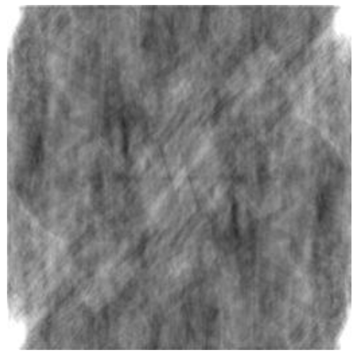
Problem 1

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)

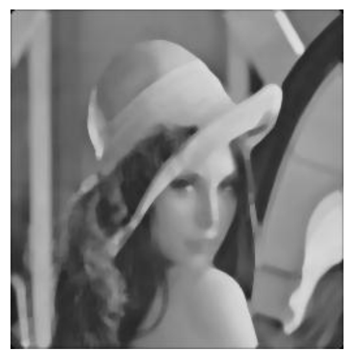


1

2

3

4



5

(a) Median filtering
(b) Homomorphic filtering
(c) Square transformation
(d) Reconstruction using Fourier phase angle
(e) Logarithmic transformation
(f) Reconstruction using Fourier phase and amplitude
(g) Binarization
(h) Canny filter
(i) Reconstruction using Fourier amplitude
(j) Histogram equalization

Problem 2

2a) What is the output of the median filter of size 3x3x3 as applied to the underlined pixel of the input image f(x,y,z) ? Assume that pixel values outside the image are equal zero.

f(x,y,z=50):	f(x,y,z=51):	f(x,y,z=52):
50 48 52	99 <u>**47**</u> 32	45 55 65
45 38 75	41 58 39	39 49 59
32 44 46	46 43 52	40 53 38

(1p)

2b) A grayscale input image X, normalized to values between 0..1, is subject to the two following transformations: First we calculate the $\log_2(X)$ and directly after that we apply the exponential transformation. In other words, the output image Y is:

$$Y = \exp\left(\log_2(X)\right) = e^{\log_2(X)}$$

Will the output image Y be **darker, lighter or unchanged**, compared to the original input image X? Plot the corresponding gray-level transformation.

(3p)

2c) What is the Fourier transform of the filter below (assume sampling interval Δ=1):

1 0 0
0 2 0
0 0 -1

(1p)

2d) Calculate the **gradient magnitude** and the **gradient direction** in the position of the center (underlined) pixel in the image below. Use Sobel or Prewitt edge detection filter.

(5p)

5 4 3 2 1
4 5 4 3 2
3 4 <u>**5**</u> 4 3
4 5 4 5 4
1 2 3 4 5

Problem 3

3a) The size of a binary image is 8 x 4 (8 rows and 4 columns). What is the size of the corresponding GLCM (gray level co-occurrence matrix)?

(1p)

3b) The textural feature Entropy (calculated from a GLCM for direction 0 degrees and distance d=1) is equal ZERO for the image as in (3a).
Find the corresponding GLCM and images that can generate such a GLCM.

The Entropy is defined as:

$$Entropy = -\sum_{i,j} p(i,j) \cdot \log_e(p(i,j))$$

where i, j are gray levels and p(i,j) are the corresponding probabilities.

(4p)

Note that by convention $x \cdot \log_e(x) = 0$ for $x = 0$, (since $\lim_{x \to 0} x \cdot \log_e x = 0$).

3c) Compute the texture feature Contrast (from the *normalized* GLCM) for the 7 x 3 image below ($dx = +1, dy = \pm 2$).

(4p)

3 4 3
4 3 4
3 4 3
4 3 4
3 4 3
4 3 4
3 4 3

3d) Explain the difference between *supervised* and *unsupervised* classification.

(1p)

Problem 4

4a) Show that the sum of the regular second order moments $m_{2,0} + m_{0,2}$ is rotationally invariant. Here, the $m_{0,2}$ and $m_{2,0}$ are regular moments for an image function $f(x,y)$ defined as:

$$m_{i,j} = \sum_{x,y} x^i\, y^j f(x,y) \quad i = 0,1 \ldots j = 0,1, \ldots$$

(3p)

4b) Suppose that we are searching a horizontal edge in an image of size NROWS x NCOLS, using dynamic programming (DP). The edge starts at the first column and ends at the last column. How much faster is DP, compared to the exhausted search (brute force method), for this kind of problem?

(2p)

4c) Explain the terms *sensitivity* and *specificity* in the context of detecting objects of interest (e.g. object and background) in 2-D images?

(1p)

4d) Explain the relationship between the *mean shift filtering* and the *mean shift segmentation* ?

(1p)

4e) Explain the importance of the constant λ in the optical flow algorithm.

(1p)

4f) What is the difference between *a snake* and *a live-wire* ?

(1p)

4g) Which of the guest lectures was the most interesting?

(1p)

Problem 5

5a) The image below presents a partial solar eclipse (occultation). Describe how to find the position (center and radius) of the sun and the moon using the Hough transform. Give some numerical examples.
Note: The Sun is light, the moon is dark.

(9 p)

5b) What is the Hough transform of just one pixel? (1p)

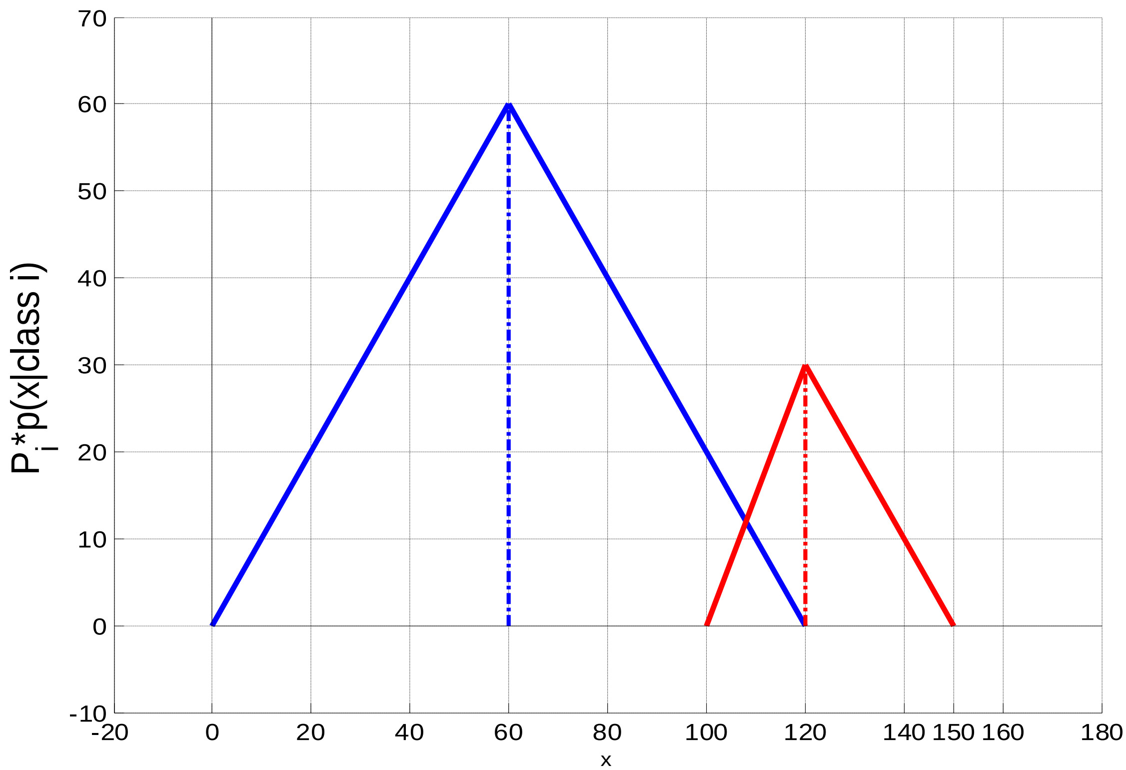
Problem 6

6a) A microscope image that presents cells against background should be segmented by thresholding. The thresholding should be carried out so that the total number of misclassified pixels is minimized. The diagram below shows the estimated histograms for the background and the cell pixels.

Find the optimal threshold value T_{opt} for this segmentation problem and the corresponding value *of minimum error.*

The triangular distribution to the left represents $P_1 \cdot p(x|background)$, while the distribution to the right represents $P_2 \cdot p(x|object)$.
P_1, P_2 - a priori probabilities of background and object.

(4p)



6b) See the next page, page 6.

6b) A 3 x 6 image is shown below. As can be seen, the image consists of "concentric" layers. The coordinates of the inner layer are (1, 3), (1, 4), (1, 5), and (1, 6). For each position (x, y) in the image there is an associated cost c, e.g. c(2, 1) = 8. The problem is to find all the paths from the **inner** layer to the **outer** layer (two travel steps are required for each path) so that the cumulative cost is minimized. Each layer may only be visited once. The allowed travel directions are **north, east, and north-east**. There is a penalty term **p = 1** associated with the travel directions north and east. For the travel direction north-east **p = 0**. The result should present the optimal path(s), e.g. by specifying the three coordinate pairs of this path. It should also present the values of the cumulated travel costs in the form of a 3 x 6 cumulative matrix with clearly indicated back tracing pointers.

(6p)

	1	**2**	**3**
1	7	8	8
2	5	5	2
3	6	6	4
4	6	6	7
5	4	4	6
6	4	5	7

← image x coordinate

image y coordinate

Inner layer consists of pixels: (1,3), (1,4), (1,5) and (1,6) ← (x,y)
Middle layer: (1,2), (2,2), (2,3), (2,4), (2,5) and (2,6)
Outer layer: (1,1), (2,1), (3,1), (3,2), (3,3), (3,4),(3,5) and (3,6)

Allowed travel directions: