Master in Computer Vision Barcelona

UAB UOC UPC upf.

Module: **M1. Introduction to human and computer vision** **Final exam**
Date: December 3rd, 2018 **Time: 2h30**
Teachers: Marcelo Bertalmío, 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 Marcelo Bertalmío (2 points)

1. Explain the trichromacy property and the experiments to derive the color matching functions.

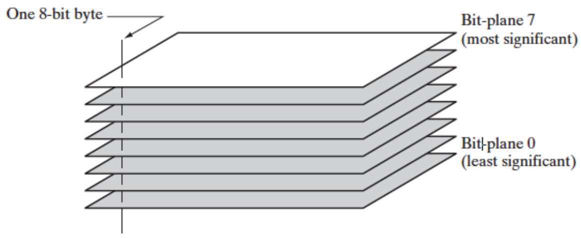
2. Define color constancy and state von Kries law.

3. What were the reasons to propose the XYZ color space alongside RGB? How is the transform from RGB to XYZ, linear or non-linear? Why, for any given display, there are always colors that we can see but that the display is not able to reproduce?

4. Describe the two most popular schemes that cameras use to perform automatic white balance.

Problem II Philippe Salembier (2 points)

1. Assume a gray level image is quantized with 8 bits, we are interested in highlighting the contribution of specific bits to the total gray level appearance. Consider that the image is composed of eight "1-bit planes", ranging from bit-plane 0 for the least significant bit to bit-plane 7 for the most significant bit, as shown in the figure below:



Separating a digital image into its bit-planes (bit-plane slicing) is useful for analyzing the relative importance played by each bit of the image.

a. The images below correspond to bit-planes 3 and 7 of the original image on the left. Could you tell which image corresponds to which bit-plane and why?

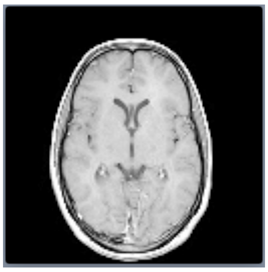

Original image


bit-plane X


bit-plane Y

b. Propose a set of range transforms $s = T_i(r)$, $0 \leq i < 8$ capable of producing all the individual bit-planes (i) of an 8-bit gray level image. Note: You may define the range mapping either through a graphic representation (which is probably easier) or through an analytical formula.

2. You have to segment a set of 10.000 Magnetic Resonance Images (MRI) similar to the one shown on the right side of the page. You want in particular to extract pixels corresponding to the cerebrospinal fluid. From this dataset, you also have access to a set of 50 images which have been manually segmented by experts in MRI analysis.



After analyzing a reasonable set of images, you conclude that cerebrospinal fluid areas are sufficiently contrasted and that you may use a simple thresholding technique to extract them.

Describe precisely how you would define the parameters of the algorithm so that optimal results are obtained.

3. In image processing on a square grid, the Laplacian operator estimates the sum of second partial derivatives of the image with respect to the vertical and the horizontal coordinates.
   a. This operator can be implemented through a linear translation invariant (LTI) filter. Define its impulse response and explain how this impulse response is related to LTI filters that estimate the first derivative of the image. Illustrate the behavior of the filters on a simple transition between a dark object to a bright object.
   b. In mathematical morphology, there exist three operators that are related to the estimation of the first derivative of an image. Define these operators and illustrate their behavior on a simple transition between a dark object to a bright object
   c. Relying on the tools discussed in the previous point, propose a morphological Laplacian operator that would also estimate the sum of second partial derivatives of the function with respect to the vertical and the horizontal coordinates. Finally, illustrate the behavior of this operator on a simple transition between a dark object to a bright object.

4. Define whether an erosion with an arbitrary structuring element is increasing, anti-extensive and idempotent. In case the property does NOT hold, find a counterexample illustrating the lack of the property.

Problem III Javier Ruiz (3 points)

1. Consider three filters of size 3x3 whose impulse responses are:

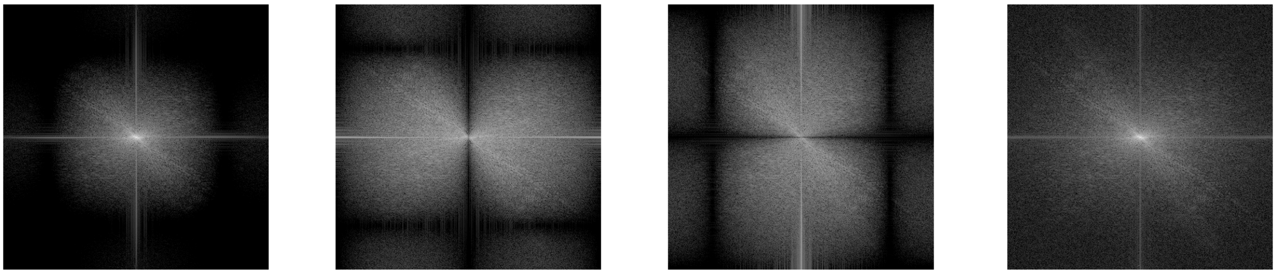
$$h_1[m,n] = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \qquad h_2[m,n] = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \qquad h_3[m,n] = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

Consider the input image x[m,n] shown on the top row of the following figure. **Justify** which images on the bottom row correspond to the outputs of the three filters above (please note that the output images have been transformed so grey levels match the input image dynamic range):

Input image x[m,n]

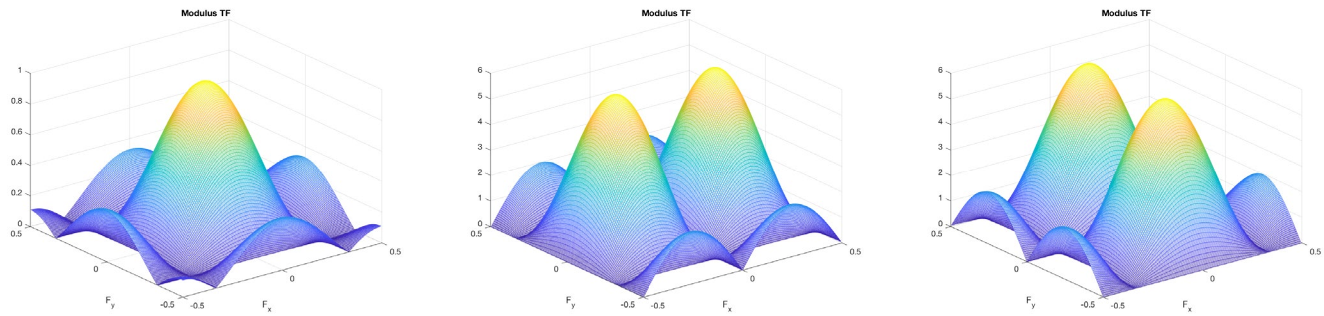
(a) (b) (c)

2. Using the same filters of the previous question **justify** to what images (input image, filtered with h_1, filtered with h_2 or filtered with h_3) correspond the following modulus of the Discrete Fourier Transform (centred representations):



(a) (b) (c) (d)

3. Using the same filters of the previous question justify which filter corresponds to which modulus of its Fourier Transform.

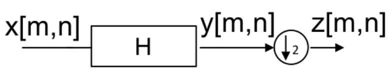


(a) (b) (c)

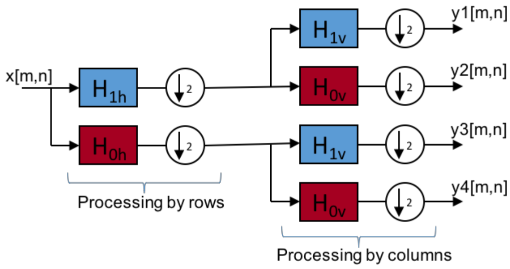
4. Under which condition the Discrete Fourier Transform of MxN samples of an image, X[k,l], represents the sampled version of its Fourier Transform $X(F_x,F_y)$?

$$X[k,l] = X(F_x,F_y)\Big|_{F_x=\frac{k}{M},F_y=\frac{l}{N}}$$

5. Consider the following system using an anti-aliasing filter H and a down-sampling process by a factor of two in both the horizontal and vertical dimensions.
What would the ideal anti-aliasing filter be? What would its cut off frequency be?



6. 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.



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

1. The Canny edge detector uses three parameters, *sigma, low_threshold, high_threshold*. Explain what do these parameters control and what is the effect of increasing / decreasing their values.

2. Explain the basic idea of the Harris corner detection algorithm. Use the notion of eigenvalues and thresholds on these. How can an edge be defined in terms of the eigenvalues defined above?

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

1. Segmentation with region merging
   The similarity criterion for a region merging segmentation algorithm is given by:

   $$C(R_1, R_2) = \alpha C_{color}(R_1, R_2) + (1-\alpha) C_{cont}(R_1, R_2)$$

   where:

   $$C_{color}(R_1, R_2) = N_{R1} \| M_{R1} - M_{R1 \cup R2} \|_2^2 + N_{R2} \| M_{R2} - M_{R1 \cup R2} \|$$
   $$C_{contour}(R_1, R_2) = -Length\ of\ common\ contour$$

   a) Explain the operation of the region merging algorithm.
   b) Describe the effects of the two components C_{color} and $C_{contour}$. Particularize the explanation for the two particular cases where $\alpha = 0$ and $\alpha = 1$.

2. RANSAC algorithm
   a) A key parameter in the RANSAC algorithm is the threshold used to determine if a given point is an inlier or an outlier. Explain the effect of using a too small or too large value for this parameter when using RANSAC to obtain the parameters of a line given a set of contour points in an image.
   b) Let's assume that, for each point, we have a quality score that measures the likelihood of the point belonging to the model. Explain how these scores can be used to improve the operation of the RANSAC algorithm (This is known as the PROMEDS algorithm)