Master in Computer Vision Barcelona

UAB UOC UPC upf.

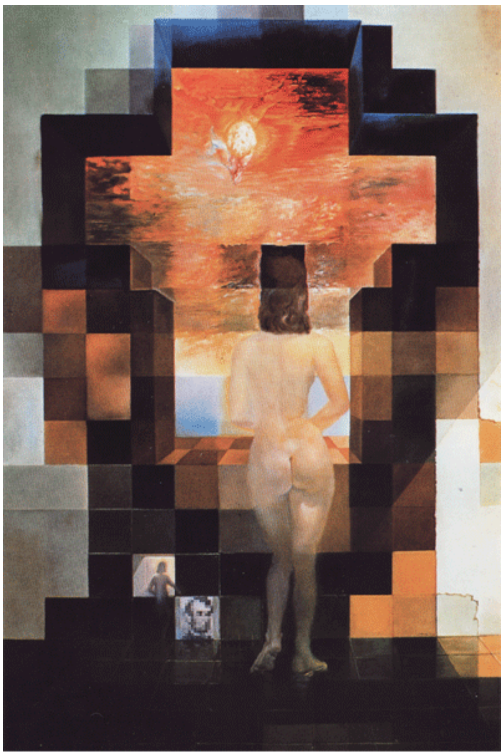
Module: **M1. Introduction to human and computer vision** **Final exam**
Date: November 30th, 2015 **Time: 2h30**
Teachers: Marcelo Bertalmío, David Kane, Ramon Morros, Javier Ruiz, Philippe Salembier, Verónica Vilaplana

- 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: The human visual system (HVS) is capable of operating over a huge range of light levels, from 10^{-3} cdm^{-2} on a clear night, to 10^{7} cdm^{-2} to when looking directly into sunlight. However, the human visual system does not work the same at high and low light levels. Describe some of the differences between human vision at high and low light levels. Please include reference to the activity of (a) retinal rods and cones (b) the perception of color and (c) the perception of coarse and fine details.

2: The painting Gala Contemplating the Mediterranean Sea by Salvador Dalí appears to contain two overlapping images; One of the wife of Salvador Dalí looking out to sea and another of Abraham Lincoln. Describe with reference to the contrast sensitivity function (CSF) of the human visual system (HVS) why the image of Gala is more visible when the viewer stands close to the image and why the image of Abraham is more visible when the viewer stands further away from the image.



Far  view

Near view

Problem II Philippe Salembier (2 points)

1: Consider the following image which is quantized with 4 bits.

$$\begin{array}{cccc} 1 & 4 & 4 & 4 \\ 1 & 4 & 4 & 5 \\ 1 & 5 & 4 & 5 \\ 4 & 5 & 4 & 1 \end{array}$$

Compute the image after histogram equalization.
What is the effect of histogram equalization on the entropy of this image.

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?

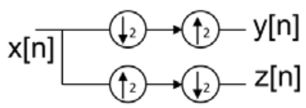
Problem III Marcelo Bertalmío (1 point)

1: Define trichromacy. Prove mathematically this property.

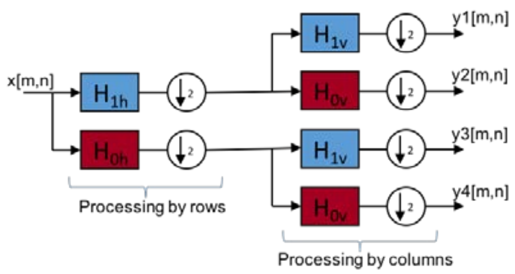
2. List and briefly explain all the color processing operations that are performed in-camera.

Problem IV Javier Ruiz (3 points)

1: Consider the following decomposition using down-sampling and up-sampling processes (without filtering). Express both Fourier Transforms Y(F)=FT{y[n]} and Z(F)=FT{z[n]} as a function of X(F)=FT{x[n]}.

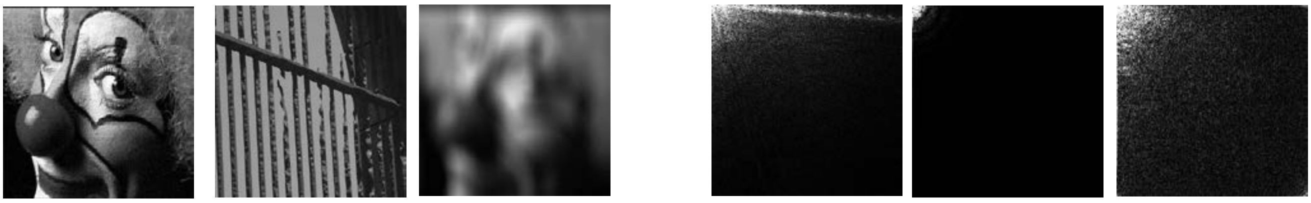


2: Consider the following wavelet decomposition of an image where H0 and H1 correspond to 1D low-pass filter and high-pass respectively. Indicate which image (approximation, horizontal detail, vertical detail and diagonal detail) correspond to each output image (y1[m,n], y2[m,n], y3[m,n] and y4[m,n]) respectively.



3: Enumerate the three discrete impulse responses that can be used to proximate the horizontal gradient $\frac{\partial f(x,y)}{\partial x}$ of an image $f(x,y)$.

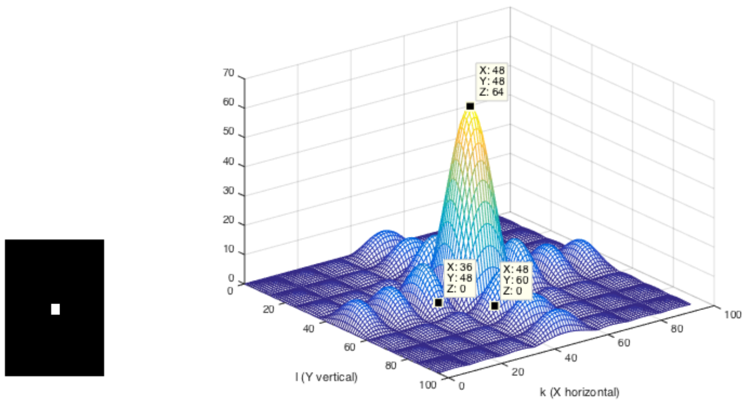
4: Justify which DCT transformation (on the right) corresponds to which image (on the left).



(a) (b) (c) (1) (2) (3)

5: Compute the Discrete Fourier Transform of NxN samples of the image defined by $x[m,n] = \delta[m] + \delta[n]$ with $\delta[k] = \begin{cases} 1 \; if \; k = 0 \\ 0 \; otherwise \end{cases}$

6: Consider the image x[m,n] of 96x96 pixels composed by a black background of level 0 and a white square of level 1 of PxP pixels (Figure a). Figure b represents the magnitude of the Discrete Fourier Transform of 96x96 samples using the centered representation. From the DFT representation, obtain the size P of the white square of the image.

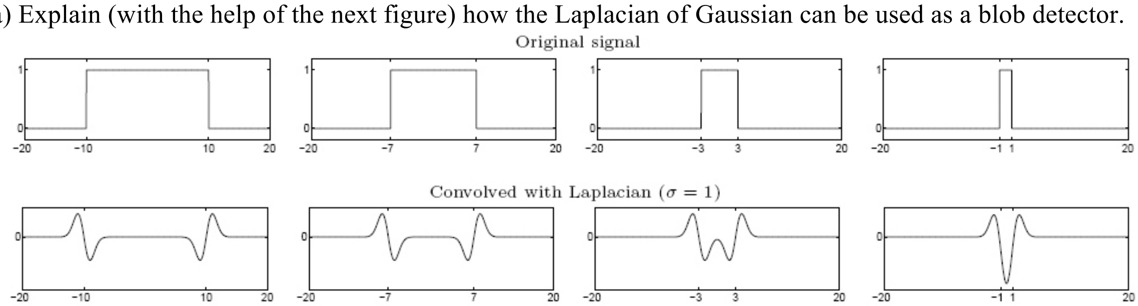


a) Image x[m,n] b) Magnitude of the DFT with 96x96 samples

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

1: a) Define invariance and covariance in the context of key-point detection.
b) Is the Harris corner detector invariant or covariant to (i) affine intensity changes, (ii) image translation, (iii) image rotation, (iv) image scaling?
Why or why not?
c) Give an example of a computer vision application in which corners are more appropriate features to use than, for example, lines.

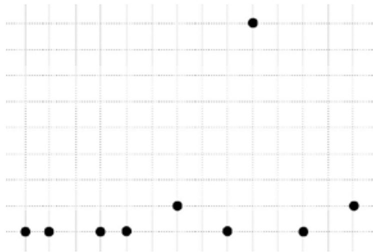
2: a) Explain (with the help of the next figure) how the Laplacian of Gaussian can be used as a blob detector.



b) Why do we need to perform scale normalization?
c) What is the characteristic scale of a blob?

Problem VI	Ramón Morros	(2 points)

1:



After a contour detection step, we obtain a set of contour points with the following coordinates:

$x_0 = (0, 1)$ $x_1 = (1, 1)$
$x_2 = (3, 1)$ $x_3 = (4, 1)$
$x_4 = (6, 2)$ $x_5 = (8, 1)$
$x_6 = (9, 9)$ $x_7 = (11, 1)$
$x_8 = (13, 2)$

We use RANSAC to estimate the parameters of the line (y = ax + b) that better fits the set of points. Three pairs of points are selected randomly to compute three RANSAC iterations: $r_1=[x_1,x_6]$, $r_2=[x_0,x_7]$, $r_3=[x_5,x_6]$.

a) Give the parameters of the line found after the three iterations of RANSAC if the threshold is d = 1.1. Explain concisely the steps performed.

b) Explain how can this result be improved in order to obtain a line that better fits the resulting inliers.

NOTE: the problem can be resolved graphically; hence a calculator is not needed.

2: Segmentation using Mean-Shift:

a) Explain the mean-shift algorithm applied to segmentation in the feature space.

b) Discuss the application of the algorithm in the case of high dimensionality feature spaces.

3: Let's assume we want to segment an image using a region-merging approach. Initially, the similarity between regions is modeled using a criterion based on the approximation of the Mean Squared Error, given by Eq. (1). When segmenting the image, we observe that this criterion leads to noisy contours. Propose a variation of the criterion to obtain regions with smoother contours.

$$C_{color}(R_1,R_2) = N_{R1}\left\|M_{R1} - M_{R1\cup R2}\right\|_2^2 + N_{R2}\left\|M_{R2} - M_{R1\cup R2}\right\|_2^2 \quad (1)$$

4: Schematically explain the Max-Lloyd algorithm used to perform the k-means clustering.