Master in Computer Vision Barcelona

UAB UOC UPC upf.

Module: **M1. Introduction to human and computer vision** **Final exam**
Date: December 2nd, 2013
Teachers: Marcelo Bertalmío, Ramon Morros, Albert Oliveras, Nava Rubin, Javier Ruiz, Verónica Vilaplana **Time: 2h30**

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

Part I

1: Explain what is the shape of the color gamut of a display device, plotted in xy chromaticity coordinates, and what is the reason for this shape. Explain why, for any device, there are always colors that we can perceive but that the display is not able to reproduce.

2: Explain the two most popular techniques for in-camera automatic white balance.

Part II

3: The following Matlab program generates the granulometry ('pecstrum') shown in figure 1 of the 'circles' image of figure 2.

```
I = imread('circles.jpg');
imagesc(I);colormap('gray');
max_size = 16;
x = ((-max_size+1):max_size);
pecstrum = granulometry(I,'disk',max_size,'mav');
figure(1), plot(x, -derivate(pecstrum)), grid, title('Derivate Granulometry with a
''disk'' as SE')

function pecstrum = granulometry(A, type_SE, steps, measure)
for counter = 1:steps
    remain = imopen(A, strel(type_SE, counter-1));
    pecstrumA(counter) = sum(abs(remain(:)));
    remain = imclose(A, strel(type_SE, counter-1));
    pecstrumB(counter) = sum(abs(remain(:)));
end
pecstrum = cat(2, fliplr(pecstrumB), pecstrumA);
end
```

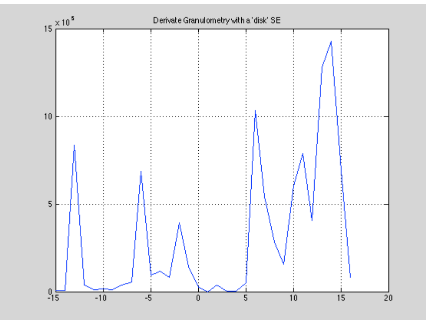


Figure 1: "pecstrum"

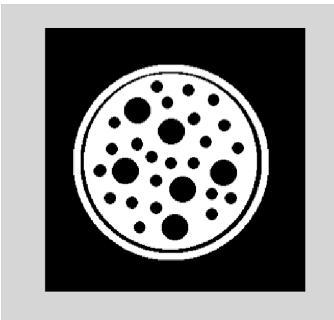


Figure 2: "circles"

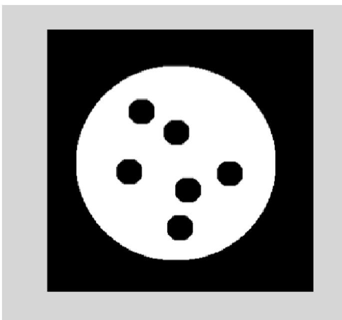
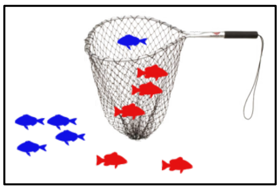


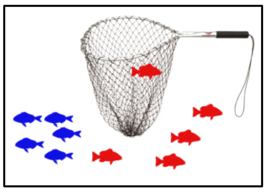
Figure 3

Write a Matlab program that generates the image of figure 3 from the image 'circles' and explain the purpose of each instruction.

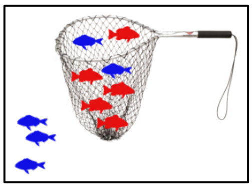
4: In the context of a fishing game for kids, where the objective is to fish all the red fishes, 3 players get the following results:



Player 1



Player 2



Player 3

As it is not a trivial situation to evaluate, we decided that the winner will be assessed on F measure (harmonic mean of precision and recall). To get an ordered list of the players, fill the following table:

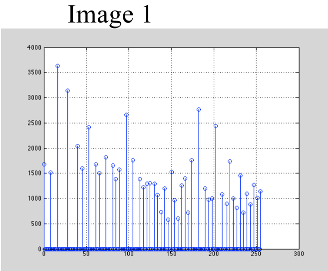
	Player 1	Player 2	Player 3
TP			
T			
P			
Precision			
Recall			
F measure			

5: Find and explain the correspondence between the following images and histograms.

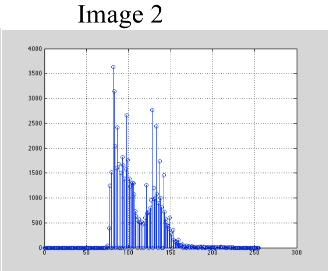
Image 1

Image 2

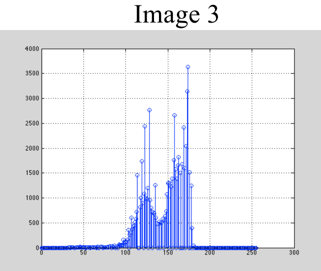
Image 3



Histogram 1



Histogram 2



Histogram 3

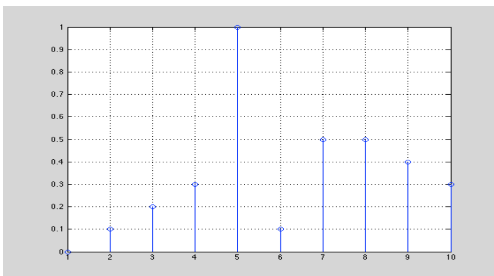
Explain your reasoning:

	Histogram Number
Image 1	
Image 2	
Image 3	

6: Write the mathematical expressions of the following operations: Dilation, Erosion of a 1D signal x[n] with a Structuring Element b[n]: $\delta_b\{x[n]\} = x[n] \oplus b[n] =$

$$\varepsilon_b\{x[n]\} = x[n] \Theta b[n] =$$

According to the previous definitions, draw in the following graphic the corresponding dilation and erosion of the discrete signal x[n] by a flat structuring element $b[n] = \{-\infty, .., -\infty, \underline{0}, 0, 0, -\infty, .., -\infty\}$



Part III

7: In Mean-Shift segmentation, which parameter has to be specified? Discuss its influence in the final segmentation result.

8: K-Means vs. GMM/EM (Expectation Maximization) segmentation: which are the parameters needed in either case to represent the clusters during the iterative steps of the algorithms? Comment the pros and cons of each algorithm.

9: Let us suppose we are using the Hough transform to find circles in an image (using a naïve implementation). 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 a circle with center *(a,b)* and radius *r* can be written as:

$$a = x - r\cos(t)$$

$$b = y - r\sin(t)$$

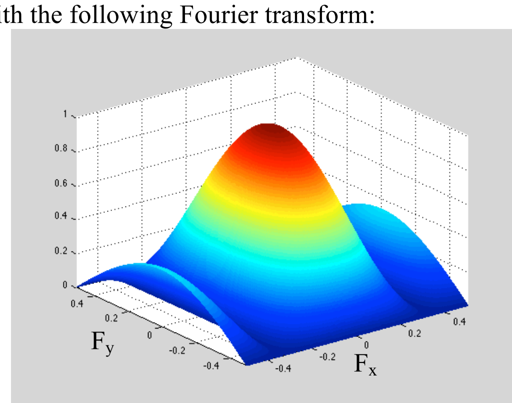
10: Discuss the advantages & drawbacks of LS vs. Hough Transform vs. RANSAC to find instances of a given shape in an image.

Part IV

11: Compute the Fourier transform, indicating the value in $F_x=0$ and $F_y=0$, of the image of MxM pixels defined by

$x[m,n] = \delta[m]$ with $\delta[m] = \begin{cases} 1 \; if \; m = 0 \\ 0 \; otherwise \end{cases}$

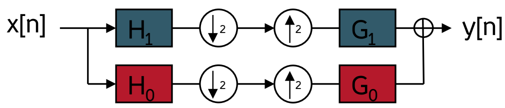
12: Consider the average filter h[m,n] with the following Fourier transform:



Justify the dimensions MxN (M columns and N rows) of the impulse response of the average filter h[m,n].

13: Enumerate the laplacian pyramid elements and the steps needed to construct it from an image X for 3 levels of the pyramid (use G_i to represent the blur-and-downsample operator and F_i to denote the blur-and-upsample at level i of the pyramid).

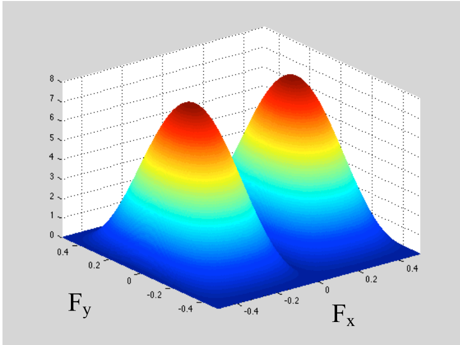
14: Consider the following filter bank decomposition of a 1D signal x[n]. Justify the conditions on the filters H_0, H_1, G_0 and G_1 to achieve perfect reconstruction.



If $H_0=G_0$ correspond to two low pass filter with cut-off frequency $F_c=1/4$ and $H_1=G_1$ correspond to high pass filters with $F_c=1/4$, justify that they are bi-orthogonal.

15: Discuss the advantages and disadvantages of the Discrete Cosine Transform (DCT) versus the Karhunen-Loeve Transform (KLT).

16: Justify which sobel filter ($\boldsymbol{h_1[m,n]} = \begin{bmatrix} \mathbf{1} & \mathbf{2} & \mathbf{1} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{-1} & \mathbf{-2} & \mathbf{-1} \end{bmatrix}$ or $\boldsymbol{h_2[m,n]} = \begin{bmatrix} \mathbf{1} & \mathbf{0} & \mathbf{-1} \\ \mathbf{2} & \mathbf{0} & \mathbf{-2} \\ \mathbf{1} & \mathbf{0} & \mathbf{-1} \end{bmatrix}$) corresponds to the frequency response below. What kind of contours does it detect?



Part V

17: Edge Detection

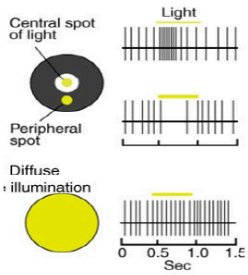
Compare the Canny edge detector and the Laplacian-of-Gaussian (LoG) edge detector for each of the following questions.
(a) Which of these operators is/are isotropic and which is/are non-isotropic?
(b) Describe each operator in terms of the order of the derivatives that it computes.
(c) What parameters must be defined by the user for each operator?
(e) Which detector is more likely to produce long, thin contours? Briefly explain

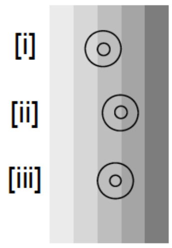
18: Corner detection

The Harris corner detection algorithm computes a 2×2 matrix at each pixel in terms of derivatives at that point and then computes the two eigenvalues of the matrix, λ_1 and λ_2, where $\lambda_1 \leq \lambda_2$.
(a) Which are the elements of the matrix?
(b) How can the two eigenvalues be used to label each pixel as either a locally smooth region (S), an edge point (E), or a corner point (C)? Give your answer by specifying "Label pixel S if …", "Label pixel E if …" and "Label pixel C if …"

Part VI

19:



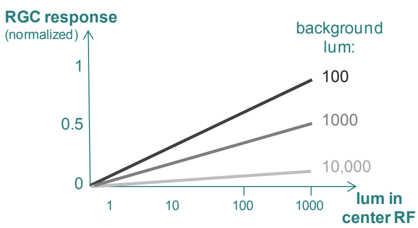


The left figure (taken from the slides shown in class) shows how a typical retinal ganglion cell (RGC), with a center-surround receptive field of type "ON-center", responds in lab experiments. Three cases are shown: when light is projected only on its center (top panel), only in the surround region (middle) or diffusely all over its receptive field (bottom panel).

For the image shown on the right (vertical stripes of different gray levels), consider three such RGCs with receptive field locations as marked (denoted by [i]-[iii]). For each, indicate whether it will produce <u>more</u>, <u>less</u> or the <u>same</u> number of spikes/sec (on average), compared with its response to a homogeneous gray image.

[i] ________ [ii] ________ [iii] ________

20:



Experiments have shown that RGCs responses can be affected also by changes in the amounts of light falling *outside* their receptive field (RF) center- and surround- regions. Specifically, as shown in the schematic diagram above (taken from the slides shown in class), the average level of luminance in the "background" (a few degrees outside the RF of each RGC) will affect the gain of the cell's response to light within its RF center.
A. What is the purpose of this phenomenon? (ie, what is its computational advantage?)
B. How is it called?
C. What mechanism serves a similar purpose in a film-based (non-digital) camera?
D. What is the main advantage of the RGC mechanism, compared to that of the camera?
E. (Optional – extra points) How is this mechanism achieved (implemented) by RGCs?