1}(.))$ increasing, idempotent and anti-extensive or extensive?

Problem III Javier Ruiz (3 points)

1. Consider the following 5x5 image $x[m,n] = \begin{bmatrix} \underline{0} & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$ filtered by the Laplacian filter $h[m,n] = \begin{bmatrix} 0 & 1 & 0 \\ 1 & \underline{-4} & 1 \\ 0 & 1 & 0 \end{bmatrix}$.

Answer the following questions:

a) Compute the resulting image $y[m,n]$ of filtering $x[m,n]$ with the Laplacian filter.
b) Is the Laplacian filter robust against noise? How can you increase the robustness when filtering?
c) How can you detect contours on the resulting image $y[m,n]$?

2. Consider the following 1D filter defined by the impulse response $h[m] = [1, \underline{0}, 1]$

d) Compute the frequency response, $H(F)$, (note: leave the expression in trigonometric form)
e) Represent the modulus, $|H(F)|$, of the frequency response.

Now we use the same filter to also process the rows of an image, therefore the 2D filter is defined as $h[m] * h[n]$

f) Calculate the values of the 2D impulse response of the filter as a 3x3 matrix.
g) How would you categorize this 2D filter (low-pass, high-pass, band-stop, band-pass)?

3. We would like to compute the discrete wavelet transform of a 2D image using the Haar wavelet: $h_0[n] = \frac{1}{\sqrt{2}}\{\underline{1},1\}$, $h_1[n] = \frac{1}{\sqrt{2}}\{-\underline{1},1\}$, $g_0[n] = \frac{1}{\sqrt{2}}\{\underline{1},1\}$ and $g_1[n] = \frac{1}{\sqrt{2}}\{1,-1\}$.

a) Draw the filter bank decomposition scheme that allows computing one level (scale) of the 2D discrete wavelet decomposition of images.
b) Is the Haar wavelet an orthogonal wavelet? Does the Haar wavelet have linear phase? (justify)
c) If the original image has NxN pixels, where can we find the diagonal wavelet coefficients of scale 1 in the decomposition? Precisely define the area corners.

Problem IV Verónica Vilaplana (1 point)

1. What is the difference between the derivative of a Gaussian filter and the difference of Gaussians filters? Mention one application of each.
2. How do you make a patch descriptor rotationally invariant? How is it done in SIFT?

Problem V Ramón Morros (2 points)

1. After detecting the contours in an image, to find straight lines, the Least Square method proceeds by minimizing the energy functional E = $\|\mathbf{Ap}-\mathbf{y}\|^2$.
    1. Explain how are **A** and **y** formed.
    2. Solve the minimization problem to obtain **p**.

2. For the RANSAC method, the number of iterations can be computed using:

$$k = \frac{\log(1-p)}{\log(1-w^n)}$$

a. Explain the different terms (k, p, w, n) in the equation.
b. Explain how to compute the number of iterations of the above formula if the percentage of outliers is not know *a priori*. Use pseudocode for the explanation.

3. In region growing, describe the most common similarity criterion (the one explained in class).

4. Explain the concept of Region Adjacency Graph (RAG) used in region merging. For the given gray level image and the corresponding partition, construct the RAG using the Approximation of Mean Squared Error as similarity criterion

3	2	1	5
11	13	12	6
19	20	21	7

Gray level image

1	1	1	2
3	3	3	2
4	4	4	2

Partition