Centre for Image Analysis
Swedish University of Agricultural Sciences
Uppsala University

Exam in
Computer Assisted Image Analysis I

***Exam A*, 2013-03-11**

- time: 8:00 to 13:00
- place: Polacksbacken, skrivsal (examination hall)
- tools: dictionary, one A4 sheet (2-sides) with handwritten notes
- bonus points: 2 points added for each lab completed on time
- grades: 3: 20pts; 4: 26pts; 5: 34pts

The cover sheet shall always be filled in and returned even if no exam questions have been answered. Write your name on all papers that you hand in. Do not use red ink. Start on a new paper for each new question. Sort the answer sheets in the order of the questions before you turn them in. Use drawings and figures to illustrate your answers when suitable. Please write answers in English. Results will be posted on the Student Portal (Studentportalen).

GOOD LUCK!

/Anders, Cris, Azadeh, Vlada and Filip.

1 True or False, 5p

Each correct answer gives 0.5p, and each incorrect answer gives -0.5p. You can not get less than 0p in total.

a) The watershed algorithm is an example of bottom-up segmentation.

b) The zero frequency component of the Discrete Fourier Transform is the sum of all pixel values.

c) Transform coding refers to methods where several lossless compression methods are combined after each other.

d) (10, 240, 0) represents a greenish color in the HSV system (8-bit uint used).

e) Histogram equalization of a digital image is an invertible operation.

f) The Gaussian filter can be used to remove noise.

g) In K-means clustering, the number of clusters is automatically determined.

h) Padding refers to adding a border around an image.

i) HSV and HSL were designed to mimic the human perception of colors.

j) The P2A measure is computed from the co-occurrence matrix.

2 Local neighborhood operations 5p

0	0	0	0	4	0
0	6	6	6	3	0
6	9	9	6	5	0
0	5	6	9	4	0
0	0	0	0	0	0
9	0	0	0	0	0

a) How many bits (in total) are needed to store this image uncompressed with a fixed number of bits per pixel. (1p)

b) Apply and compare mean- and median filtering in a 3×3 window for this image. Assume 0s (zeros) outside image and round off to closest integer value. (2p)

c) Show that averaging in a 3×3 neighborhood can be described as the scalar product of two vectors. (2p)

3 Object description 5p

a) Find the border of the object (black) below by selecting the set of all 4-neighbors to the background (white). (1p)

b) Find a chain code for the border in a) using 8-directional chain code (connecting the center points of the border pixels). (1p)

c) Assume the chain code that you found for another object is 000064644330. Make it more invariant to rotation. (hint: by a two-step procedure) (2p)

d) Estimate the perimeter of the object in c). (1p)

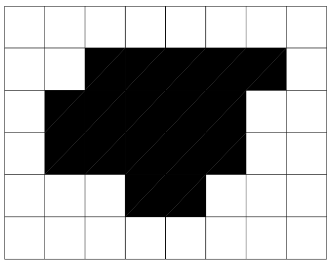


Figure 1: A small binary object.

4 Morphology and Distances, 5p

Consider the following image and structuring element

0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	1	0	0
0	1	0	0	1	1	1	1	0
0	1	1	0	1	1	1	0	0
0	1	1	0	1	1	1	1	0
0	0	0	0	1	1	1	0	0

1	1	0
1	1	1
0	1	0

(a) Compute morphological erosion. (1p)

(b) Compute morphological dilation. (1p)

(c) Describe which morphological operators you intend to use to remove salt & pepper noise in a binary image. (1p)

For calculations, assume zeroes outside the image border.

(d) Compute the distance of every background point (denoted with 0) to the object (denoted with 1) using $< 3, 4 >$ distance transform. (2p)

1	0	1	1	1	1	1	1	1
1	0	1	0	1	1	0	0	1
1	0	0	0	1	1	1	1	1
1	0	0	0	1	1	1	0	1
1	0	0	0	1	1	1	1	1

5 Coding and compression, 5p

a) Compute run-length coding of the image below as well as on the difference coded version next to the image. (2p)

b) Can you predict roughly how the Huffman coding would perform on this raw image compared to the difference encoded version of it? What measure can you use to predict a lower bound for the average code length? Motivate your answer. (2p)

c) Explain why plain Huffman coding is always a bad choice for binary images. (1p)

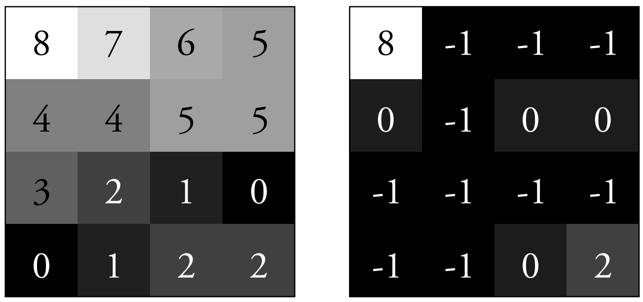
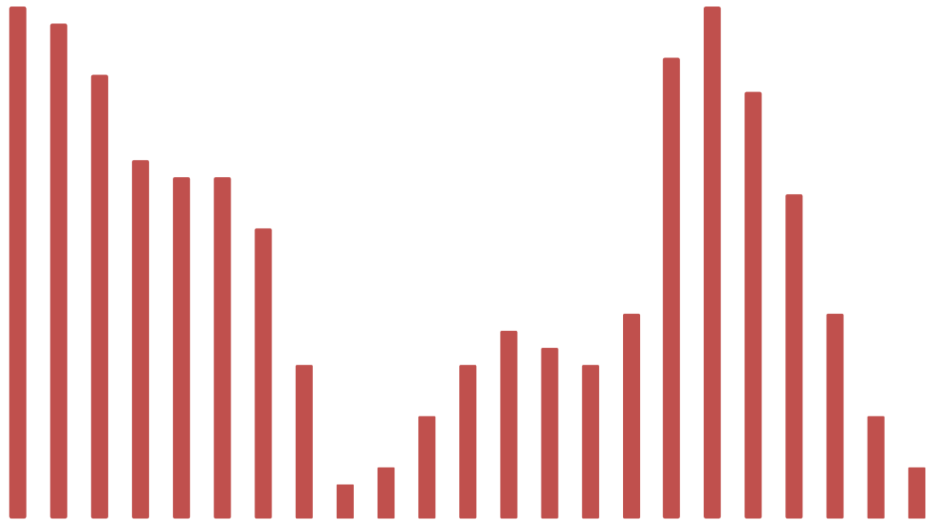


Figure 2: Left: Original image. **Right:** Left image difference coded.

6 Segmentation 5p

In Fig. 3 you see a a 1-dimensional image with 23 “pixels”, visually represented using both numerical values and a bar graph.



Indices	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Values	30	29	26	21	20	20	17	9	2	3	6	9	11	10	9	12	27	30	25	19	12	6	3

Figure 3: 1-dimensional image.

a) Segment this image applying watershed and explain the algorithm step by step. In how many regions is the image divided and where are the boundaries between these regions. (3p)

b) What is the difference of this method compared to seeded watersheds. (1p)

c) Suppose you get way to many objects (a fragmented result) when you use watershed segmentation. How could you tackle this problem? (1p)

7 Classification 5p

a) Explain all steps in $K-$means clustering. (2p)

b) Consider the following set of points $A_1(1,0)$, $A_2(1,2)$, $A_3(6,7)$, $A_4(5,5)$, $A_5(2,1)$, $A_6(4,6)$. Apply $K-$means clustering for $K=2$. Show the iteration(s).
The distance function between two points $A(x_a, y_a)$ and $B(x_b, y_b)$ is defined as $d(A,B) = |x_a - x_b| + |y_a - y_b|$. (2p)

c) Explain a plausible real-world application for K-means clustering, i.e. an example where this method solves a real problem. (1p)

8 The Wiener Filter 5p

The Wiener filter is the mean square error solution to the problem of finding an image $\hat{f}$ that best approximates the undisturbed image f: $\hat{f} = \underset{(\hat{f})}{\text{argmax}} \sum((\hat{f}) - f)^2$, given an observation $g = f \otimes h + n$, where h is the known point spread function h and n is noise. To solve this mean square error problem, it is assumed that noise is additive and uncorrelated to the image.

a) What does additive noise mean? Show that you understand this e.g. by giving one example of additive noise and one example of non-additive noise. (1p)

b) What might happen at the borders of the filtered image when the Wiener filter is implemented using DFT. How can it be avoided? (1p)

c) You have an image of a car driving by at speed, and consequently its license plate is blurred. Describe the process you would go through to deblur the image and make the license plate readable. (2p)

d) What will happen with the background of this image, given that the camera was stationary and therefore the background was not blurred? (1p)