Computer Assisted Image Analysis 1
GW 1, 2.1-2.4

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Course Overview

- 9+1 lectures (Filip, Damian)
- 5 computer exercises (Tomas, Amit, Damian)
About me

- Associate professor (docent) in Image Processing.
- Two affiliations:
  - Centre for Image Analysis, IT department
  - Department of surgical sciences, Radiology.
- Medical image analysis, Interactive methods in image analysis, combinatorial optimization, graph based methods.
- Webpage: http://www.cb.uu.se/~filip/
- Email: filip.malmberg@it.uu.se
Interactive image segmentation

http://www.cb.uu.se/~filip/SmartPaint/

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Interactive image segmentation
Virtual surgery planning
Large scale, whole-body MR image analysis

Correlation map
Local tissue volume vs. weight

Females, n=68
What is image analysis?

Extraction of meaningful information from (digital) images ...

... by means of digital image processing/analysis techniques.

Image analysis is highly interdisciplinary with foundations in mathematics, signal processing, statistics, computer science ...
Drug development: How does a drug affect the protein expression in individual cells?

Material characterization: How does the length, orientation and mixing of fibres affect the quality of the paper?

Text & character recognition: Who wrote this book and does it contain anything of interest to me?

Face recognition: Is this the same person and who is it?
Course content: concepts and techniques to understand and solve image related problems

Lectures

- Introduction
- Pointwise operators
- Filtering
- Filtering 2 (fourier domain)
- Mathematical morphology
- Segmentation
- Classification
- Color and compression
- Object Description
- Review

Computer exercises

- Basic image handling and pointwise operators
- Filtering
- Segmentation
- Classification
- Problem solving competition
Then what?

- Computer Assisted Image Analysis I, period 2
- Human Computer Interaction
- Computer Assisted Image Analysis II, period 3, 10ECTs
- Medical Informatics, period 3, 5ECTs
- Master Thesis in Image Analysis, Visualization, Human Computer Interaction
- Industry: SAAB, Autoliv, RaySearch Laboratories, SKL, CellaVision
Computer Assisted Image Analysis II

Course contents
• Methods for solving problems in image analysis.
• Filtering for image enhancement and analysis.
• Registration of images, search methods and optimisation.
• Digital geometry.
• Image segmentation.
• Image-based measurements.
• Computer vision.
• Pattern classification and recognition.
• Analysis of 3D images and time series.

10 ECTS includes lectures, lab exercises and a project.
Medical informatics

• **Learning Goals**
  • Decide which health care problems that are suitable to address with computerized visualization and analysis methods
  • Describe how health care related work can be supported by computerized tools
  • Choose and apply suitable methods, e.g. image analysis to solve specific health care problems
  • Describe how demands and needs for different health care actors can be investigated and fulfilled
  • Describe challenges encountered when designing and deploying systems for advanced analysis and information handling within the health care system

• **Course Contents**
  • Medical documentation and electronic patient records
  • Techniques for image reading, analysis and processing
  • Medical terminology and standards
  • Modelling, simulations and visualizations as tools for diagnoses and therapy planning
  • Medical knowledge representation and decision support
  • User interfaces in health care
  • Telemedicine

5 ECTS includes lectures, computer exercises and study visits
General information

- Course webpage
  http://www.it.uu.se/edu/course/homepage/bild1/ht17/

- Computer exercises: work in groups of 2-3 people. *Note: there are many students taking the course this year, please follow this guideline so that we have time to help everyone!*

- Registration, signing up for exam, dropping out etc.: you know better than me or ask the student office (it-kansli@it.uu.se).
Examination

• Labs+ written exam
• The labs are mandatory, attendance at the lab sessions is not.
• Labs are examined by oral presentation at the next lab session (i.e. examination of Lab 1 at lab session 2, etc.)
• Helping each other between groups is allowed and encouraged! During examination, all members of the group are expected to be able to answer questions about the solution.
• If you cannot attend a lab, you can email a report to the lab assistants.
Important info about the exam

• You must sign up for the exam via the student portal, no later than 12 days before the exam date! Otherwise, you will not be allowed to take the exam.

• Sign up opens two weeks after the course start.
Course literature

- Lecture Notes
- Computer exercise instructions
- (Digital image processing using matlab)
Swedish Society for Automated Image Analysis, SSBA

www.ssba.org.se
• Free membership for students
• Newsletter (PDF)
• Annual symposium
• Annual summer school (3-4 days)
• Member of IAPR

International Association for Pattern Recognition, IAPR

www.iapr.org
• Newsletter
• Conferences
• Journals
Image processing and analysis

- The world
- Imaging
- Visualization
- Image analysis
- Image processing
- Computer graphics

Data → Image → Image analysis → Computer graphics → Image → Imaging → Visualization → The world
Problem solving using image analysis: fundamental steps

1. Image acquisition
2. Preprocessing, enhancement
3. Segmentation
4. Feature extraction, description
5. Classification, interpretation, recognition
6. Result

Knowledge about the application
Fundamental steps

Intermediate level

Segmentation -> Representation

Preprocessing

Image acquisition

Knowledge base

Classification

Low level

Problem

High level

Result
Preprocessing

- Remove/reduce noise
- Background correction
- Enhance features (not illustrated here)
Segmentation

- Grey-level thresholding, edge information, watershed, template matching......
Feature extraction

- Quantitative measures e.g., size, shape, texture...
Classification/recognition/interpretation
Computers vs. humans

**Computer**
- quantitative analysis
- complicated computations
- cheap, fast
- objective

**Human**
- recognize complex patterns in images with noise
- describe relationships
- interpret based on experience

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Computers vs. humans
Computers vs. humans
Why automated/computerized image analysis?

• Fast
• Objective
• User Independent
• Accurate
Perception and Objectiveness

- Which square is brighter: A or B?
Perception and Objectiveness

● Which square is brighter: A or B?
Quantification: How much is dark and bright respectively?
Image formation process

Light/energy source

Reflected (or transmitted) energy

Imaging system

Projection onto internal image plane

Digital output image

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Sensors

- Pointscanner

- Linescanner

- Arraysscanner
Electromagnetic spectrum
Other common imaging modalities

- Ultrasound, electrons (SEM, TEM)
Digital images

- A set of points or positions that each have a certain intensity or grey-value
Digital images

• A set of points or positions that each have a certain intensity or grey-value
Digital images

- A set of points or positions that each have a certain intensity or grey-value

```matlab
>> I = imread('rat.png') ;
>> A = I(26:34,125:133)
A =
94 100 104 119 125 136 143 153 157
103 104 106 98 103 119 141 155 159
109 136 136 123 95 78 117 149 155
110 130 144 149 129 78 97 151 161
109 137 178 167 119 78 101 185 188
100 143 167 134 87 85 134 216 209
104 123 166 161 155 160 205 229 218
125 131 172 179 180 208 238 237 228
131 148 172 175 188 228 239 238 228
```
Expressed differently

\[ f(x, y) = v \]

(Two dimensional image)

- \( v \) = intensity or gray scale
- gray scale: from 0 (black) to \( v_{\text{max}} \) (white)
Digitization

• To represent the continuous image in a computer, it needs to be digitized.

• Spatial sampling - Discretizing a continuous function in terms of coordinate value. Recording the function values at a finite set of points.

• Gray level quantization - Discretization of amplitude values
Digitization

- Sampling rate – spatial resolution
- Quantization - grey level resolution
Spatial (x,y) sampling
Methods for image sampling (in space)

- Uniform - same sampling frequency everywhere
- Adaptive - higher sampling frequency in areas with greater detail (not very common)
- The discrete sample is called a *pixel* (from picture element) in 2D and *voxel* (from volume element) in 3D and is usually square (cubic), but can also have other shapes (i.e. elongated or hexagonal grids).
Sampling density and resolution

- Resolution is the smallest discernible detail in an image.
- The sampling density (together with the imaging system) limits the resolution.
- Sampling density at scanning is often measured in dpi = dots per inch = pixels per 2.5 cm on the input object (e.g. paper). The “dot-size” may however be greater than the distance between two samples, leading to a lower resolution. Always test!
- Sample twice as often as the smallest detail you need to resolve. (Why?)
Aliasing when sampling

The image information may be obscured if the sampling frequency is different from "frequencies" in the image.
Examples of aliasing effects

The frequency of thin lines is too low to be correctly represented when the image is sub-sampled to ¼ of its size.

This image was scanned from a magazine, resulting in a pattern due to the frequency of the raster in the printing.
How to sample?

- The Nyquist–Shannon Sampling Theorem is a fundamental theorem in signal and image processing.
- If a function $x(t)$ contains no frequencies higher than $B$ Hz(Hertz), it is completely determined by giving its values at a series of points spaced $1/(2B)$ seconds apart.
- Avoid aliasing: Remove higher frequencies prior to sampling.
Gray level quantization
## Common quantization levels

Image values when using integers, in interval $[0, 2^n - 1]$.

<table>
<thead>
<tr>
<th>Bits</th>
<th>Interval</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 1</td>
<td>$[0, 1]$</td>
<td>“binary image”</td>
</tr>
<tr>
<td>n = 5</td>
<td>$[0, 31]$</td>
<td>what the human can resolve locally</td>
</tr>
<tr>
<td>n = 8</td>
<td>$[0, 255]$</td>
<td>1 byte, very common</td>
</tr>
<tr>
<td>n = 16</td>
<td>$[0, 65535]$</td>
<td>common in imaging systems</td>
</tr>
<tr>
<td>n = 24</td>
<td>$[0, 16.2 \times 106]$</td>
<td>common for color images (3×8 bit for RGB)</td>
</tr>
</tbody>
</table>
Methods for quantization (in amplitude)

- Uniform (linear) – the intensities of the object are mapped directly to the gray-levels of the image
- Logarithmic - higher intensity resolution in darker areas (the human eye is logarithmic)
Binary images
RGB images

Red + Green + Blue =

Three channels, 2D image
3D (volume) images
3D (volume) images
Choice of imaging and sampling

• What will the image be used for?
• What are the limitations in memory and speed?
• Will we only use the image for visual interpretation or do we want to do any image analysis?
• What information is relevant for the analysis (i.e. color, spatial and/or gray-level resolution)?
Images and interpolation

- In a digitized image, the intensity value is only known at the sample points.
- To obtain intensity values at other points, we need to use some kind of interpolation scheme.
- Example: Applying a geometric transform to an image (e.g. rotation, translation, scaling) typically requires us to *resample* the image at non-pixel locations.
Images and interpolation

Nearest neighbor

Bi-linear, Interpolation from four closest neighbors

Bi-cubic, Interpolation from sixteen closest neighbors
Resampling, grey-level interpolation

Re-sampling:

\[ I_{\text{transformed}}(p) = I(T^{-1}(p)) \]

Generally not an integer coordinate!
original image

rotation with NN interpolation

Rotation with bi-linear interpolation
Next Lecture: pointwise operators

- Histograms, contrast/brightness, transfer function, image arithmetic etc.
- GW: 2.6.1-2.6.4, 3.1-3.3
MATLAB and images

- In MATLAB images are treated and indexed as matrices.
- Have a quick glance at the contents of the image processing toolbox.
- `imread`, `imwrite` to read and write images of several known formats.
- `imshow`, `imagesc` to view images/matrices.
- `for`, `while`, `if`.
- `+`, `-`, `*`, `.*`, `/`, `./`, `.^2` etc.
- Scripts and functions.
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