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INF 3300, INF 4300 Digital Image Analysis


Introduction and motivation

Lars Aurdal,
Norsk Regnesentral,
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Plan

1. Practical information.
2. What is image analysis.
3. What will you learn.
4. Repetition of key material from INF2310.

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Practical information - Schedule

1. Lectures:
 - a. When: Tuesday 1215-1400.
 - b. Where: In Store Auditorium.
2. Exercise lectures:
 - a. Group 1:
 - 1) When: Wednesday 1015-1200.
 - 2) Where: Room 121, PO.
 - b. Group 2:
 - 1) When: Monday 1215-1400.
 - 2) Where: Room 121, PO.

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Practical information - Lecturers

1. Anne Schistad Solberg:
 - a. IFI/UIO (Fourth floor, IFI building).
 - b. Telephone: 22852435.
 - c. Email: anne@ifi.uio.no
2. Lars Aurdal:
 - a. Norwegian Computing Center (Fourth floor, IFI building).
 - b. Telephone: 22852615.
 - c. Email: aurdal@nr.no
3. Contact us by mail.

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Practical information – Student lecturers


1. Bjarne Roe.
 - a. Email: bjarnro@student.matnat.uio.no

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Practical information – Web page

<http://www.uio.no/studier/emner/matnat/ifi/INF3300/>

1. You'll find:
 - a. Information about the course.
 - b. Lecture plan.
 - c. Foils.
 - d. Exercise material.
 - e. Course requisite description.
 - f. Exam information.
 - g. Messages.

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Practical information – news page

1. The course newsgroup is:
ifi.kurs.inf3300
2. All students are required to check this page on a regular basis.



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Practical information – Course material

1. All foils will be made available on the course web site.
2. The foils define the course requisites.
3. Exercises will be introduced as we go along.
4. There are no books defining the course requisites.



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Practical information – Exercises and project exercise

1. The ordinary exercises are NOT obligatory.

- a. But do them anyhow...
- b. The ordinary exercises can be solved in any language, solutions will be provided in Matlab.

2. One large project exercise.

- a. Individual response.
- b. Counts for 30% percent of the final grade.
- c. More information about this exercise later.



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Practical information - exam

1. Written or oral exam depending on the number of students participating at the exam.
2. Counts for 70% of the final grade.
3. No written sources of information available during the exam.
4. More information later.



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Practical information – course quality inspector

1. The quality inspector (tilsyns sensor) for this course is Tor Lønnestad at Telemark College.
2. More about the quality inspector system at the address:
<http://www.ifi.uio.no/studinf/kvalitetssikring/tilsyns sensor.html>



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Practical information – quality control

1. Main purpose: Give the students an occasion to provide feedback to the lecturers on the quality of the course so that changes can be implemented during the course.
2. Also important in order to increase the course quality over the years.
3. More information at the address:
<http://www.ifi.uio.no/studinf/kvalitetssikring/undervei sevaluering>



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Practical information – quality control

1. You may as a class choose to elect a representative.
2. Midway and at the end of the course we will set aside some time for filling in evaluation forms.

Practical information – rules of the game

1. In recent years some very flagrant cases of plagiarism and cheating have been disclosed.
2. Many students claim to have had no knowledge of the rules for source citation etc.
3. You are obliged to read the document at the following web address:
 - a. Norwegian:
<http://www.ifi.uio.no/studinf/skjemaer/erklaring.pdf>
 - b. English:
<http://www.ifi.uio.no/studinf/skjemaer/declaration.pdf>

Practical information – rules of the game

1. Essential contents of this document:
 - a. All written assignments are expected to be a result of the student's own efforts. Plagiarism is unethical and may lead to severe reactions from the department.
2. Consequently, the following rules apply:
 - a. You must reference your sources.
 - b. You may obtain clues on how to solve an assignment, but copying solutions is not acceptable.
 - c. In cases of doubt, the department may request a meeting with students about their assignment.
3. Group Assignments:
 - a. Every member of the group must be able to explain the main features of the submitted assignment, must have made a fair contribution and must be able to explain their part in detail.
4. You may collaborate, but these rules still apply.

What is image analysis?

1. **Image analysis** is the art and science whose ultimate goal is to give computers "vision".
 - a. Computers that read handwritten documents.
 - b. Computers that recognize people.
 - c. Etc.
2. **Image processing** is often used in the more limited sense of simple image manipulations:
 - a. Removing noise.
 - b. Changing contrast.
 - c. Etc.

What is image analysis?

1. Image processing is typically part of the image analysis process.
2. Other parts of image analysis is pattern recognition, artificial intelligence etc.

What is image analysis – commercial applications

1. Image analysis is very difficult!
2. After 50 years of intensive research very few commercial products based on true image analysis exist.
3. The commercial potential is enormous.

What is image analysis – commercial applications

1. Some possible commercial products:
 - a. Let's say you have 10.000 digital images on your computer.
 - b. How do you find a particular image...then one where uncle John sat next to aunt Mary holding a drink in his hand?
 - c. It's simple enough if you take the time to go through them all... on the average you'll have to look at 5000 images before you find the right one.

What is image analysis – commercial applications

1. Some possible commercial products:
 - a. Something as (seemingly) simple as making a good and robust system for automatic interpretation of handwritten addresses on letters will make you very rich!
 - b. And why on earth do we have to train DOGS in order to guide the blind... after 50 years of research DOGS can still beat us.

What will you learn

1. This course is split in two:
 - a. One part (five lectures) deals with image processing.
 - b. The other part (five lectures) deals with pattern recognition.
2. The aim is to make you able to solve a typical image analysis problem using a set of image processing and pattern recognition tools.

What will you learn – image processing

1. From the field of image processing we will look at the following methods:
 - a. A brief repetition of some of the themes taught in INF2310 (those relevant for this course).
 - b. Thresholding, both global and locally adaptive methods.
 - c. Edge detection techniques and the Hough transform.
 - d. Some segmentation methods.
 - e. Advanced mathematical morphology.

What will you learn – pattern recognition

1. From the field of pattern recognition we will look at the following methods:
2. General feature extraction.
3. Moment based methods.
4. Classification (two double lectures).
5. Texture classification.

INF 2310 repetition – Segmentation and thresholding

1. Segmentation is the process that maps an input image (possibly multispectral) into an output image where each pixel in the input image is given a label indicating its membership in a group of pixels sharing some common property. Group inclusion can be based on:
 - a. Similar spectral properties.
 - b. Similar higher order spectral properties (texture).
 - c. Surrounded by the same edge.
 - d. etc.....

INF 2310 repetition – Segmentation and thresholding

1. The main problem with segmentation is well summarized by Marr: "Regions that have semantic importance do not always have any particular visual distinction. Therefore, in most cases, image segmentation results in in regions that cover semantically distinct visual entities or regions that are fragmented. Without the domain-specific knowledge about the objects in an image, it is almost impossible to obtain a satisfactory result."



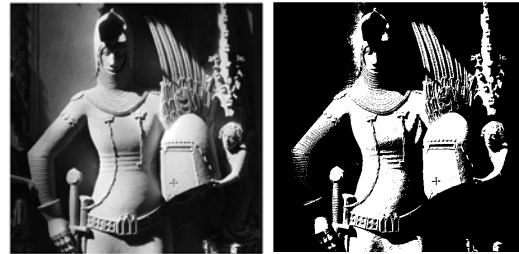
Remember, regions that have semantic importance do not always have any particular visual distinction.

INF 2310 repetition – Segmentation and thresholding

1. The only segmentation method taught in INF2310 was thresholding.
2. Thresholding is a transformation of the input image f to an output (segmented) image g as follows:

$$g(i, j) = \begin{cases} 1, & f(i, j) \geq T \\ 0, & f(i, j) < T \end{cases}$$

INF 2310 repetition – Segmentation and thresholding



Original image

Image thresholded at $T=140$

INF 2310 repetition – Segmentation and thresholding

1. Many variants of the basic definition:

$$g(i, j) = \begin{cases} 1, & f(i, j) \in D \\ 0, & \textit{otherwise} \end{cases}$$

INF 2310 repetition – Segmentation and thresholding

1. Many variants of the basic definition:

$$g(i, j) = \begin{cases} 1, & f(i, j) \in D_1 \\ 2, & f(i, j) \in D_2 \\ \dots & \\ n, & f(i, j) \in D_n \\ 0, & \textit{otherwise} \end{cases}$$

INF 2310 repetition – Segmentation and thresholding

1. Many variants of the basic definition (semithresholding):

$$g(i, j) = \begin{cases} f(i, j), & f(i, j) \geq T \\ 0, & \text{otherwise} \end{cases}$$

INF 2310 repetition – Segmentation and thresholding

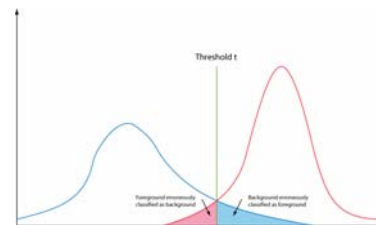
1. This seemingly simple method must be considered with some care:
 - a. How do you select the threshold, manually or automatically?
 - b. Do you apply a threshold globally or locally (on a sliding window or blockwise)?
 - c. Need to realize that this is a purely local method, no contextual considerations are taken.

INF 2310 repetition – Segmentation and thresholding

1. Automatic threshold selection will be covered in detail in the next lecture.
 - a. Otsu's method.
 - b. Ridler-Calvard's method.
2. Local thresholding methods will also be covered then.
 - a. Local applications of Otsu and Ridler-Calvard.
 - b. Niblack's method.

INF 2310 repetition – Segmentation and thresholding

1. Remember that you normally make an error performing a segmentation using thresholding:



INF 2310 repetition – Segmentation and thresholding

1. Assume that the histogram is the sum of two distributions $b(z)$ and $f(z)$, b and f are the normalized background and foreground distributions respectively, and z is the gray level.
2. Let B and F be the prior probabilities for the background and foreground ($B+F=1$).
3. In this case the histogram can be written $p(z)=Bb(z)+Ff(z)$.

INF 2310 repetition – Segmentation and thresholding

1. In this case the probabilities of erroneously classifying a pixel, given a threshold t , is given by:

$$E_B(t) = \int_{-\infty}^t f(z) dz$$

$$E_F(t) = \int_t^{\infty} b(z) dz$$

INF 2310 repetition – Segmentation and thresholding

1. The total error will be:

$$E(t) = F \int_{-\infty}^t f(z) dz + B \int_t^{\infty} b(z) dz$$

2. Using Leibnitz's rule for derivation of integrals and by setting the derivative equal to zero you can find the optimal value for t:

$$\frac{E(t)}{dt} = 0 \Rightarrow Ff(T) = Bb(T)$$

INF 2310 repetition – a sidestep

1. The Leibniz integral rule gives a formula for differentiation of a definite integral whose limits are functions of the differential variable:

$$\frac{\partial}{\partial z} \int_{a(z)}^{b(z)} f(x, z) dx = \int_{a(z)}^{b(z)} \frac{\partial f}{\partial z} dx + f(b(z), z) \frac{\partial b}{\partial z} - f(a(z), z) \frac{\partial a}{\partial z}$$

2. It is sometimes known as differentiation under the integral sign.
3. More at the excellent web site:
<http://mathworld.wolfram.com>

INF 2310 repetition – Segmentation and thresholding

$$\frac{E(t)}{dt} = 0 \Rightarrow Ff(T) = Bb(T)$$

1. This is a general solution that does not depend on the type of distribution.
2. Remember that in the case of f and b being Gaussian distributions, it is possible to solve the above equation explicitly.

INF 2310 repetition – Segmentation and thresholding

1. In INF2310 we briefly introduced two methods (Ridler-Calvard and Otsu) for determining the thresholds automatically.
2. These and other methods will be covered in much more detail in the INF3300 lecture on thresholding.

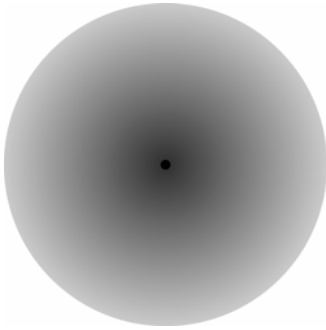
INF 2310 repetition – Edge extraction

1. Several basic edge extraction techniques were taught in INF2310.
2. In this context edges are both edges in intensity, color and texture.
3. Edges are important for many reasons:
 - a. Much of the information in an image is contained in the edges. In many cases semantic objects are delineated by edges.
 - b. We know that biological visual systems are highly dependent on edges.

INF 2310 repetition – Edge extraction

1. Stare intensely at the figure in the next slide for some time. What happens?

INF 2310 repetition – Edge extraction



INF 2310 repetition – Edge extraction

1. The edge detection operators are operators that produce strong responses in image regions where pixel values (in intensity images) change rapidly.
2. In such, they are digital approximations to the gradient operator:

$$\nabla f(x)$$

3. ...which is a vector quantity given by:

$$\nabla f(x, y) = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

INF 2310 repetition – Edge extraction

1. The gradient is a measure of how the function $f(x,y)$ changes as a function of changes in the arguments x and y .
2. The gradient vector points in the direction of maximum change.
3. The length of this vector indicates the size of the gradient:

$$|\nabla f| = \sqrt{G_x^2 + G_y^2}$$

INF 2310 repetition – Edge extraction

1. The standard operator is the so called Sobel operator.
2. In order to apply Sobel on an image you convolve the two x- and y-direction masks with the image:

-1	-2	-1	-1	0	1
0	0	0	-2	0	2
1	2	1	-1	0	1

INF 2310 repetition – Edge extraction

1. This will give you two images, one representing the horizontal components of the gradient, one representing the vertical component of the gradient.
2. Thus using Sobel you can derive both the local gradient magnitude and it's direction.

INF 2310 repetition – Edge extraction

1. Another frequently used technique for edge detection is based on the use of digital approximations to the Laplace operator given by:

$$\nabla^2(f(x, y)) = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

2. This operator changes sign where $f(x,y)$ has an inflection point, it is equal to zero at the exact edge position.

INF 2310 repetition – Edge extraction

1. It can be shown that a digital representation of this operator can be obtained by convolving the image with the following mask:

0	-1	0
-1	4	-1
0	-1	0

INF 2310 repetition – Edge extraction

1. Since this operator is based on second derivatives it is extremely sensitive to noise.
2. To counter this it is often combined with Gaussian prefiltering in order to reduce noise.
3. This gives rise to the so called Laplacian-of-Gaussian (LoG) operator.

INF 2310 repetition – Edge extraction

1. In INF3300 we will discuss the Hough transform, a method for analyzing edge elements and the relations between them.

INF 2310 repetition – Mathematical morphology

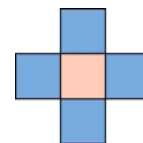
1. In INF2310 we adopted a very “algorithmic” view on mathematical morphology.
2. That is, we explained how these operators work from a visual point of view and focused on how they could be implemented on a computer.
3. This avoids us a lot of gory mathematical detail.
4. ...and that's mainly what we will do in INF3300 too.
5. If you want more details then consider INF5300.

INF 2310 repetition – Mathematical morphology

1. Start by considering the application of mathematical morphology to binary images only.
2. The fundamental tool in mathematical morphology is the structuring element.
3. The structuring element is a (small) group of pixels. One of these pixels is designated as the origin of the structuring element.
4. The relation between this small group of pixels and the foreground pixels in the image to be analyzed is what we use to define the morphological operators.

INF 2310 repetition – Mathematical morphology

1. Let's consider the following structuring element:



2. This structuring element consists of 5 pixels organized in a cross, let's consider the pink pixel in the center the origin of the structuring element.

INF 2310 repetition – Mathematical morphology

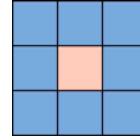
1. The first question we might ask is: "To where could I move the center of the structuring element in such a way that the entire structuring element overlaps foreground pixels?"
2. Those pixels to where the structuring element can be moved like this are called the erosion of the original image.
3. [Follow this link for an illustration.](#)



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INF 2310 repetition – Mathematical morphology

1. Another common structuring element is this:



2. The erosion using this structuring element is based on exactly the same logic as the previous one.
3. [Follow this link for an illustration.](#)



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INF 2310 repetition – Mathematical morphology

1. There are many variants of this basic theme.
2. A first variant is that you can be much more creative when it comes to choosing the form of the structuring element.
3. If you look for the position of "corners" then a smart choice of structuring element might do the trick.
4. Notice that this structuring element is not symmetrical with respect to its origin.
5. [Follow this link for an illustration.](#)



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INF 2310 repetition – Mathematical morphology

1. A common misconception is that the structuring element must contain its own origin. Not at all the case.
2. [Follow this link for an illustration.](#)



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INF 2310 repetition – Mathematical morphology

1. Another question we might ask is: "To where could I move the center of the structuring element in such a way that the structuring element overlaps foreground pixels in at least one position".
2. Those pixels to where the structuring element can be moved like this are called the dilation of the original image.
3. [Follow this link for an illustration.](#)



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INF 2310 repetition – Mathematical morphology

1. Remember that the basic operations of erosion and dilation can be combined.
2. Erosion followed by dilation is often referred to as an opening. It will remove noise and partly restore large objects.
3. The opposite, dilation followed by erosion is referred to as closing. In particular, this will close gaps on object boundaries as well as holes.



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INF 2310 repetition – Mathematical morphology

1. In INF 3300 we will look in greater detail at some more advanced methods for binary morphology.
2. The extension to gray-level morphology will also be discussed in much more detail.