Centre for Image Analysis
Swedish University of Agricultural Sciences
Uppsala University

Exam in
Computer Assisted Image Analysis I

March 8, 2012

- time: 08:00 to 13:00
- place: Polacksbacken, skrivsal (examination hall)
- tools: dictionary
- 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 your answers to questions 4, 5 and 6 in English (Swedish is optional for the other questions). Results will be posted on the Student Portal (Studentportalen).

GOOD LUCK!
/Anders, Bettina, Cris, Gustaf, Azadeh, Erik and Vlada.

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) You can use the Fourier transform to study the median filter.

b) Morphological erosion is a translation invariant operator.

c) Coding methods like Huffman coding can be applied on basically any type of data.

d) Additional features always increase the performance of a classifier.

e) Second moment of the object boundary expresses the skewness of the boundary.

f) The sum of all "bars" in the image histogram is equal to the number of pixels in the image.

g) Brightness and contrast adjustment are a reversible operations on digital images.

h) At places where the Laplace operator is zero, the image is a constant function.

i) Pincussion and barrel distortion can be described as a Linear, Shift Invariant system.

j) Pseudo coloring is used for visualization because humans can distinguish about 30 different gray values but about 350 000 different colors.

2 Morphology 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
0	0	0	1	1	1	1	0	0
0	0	0	1	0	1	0	1	0
0	0	0	0	0	0	0	0	0

0	1	0
1	1	1
0	1	0

a) Compute morphological erosion. (1p)

b) Compute morphological dilation. (1p)

c) Compute morphological closing. (1p)

d) Compute morphological opening. (1p)

If necessary, use zero-padding, i.e., assume that pixels outside the image are zero.

e) Design structuring elements B_1 and B_2 for a hit and miss transform to detect the shape in the top left corner. (1p)

3 Image Restoration, 5p

Assume that an image $f(x, y)$ is distorted by a linear time invariant system with point spread function $h(x, y)$ and additive uncorrelated noise such that the observed image is

$$g(x, y) = f * h(x, y) + n(x, y).$$

Let capital letters denote the Fourier transforms, then an optimal guess is that f can be restored as the inverse Fourier transform of

$$\hat{F}(u, v) = \frac{1}{H(u, v)} \left[\frac{|H(u, v)|^2}{|H(u, v)|^2 + |N(u, v)|^2 / |F(u, v)|^2} \right] G(u, v)$$

a) This formula can not be applied directly. Describe what has to be done first and how to do it. (2p)

b) In what sense is the Weiner filter optimal? (1p)

c) What is the name of h in an imaging system and how can you estimate it? (1p)

d) How is the Weiner filter usually simplifed? (1p)

4 Coding and compression, 5p

a) Define the difference coding method. You may write the definition as an equation or in words. (2p)

b) Apply difference coding on the image below (Fig. 1). (1p)

c) If you consider Huffman coding, what does the histogram tells you about the possible gain in compression ratio? (1p)

d) Compute the histogram of your difference coded image from b). How would you think Huffman coding would work on the difference image? Please motivate your answer. (1p)

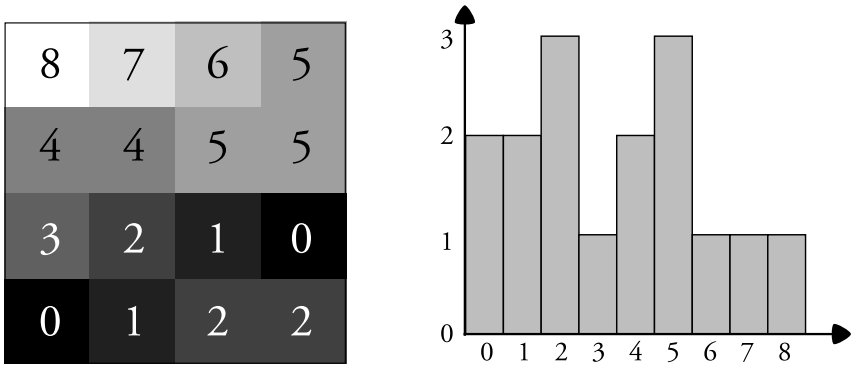


Figure 1: Left: Image to be difference coded. **Right:** histogram of the image

5 Fourier domain, 5p

The discrete Fourier transform (DFT) of an image $f[n]$ with N samples is given by

$$F[k] = \sum_{n=0}^{N-1} f[n] e^{-j\frac{2\pi k}{N}n} \quad .$$

a) What is the equation for the zero frequency ($k = 0$)? What is the meaning of zero frequency, what characteristic of the image does this represent? (2p)

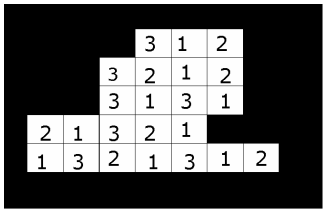
b) What is the relation between positive and negative frequencies for real-valued images? (1p)

c) Is it possible for $F[0]$ to be complex? Explain why your answer does not conflict with your answer in (b). (2p)

6 Object description 5p

a) Name two different ways for estimating a probability function from a grayscale image. (2p)

b) For the object shown in the image below, calculate "uniformity" using the co-occurrence matrix. (p = "*one pixel to the right*"). (3p)



7 Local neighborhood operations 5p

a) Construct a suitable example of a small image corrupted by noise. Demonstrate and discuss the benefits of median filtering compared to local averaging in this image using a 3×3 window. (3p)

b) Design and demonstrate the use of a small 3×3 filter that is sensitive to (finds) local extremal points in the image, i.e. local minimas and maximas. You decide yourself if you should use a linear or non-linear expression. (2p)

8 Segmentation 5p

a) Explain how the histogram of the image in Fig. 2 looks. Is it easy to find a global threshold? Elaborate you thoughts. (2p)

b) Explain how to find a global threshold for the histogram in Fig. 3. Use the example method that we talked about during the lecture and explain every step. (3p)

Figure 2: Chess board with pieces.

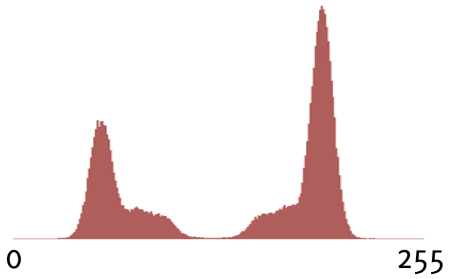


Figure 3: Histogram.