Master in Computer Vision Barcelona

UAB UOC UPC upf.

Module: **M1. Introduction to human and computer vision** **Final exam**
Date: November 27th, 2017 **Time: 2h30**
Teachers: Marcelo Bertalmío, David Kane, Ramon Morros, Javier Ruiz, Philippe Salembier, 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.

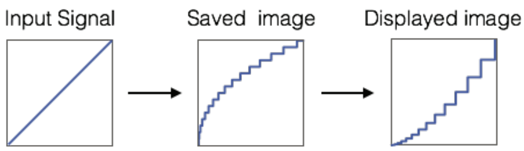
Problem I David Kane (1 point)

1. After much hard work, you develop a novel denoising algorithm that you believe will outperform existing methods. The aim of the algorithm is to reduce the visibility of noise in an image and the algorithm uses a state-of-the-art model of the human visual system to predict the visibility of noise in an image. The algorithm works by attempting to minimize the estimated visibility of noise across the whole image.

   To evaluate the model against other methods you can either run a subjective test to see which denoising method subjects prefer. Alternatively, a number of papers use a state-of-the-art image quality metric (IQM) to evaluate the denoising algorithms instead. The IQM has been developed by an external research group and provides a local estimate of the visibility of noise across an image.

   What are the advantages and disadvantages of using an IQM?

2. A simplified schematic of the image-processing pipeline is shown below. Please (a) describe the encoding and decoding non-linearities (b) explain how this pipeline helps reduce the visibility of quantization artifacts in the displayed image and (c) explain why the pipeline may have to be re-evaluated for high dynamic range displays or different viewing conditions such as a cinema or home computer.



Problem II Marcelo Bertalmío (1 point)

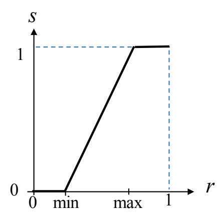
1. What is the color constancy property of the human visual system? How do cameras emulate it?
2. List and briefly explain all the color processing operations that are performed in-camera.

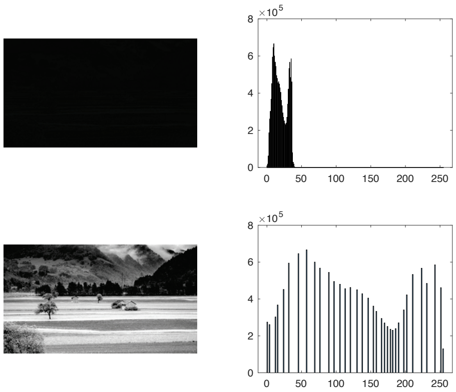
Problem III Philippe Salembier (2 points)

1. We want to increase the contrast of an image. To this goal, we can use either a range mapping as the one described in the figure on the right or an histogram equalization.

   The figure below shows on the first row an original image and its histogram. After contrast enhancement, we obtain the image and the corresponding histogram shown in the second row of the figure.

   Which contrast enhancement technique has been used? Justify your response.





2. Define the notions of Precision, Recall and F-score.

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

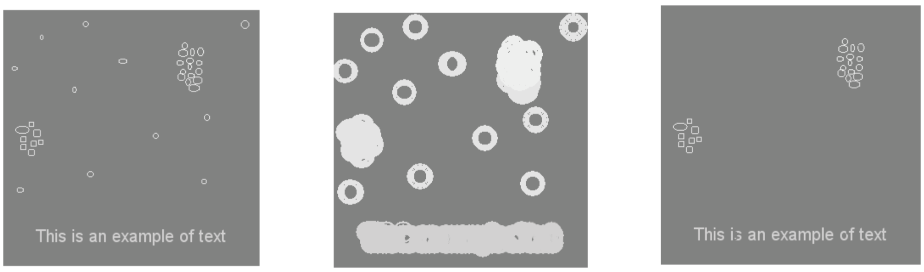
$$\begin{matrix} 0 & -\infty & -\infty \\ -\infty & \underline{-\infty} & -\infty \\ -\infty & 0 & -\infty \end{matrix}$$

Compute the dilation with this structuring element of the following image.

$$\begin{matrix} 100 & 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 100 & 200 & 200 & 200 & 200 & 100 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 100 & 50 & 50 & 50 & 50 & 100 \\ 100 & 100 & 100 & 100 & 100 & 100 \end{matrix}$$

Note: If necessary zero-padding may be assumed.

4. Consider the operator $\psi(f) = \delta_\circ(f) \wedge f$, where f is the original image, $\delta_\circ(.)$ a dilation with an annular structuring element (not a disc) centered on the space origin (without including it).
   a) Analyze de algebraic properties of $\delta_\circ(.)$ to define whether it is extensive, increasing and idempotent.
   b) Assuming that $\psi(.)$ is idempotent, show that $\psi(.)$ is an opening.
   c) The opening $\psi(.)$ is known as the annular opening. The following figure shows a processing example. What is the practical interest of this opening?

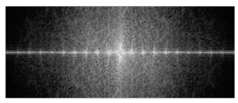


Original image: f — Dilation: $\delta_\circ(f)$ — Annular opening: $\psi(f)$

Problem IV	**Javier Ruiz**	**(3 points)**

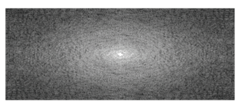
1. Justify which modulus of the DFT (centered representation on the right) corresponds to which image (on the left).

(A)



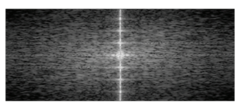
(a)

(B)



(b)

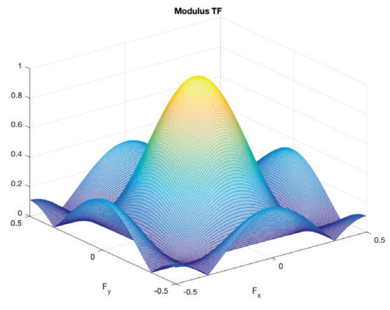
(C)



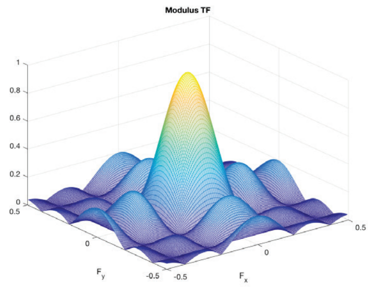
(c)

2. Using the modulation property of the Discrete Fourier Transform (DFT), express the DFT of MxN samples of the image $\tilde{x}[m-1,n]$ (periodic version of x[m,n]) in terms of $X[k,l]$, the DFT of MxN samples of x[m,n]

3. Consider two average filters of size 3x3 and 5x5. Justify which filter size corresponds to which modulus of its Fourier Transform.



(a)

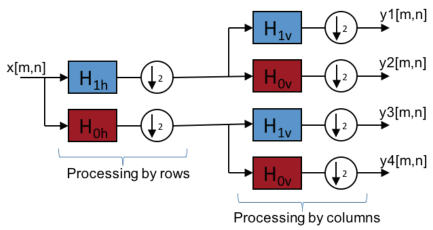


(b)

4. Enumerate the three impulse responses that can be used to approximate the vertical gradient $\frac{\partial f(x,y)}{\partial y}$ of an image $f(x,y)$. How can they be used to detect contours in an image?

5. Given a decomposition of an image X into a laplacian pyramid elements with 3 levels: L_1, L_2 and X_3. Give the steps and equation to re-construct image X from L_1, L_2 and X_3 (use F_i to denote the blur-and-upsample operator at level i of the pyramid).

6. Given the following wavelet decomposition of an image x[m,n], draw the corresponding filter-bank to reconstruct the image from the decomposition y_1[m,n], y_2[m,n], y_3[m,n] and y_4[m,n] (consider H_0, H_1, G_0 and G_1 bi-orthogonal filters).



Problem V	**Verónica Vilaplana**	**(1 point)**

1. **Canny's edge detection:**
   a. Calculating the gradient magnitude and angle is part of the Canny's method. Below you can see a part of an image $f(x,y)$

f(x,y)

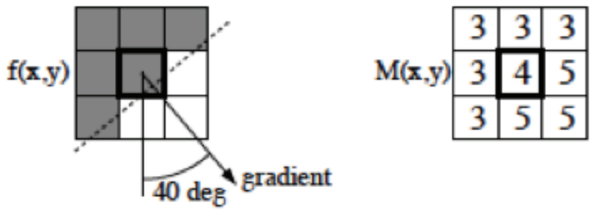
2	3	3	3	3	3
1	2	2	3	3	3
0	0	2	2	2	3
0	0	0	0	1	2
0	0	0	0	0	1

Use these two masks

$$h_x = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} / 8 \quad , \quad h_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} / 8$$

to calculate the gradient magnitude $M(x,y)$ and angle at the marked pixel. Note: As you are not allowed to use calculator for this exam, you may define the gradient angle with a closed-form expression involving classic trigonometric functions.

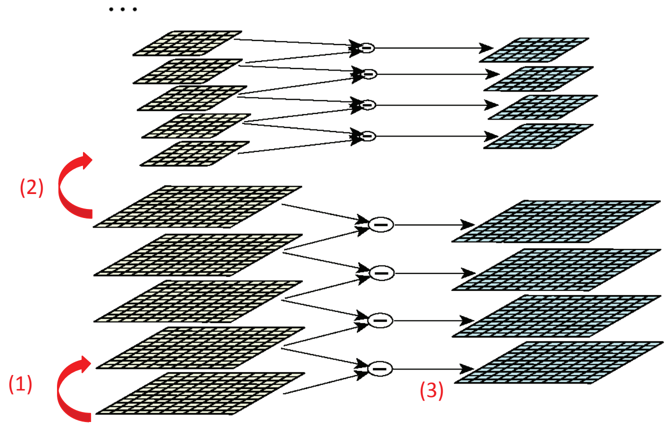
   b. Non-maxima suppression is part of the Canny's method. In the surrounding image $f(x,y)$ illustrated below, the gradient direction in the central pixel is given. Also, the corresponding gradient magnitude $M(x,y)$ is given.



Will the central pixel in $M(x,y)$ be suppressed or not? Describe carefully how you make the decision.

2. Sift detector

The SIFT (Lowe) detector finds keypoints using the image pyramid shown in the following figure



a) Explain which operations are performed in steps (1), (2) and (3).

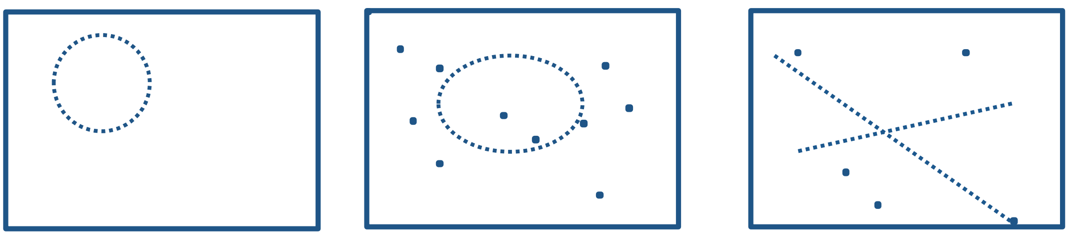
b) Explain how keypoints are found using this pyramid.

Problem VI	**Ramón Morros**	**(2 points)**

1. Let us suppose we are using the Hough transform to find ellipses in an image of WxH pixels. After contour detection, N contour points are found. Give an estimation of the computational complexity of the approach (number of basic operations: additions, multiplications, comparisons, trigonometric). NOTE: The equation describing an ellipse with center (h,k) and semi-axes (a,b) can be written as:

$$h = x - \mathrm{a} \cdot \cos(t)$$
$$k = y - b \cdot \sin(t)$$

2. Given the cases represented in the following figure, discuss the advantages and drawbacks of Least Square (LS) vs. Hough Transform vs. RANSAC to find instances of the given shape(s) in an image.
   a. Single object (circumference), no noise
   b. Single object (ellipse), noise can be present
   c. More than one object (lines), noise can be present



a) b) c)

3. Segmentation using Mean-Shift (MS):
   a. Explain the steps of the mean-shift algorithm for image segmentation in order to obtain an image partition.
   b. In remote sensing, satellite images are often captured with multispectral sensors that capture data at several wavelengths. For instance, Landsat 8 satellite collects data from 9 spectral bands and there are sensors with a larger number of bands. Discuss the application of the MS algorithm in the case of high dimensionality feature spaces.

4. In region growing segmentation, describe the concept of markers.