1) The input image below (upper left) has been subject to five different image processing operations (1-5), each of which has caused a problem to perceived (subjective) image quality. Below you will find a list of 5 procedures (a-b) and 5 problems (I-V). The task is to link each image to a specific procedure and problem (e.g. 1-a-I, 2-b-II, etc). Each correct linking will give you two points. (10 p)

1

2

3

4

5

a) Ideal low-pass filtering b) Median filtering c) Butterworth low-pass filtering
d) Interpolation e) Gray level reduction
I) Loss of corners and small details II) Ringing III) Loss of contrast resolution
IV) Jagged boundaries V) Loss of detail resolution

2a) Consider the discrete version of the two-dimensional Laplace operator h(x,y):

1 1 1
1 -8 1
1 1 1

Suggest the filter coefficients of a similar three-dimensional Laplace operator h(x,y,z). and present them by three arrays as indicated below:

$h(x,y)_{z=-1}$:	$h(x,y)_{z=0}$:	$h(x,y)_{z=+1}$:	
a b c	j k l	s t u	
d e f	m n o	v y z	
g h i	p q r	å ä ö	(4p)

b) Suggest the filter coefficients of a two-dimensional filter tuned to detect edges oriented 45 degrees with respect to the horisonal axis. The filter output should be zero in areas of the image where all the pixel values are the same. (3p)

c) What is the median value as applied to the center of the input image f(x,y,z)

$f(x,y)_{z=50}$:	$f(x,y)_{z=51}$:	$f(x,y)_{z=52}$:	
50 48 52	99 47 32	45 55 65	
45 38 75	41 58 39	39 49 59	
32 44 46	46 43 52	40 53 38	(1p)

What is the Fourier transform of the filter below:

1 2 3
4 5 4
3 2 1 (2p)

3a)

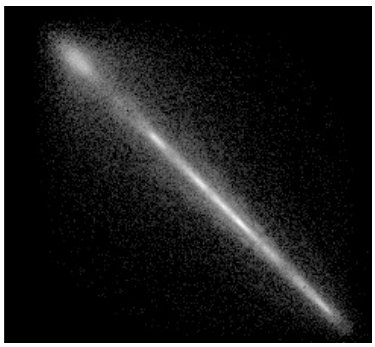
Combine the (numerical) image, verbal statement, and GLCM plot (e.g. 1 - I - A). Each correct combination gives 1 point. If you can motivate your choice you get an additional point for each correct motivation. If the motivation is clearly wrong, you get a minus point. The coordinate system is oriented as x = east, y = south. (6p)

3 1 2 5 2 5	7 6 6 7 7 6	2 6 1 8 2 9
9 2 5 2 8 2	2 2 3 2 3 3	2 7 2 9 1 8
3 8 2 6 2 7	6 6 5 6 6 5	3 6 1 8 2 8
2 4 9 2 6 2	1 1 2 1 2 2	2 7 2 9 1 8
5 2 3 8 2 5	9 8 8 9 9 8	2 6 1 8 2 9
1	2	3

I. The image presents high frequencies at 0 degrees

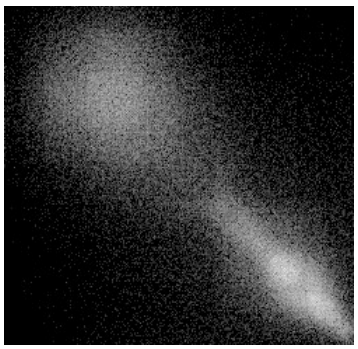
II. The image presents low frequencies at 0 degrees

III The image presents low frequencies at 135 degrees



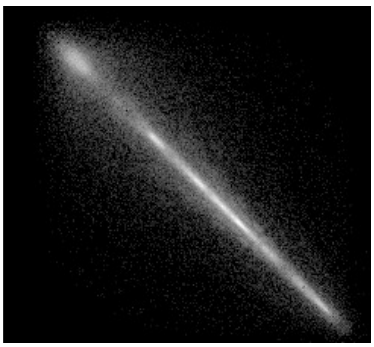
dx = 1, dy = 0

A



dx = 1, dy = 0

B



dx = 1, dy = 1

C

b) Compute the texture feature Contrast (un-normalized) for the 8 x 3 image below (dx = +/- 2, dy = 1). Coordinate system as in a). (4p)

1 2 1 2 1 2 1 2
2 1 2 1 2 1 2 1
1 2 1 2 1 2 1 2

4a) Consider a gradient image f(x,y) where:

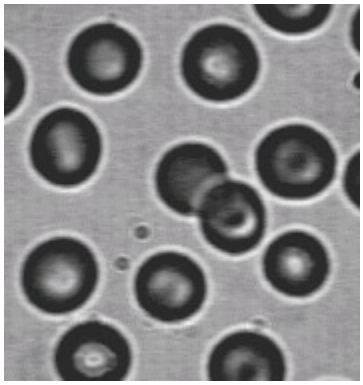
f(0,0) = 1, f(1,0) = 6, f(2,0) = 2, f(3,0) = 7
f(0,1) = 2, f(1,1) = 3, f(2,1) = 1, f(3,1) = 2
f(0,2) = 9, f(1,2) = 6, f(2,2) = 9, f(3,2) = 9
f(0,3) = 2, f(1,3) = 1, f(2,3) = 3, f(3,3) = 4

Apply the Canny edge detector with $T_{low} = 5$ and $T_{high} = 8$. Neighboring pixels are the eight pixels surrounding the center pixels. Which of pixel positions (x,y) will be part of the resulting edge map? (4p)

b) In the microscope image shown below, dark and almost circular blood cells are present against a gray background. Suggest and motivate a suitable algorithm or transform for detecting the cells, even the ones overlapping and partly located outside the image.

(1p)

c) Describe each step of your detection method. (2p)

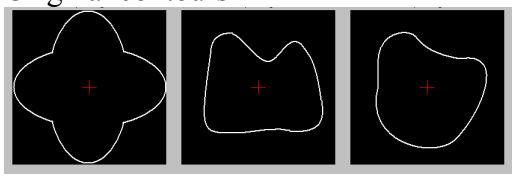


d) Consider the image below. In the middle of the image as you go top-down, the gray area turns to a darker area. Suggest a boundary detection algorithm that could find this transition from gray to dark. (1p)

e) Describe each step of your detection method. (2p)

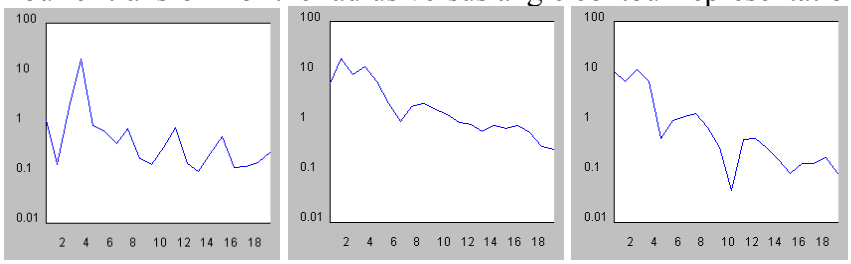
5

Original contours



1 2 3

Fourier transform of the radius versus angle contour representation



A B C

a) Answer correct/not correct to the following proposals:

i) The high forth harmonic of the Fourier transform in A suggests that is has been derived from the original contour 1. (1p)

ii) The low forth harmonic of the Fourier transform in C indicates that is has been derived from the original contour 3. (1p)

iii) The low second harmonic of the Fourier transform in A suggests that the forth harmonic of the same transform should be high. (1p)

iv) The overall higher response of the Fourier transform in B (as compared to A and C) suggest that the original contour is the smoothest. (1p)

b) Explain why the skeletonization algorithm referred to as “Attack-from-different-directions” always will result in a one-pixel thick skeleton structure (1p)

c) Why will this algorithm work best for elongated structures? (1p)

d) What happens if a dilation operation is followed by an erosion (1p)

e) What happens if 5 successive dilations are followed by 5 successive erosions? (1p)

f) What is the difference between image processing and image analysis? (1p)

g) What happens if a student on the image analysis course scores 28 points or more? (1p)

6) An object centered at origo has got the following pixel intensities (f(x,y):

f(-1,1) = a
f(1,1) = b
f(0,0) = 1
f(-1,-1)= c
f(1,-1) = d

The sum of the pixel values located on a line that goes through origo and oriented 45 degrees is the same as that of another line passing through origo and oriented perpendicular to the first line.

Applying *un-normalized* edge detection filters in x- and y-direction, centered at origo, gives the following result:

-1 0 1
-1 0 1 : $f_x(0,0) = 2$
-1 0 1

-1 -1 -1
0 0 0 : $f_y(0,0) = 4$
1 1 1

Computing a second order moment which is invariant to rotation gives the result
$f_{moment} = 28$

Compute the center of gravity of the object. (10p)