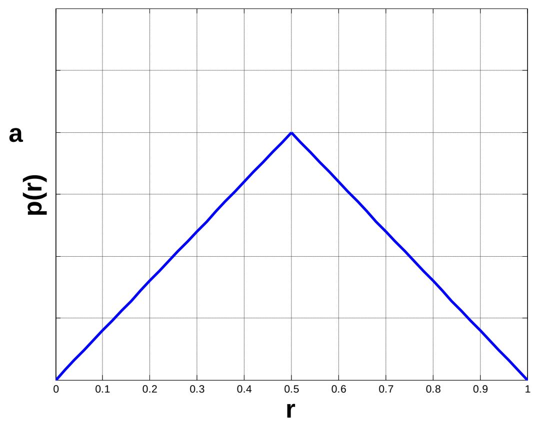
Problem 1

1a) Consider the image grayscale, r, to be a continuous random variable with the range [0,1] and the probability density function p(r), as in the figure below (p(0)=0, p(0.5)=a, p(1)=0). The image is subject to a grayscale transformation s=T(r) so that the probability density function of the output image, p(s), becomes a constant. Find the transformation T(r) and plot it.

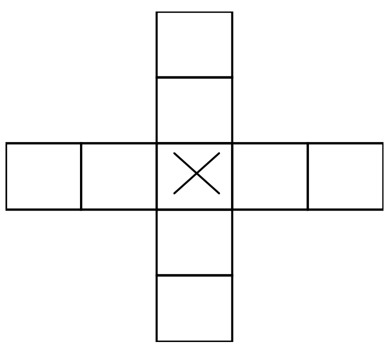
(7 p)



1b) What is the difference between image quantization and image binarization ?

(1p)

1c) What is the median value as applied to the center of the input image f(x,y) using the following neighborhood for median filtering:



f(x,y):

49 46 50 22 21
50 48 51 51 21
50 48 52 53 54
45 38 75 76 74
32 44 46 47 48

(2p)

Problem 2

2a) The image below presents a partial solar eclipse (occultation). The Sun is light, the moon is dark.

Write an algorithm for the Sun and the Moon detection using the Hough transform, where the objects (the sun and the moon) are assumed to be circular. Note that you should develop **your own** Hough transform algorithm (including parameter space investigation and voting). Consider two cases:

(1) when the centers of the objets are known
(2) when the centers of the objects are unknown

Note: The solutions/algorithms should be written in such a way, that they can be easily used for writing a computer program (= implementation).

(6p)

2b) We are detecting straight lines in a grayscale image and perform the Hough Transform in $\boldsymbol{s}, \boldsymbol{\theta}$ space, i.e. we represent the lines as

$$s = x\cos(\theta) + y\sin(\theta)$$

The above Hough transform resulted in the two most frequent points:

(1) Point # 1 : s = 10 , θ= 30°
(2) Point # 2: s = 30, θ= 0°

What are equations for these two most likely lines (represented by the above two points) using the common line representation $y = kx + q$?

(4p)

Problem 3

3a) Explain the difference between ACM (Active Contour Modelling) and ASM (Active Shape Modeling).

(2p)

3b) Explain the property called "Textural Entropy", for grayscale images. Construct/draw two grayscale images with different textural entropies and explain which image has the higher textural entropy.

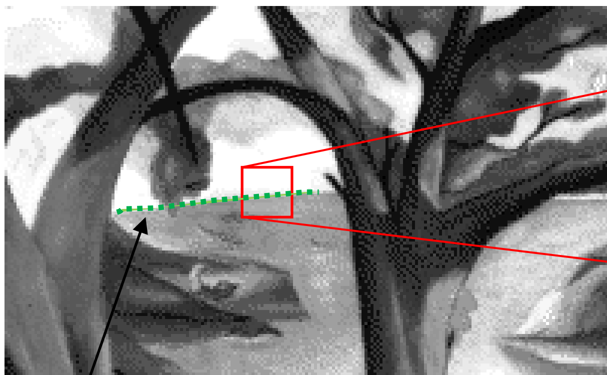
(5p)

3c) Describe shortly the main steps of the Mean Shift image segmentation.
What are advantages of the Mean Shift segmentation algorithm compared to other segmentation techniques ?

(3p)

Problem 4

4a) Suppose that we want to detect the horizon line in the image below.



f(x,y):

y

4	4	4	4
4	4	4	4
2	3	3	2
2	3	3	3

x

Horizon line (to be detected)

Apply Dynamic Programming for detecting the horizon line (the optimal path from the left to the right border) of the image f(x,y), above, representing a part of the original image. The values in the image f represent the grayscale values (intensity). The answer should include the cost accumulation matrix with back tracing pointers and the coordinates of the optimal path.

(10p)

Problem 5

Below you find one input image (normalized 0..1) and five output images. There is also a list of ten image analysis procedures. The task is to link each output image to a specific procedure (1-a, 2-b, etc.). Each correct link will give one point. For each link, an additional point will be given, if you can clearly justify your choice.

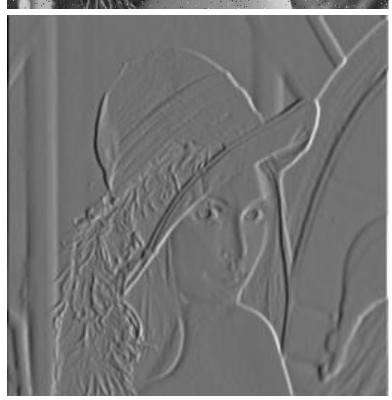
(10 p)

1

2

3

4



5

(a) Canny filter
(b) Gaussian noise
(c) Square transformation
(d) Reconstruction using Fourier amplitude
(e) Logarithmic transformation
(f) Sobel filter horizontal
(g) Mean shift segmentation
(h) Sobel filter vertical
(i) Reconstruction using Fourier phase angle
(j) Salt and peppar noise

Problem 6

6a) Given two input images, I_1 and I_2, compute the optical flow value, i.e. velocity components U and V, at point (3,3). The upper left corner of the images has the coordinate (1,1). Run the algorithm for two iterations and set the weighting factor λ=0.5.

$$I_1 = \begin{bmatrix} 2 & 2 & 2 & 0 & 0 \\ 2 & 2 & 2 & 0 & 0 \\ 2 & 2 & 2 & 0 & 0 \\ 2 & 2 & 2 & 0 & 0 \\ 2 & 2 & 2 & 0 & 0 \end{bmatrix} \qquad I_2 = \begin{bmatrix} 2 & 2 & 0 & 0 & 0 \\ 2 & 2 & 0 & 0 & 0 \\ 2 & 2 & 0 & 0 & 0 \\ 2 & 2 & 0 & 0 & 0 \\ 2 & 2 & 0 & 0 & 0 \end{bmatrix}$$

Applied to I_1, calculate I_x and I_y using the filters [1 0 -1]/2 and $\begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix}/2$, respectively.

For calculating the average velocities, use the filter $L = \begin{bmatrix} \frac{1}{12} & \frac{1}{6} & \frac{1}{12} \\ \frac{1}{6} & 0 & \frac{1}{6} \\ \frac{1}{12} & \frac{1}{6} & \frac{1}{12} \end{bmatrix}$

(7 p)

6b) Explain the importance of λ. What happens with the velocity field when $\lambda \to \infty$?

(2p)

6c) What are the limitations of the Optical Flow algorithm ?
What may cause the algorithm to fail ?

(1 p)