

UNIVERSITY OF OSLO

Faculty of Mathematics and Natural Sciences

Exam: IN5520 / IN9520 – Digital image analysis
Date: Thursday December 10, 2020
Exam hours: 15.00-19.00 (4 hours)
Number of pages: 6 pages
Enclosures: None

- Read the entire exercise text before you start solving the exercises.
Please check that the exam paper is complete.
If you lack information in the exam text or think that some information is missing, you may make your own assumptions, as long as they are not contradictory to the “spirit” of the exercise. In such a case, you should make clear what assumptions you have made.
- You should spend your time in such a manner that you get to answer all exercises.
If you get stuck on one question, move on to the next question.
- There are 8 exercises (master students answer 7). They are weighted proportional to the number of sub-questions.
- Your answers should be **short**, typically a few sentences and / or a sketch should be sufficient.
- Do not give just a numerical answer, but demonstrate your reasoning.
- If you are using information from other sources than the textbook and the lecture notes, you should always include references to these external sources.
- During the exam, there will be a zoom-session for questions at 16.00. Ask questions orally. Look through the exercise set before this to identify all your questions.
- Lecture notes, slides, exercises, as well as any online information are allowed. However, it is FORBIDDEN to collaborate or communicate with any person about the exercises during the exam period. You may be subject to a control conversation regarding the authenticity of your exam submission.
Ref: <https://www.mn.uio.no/english/about/hse/corona/kontrollsamtale.html>.
Such a conversation will not impact grading of your exam, but it can lead to the institute raising a fraud case. Read more about fraud definitions here:
<https://www.uio.no/english/about/regulations/studies/studies-examinations/routines-cheating.html>

Good luck!

Exercise 1: Texture Analysis

Assume that you are given a gray level image of size $M \times N$ pixels with b bits per pixel.

- a) Describe how a normalized Gray Level Cooccurrence Matrix (GLCM) is computed, and which parameters this involves.
- b) Describe the procedure of extracting features from the matrix that directly describe the contents of the matrix, and thereby indirectly describes the texture being analysed; exemplified by a couple of well known features from two different feature categories.
- c) Describe – without any equations - how a Gray Level Cooccurrence Matrix can be used for the purpose of globally thresholding a gray level image so that the resulting binary image has the smallest possible complexity, i.e. the smallest number of transitions between 0 and 1 in 4-connectivity.
- d) How would you go about making the above approach to thresholding adaptive, i.e. obtaining a varying threshold surface over the image?
Discuss using both overlapping and non-overlapping windows.

Exercise 2: Watershed Segmentation

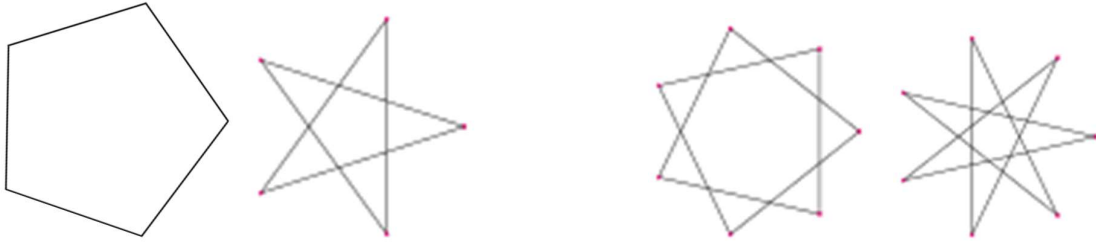
- a) Explain the principal steps of Watershed Segmentation of graylevel images.
- b) Explain how graylevel morphology can be used to detect local minima, prior to Watershed Segmentation.
- c) Under what circumstances may this local minimum detection scheme become uncertain or even fail?
- d) Given a binary object consisting of two partially overlapping squares, as shown in the right hand figure. Explain how you would split this object in two, using a distance transform and Watershed Segmentation.



Exercise 3: Geometric Moments, Hough Transform and polygons

From an n -sided regular (equiangular and equilateral) polygon, a star-shaped string-object is produced by joining every m 'th vertex of the polygon.

A common example is the *pentagram*, which has the same vertices as the *pentagon*, but connects every second vertex, giving a “stariness” of $\{5/2\}$, known as Schläfli ratio (figs to the left below).



- Describe the use of geometric moments and normal-representation Hough transform to detect this kind of non-overlapping star-shaped string-objects – limited to the $\{7/2\}$ and $\{7/3\}$ *heptagrams* (two figures to the right above) - on a production line in the domestic decorations industry, based on digital images of one object per image, and sorting the objects by their “stariness” or Schläfli ratio.
- Describe the use of convex hull (CH) based descriptors as a proxy for the above “stariness” measure of the two *heptagrams* above.
- Describe other geometric features that would be useful to distinguish between “stariness” of different m -values for a regular star polygon having n vertices exemplified by the two *heptagrams* above

Exercise 4: For PhD-stud.: Feature extraction for a classification task

- You are given the task of designing a system for fish species classification. Based on fish caught from a ship you should classify them as either salmon or cod. Two example images are shown below (left: salmon, right: cod).



Discuss briefly three image-based features that you would suggest for a binary classification problem of fish as either salmon or cod. Does your suggested feature require that any particular camera system is used? Consider if the features should characterize subparts of the fish. Does your suggested algorithm require any preprocessing?

- Your first dataset consisted of 100 cod and 15 salmon. How would you give the accuracy of your classifier?

Exercise 5: Support vector machine classification

- a) Explain why SVM classifiers often focus on the sign of a dot product.
- b) Explain by your own words what ξ_i is in the equation

$$J(w, w_0, \xi) = \frac{1}{2} \|w\|^2 + C \sum_{i=1}^N I(\xi_i)$$

$$\text{where } I(\xi_i) = \begin{cases} 1 & \xi_i > 0 \\ 0 & \xi_i = 0 \end{cases}$$

and ξ is the vector of parameters ξ_i .

- c) Describe briefly how a set of binary SVM-classifiers can be used on a multiclass problem.
- d) Consider the figure below for an example with 3 classes. The figure shows the SVM boundaries for 3 class pairs. The blue/black line is the boundary between class 1 and 2, the red line the boundary between class 1 and 3, and the green line the boundary between class 2 and 3. All point within a region will be classified as the same class. For each pairwise classifier, the signs denote the classes, - is the class with the smallest label number and + the class with the highest label number of the pair.

Based on your candidate number, select a point in region 1-5, and describe how it is classified.

Let d be the last digit in your candidate number.

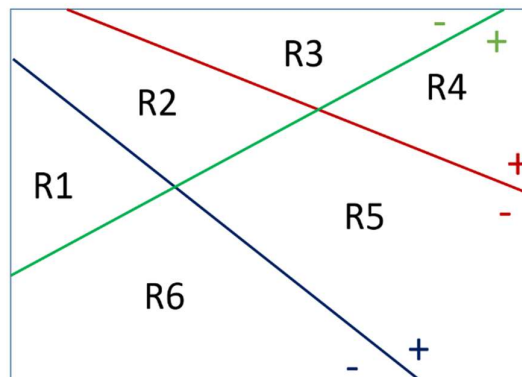
If $d=0-1$: select a point in region 1

If $d=2-3$: select a point in region 2

If $d=4-5$: select a point in region 3

If $d=6-7$: select a point in region 4

If $d=8-9$: select a point in region 5



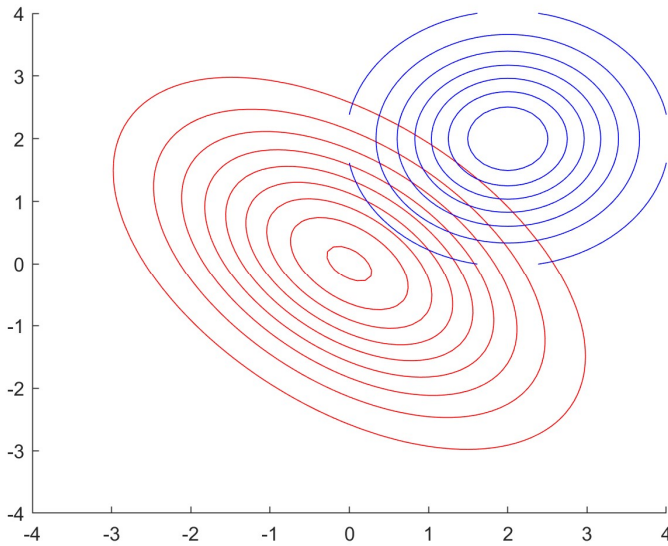
Exercise 6: A Gaussian classifier

In this exercise we will work with a Gaussian classifier and two classes defined with:

$$\mu_1 = \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \quad \Sigma_1 = \begin{bmatrix} 2 & -1 \\ -1 & 2 \end{bmatrix}, \quad \Sigma_1^{-1} = \begin{bmatrix} 0.667 & 0.333 \\ 0.333 & 0.667 \end{bmatrix}, \quad |\Sigma_1| = 3$$

$$\mu_2 = \begin{bmatrix} 2 \\ 2 \end{bmatrix}, \quad \Sigma_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad \Sigma_2^{-1} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad |\Sigma_2| = 1$$

The classes are outlined in the plot below:



We are also given a set of samples that we will classify. There are 10 samples in the table. Select the sample that corresponds to the last digit in you candidate number

Candidate number (last digit)	Test sample
0	(1,1)
1	(3,0)
2	(0,1)
3	(2,1)
4	(1,0)
5	(1,2)
6	(0,3)
7	(2,0)
8	(0,2)
9	(3,1)

Compute the probability that your sample x belongs to class 1 and class 2, $p(x|\omega=1)$ and $p(x|\omega=2)$. Include all your computations here.

Exercise 7: Subsets of features

In this exercise, we are working with a dataset with 4 features.
The mean and covariance matrix for all the samples are:

$$\mu = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad \text{and} \quad \Sigma = \begin{bmatrix} 2 & -1 & 0.5 & 0 \\ -1 & 3 & -1 & -1 \\ 0.5 & -1 & 3 & -1 \\ 0 & -1 & -1 & 2 \end{bmatrix}$$

The eigenvalues and eigenvectors of this matrix are:

$$\begin{aligned} \lambda_1 &= 0.53 & v_1 &= [-0.21 \quad -0.54 \quad -0.44 \quad -0.67]^T \\ \lambda_2 &= 1.56 & v_2 &= [-0.88 \quad -0.22 \quad 0.32 \quad 0.24]^T \\ \lambda_3 &= 3.43 & v_3 &= [0.07 \quad -0.40 \quad -0.59 \quad 0.58]^T \\ \lambda_4 &= 4.47 & v_4 &= [0.40 \quad -0.70 \quad 0.58 \quad 0.05]^T \end{aligned}$$

- a) Now we do feature selection. Select feature k and m depending on the last digit d in your candidate number:
- $d=0-1$: $k=1, m=2$
 - $d=2-3$: $k=1, m=3$
 - $d=4-5$: $k=1, m=4$
 - $d=6-7$: $k=2, m=3$
 - $d=8-9$: $k=2, m=4$

Set up the covariance matrix for your selected features.

- b) We now want to visualize this covariance matrix as an ellipse.
Set up an expression for computing the minor and major axis for this ellipse,
and compute the values for your selected combination of 2 features.

Exercise 8: Statistics

A city has two hospitals. In the biggest hospital, about 50 children are born each day, in the smaller hospital about 20. It is common knowledge that about 50% of all newborn are girls, but the exact percentage in any given hospital may vary from day to day. Sometimes it may be lower than 50%, sometimes higher.

For a period of time, each hospital recorded the number of days on which more than 60% of the babies born were girls. Which hospital do you think recorded more such days?

- 1) The larger hospital
- 2) The smaller hospital
- 3) About the same (i.e., within 5% of each other)

Please explain the reason(s) for your answer,
and try to relate to another well known classification problem!

Thank You for Your Attention!