Computer Assisted Image Analysis 1
GW 1, 2.1-2.4
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Course Overview
• 9+1 lectures (Ida-Maria, Robin, Cris)
• 5 computer exercises (Tomas, Kristina)

Who am I?
• MSc Molecular Biotechnology Engineering, 2000
• PhD Image Analysis, CBA, 2005
• Image Analyst, CSIRO, Australia, 2005-2007
• Head of R&D, Vironova AB since 2007
• Researcher/Associate senior lecturer at CBA since 2008

• Segmentation, shape description, texture analysis in 2D and 3D microscopic data.

Virus detection and identification
High content analysis/screening

3D interactive visualization & analysis

What is image analysis?
Extraction of meaningful information from (digital) images ....
... by means of digital image processing/analysis techniques.

Drug development: How does a drug affect the protein expression in individual cells?

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

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

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

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

Basic image handling + pointwise operators
• Filtering
• Segmentation
• Classification
• problem solving/competition

Computer Assisted Image Analysis II, period 3, 10ECTs (lectures + project)

Medical Informatics, period 3, 5ECTs (lectures, computer exercises, study visits)

Contact:
Cris Luengo
cris@cb.uu.se

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.

5 ECTS includes lectures, computer exercises and study visits

Master Thesis in Image Analysis, Visualization, Human Computer Interaction

Industry
SAAB, Autoliv, RaySearch Laboratories, SKL, CellaVision

Contact:
Robin Strand
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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
• Modeling, 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/ht14/
- Computer exercises: preferably work in pairs. 1 bonus point/exercise on exam (this year’s course) if completed in time.
- Registration, signing up for exam, dropping out etc. → you know better than me or ask the student office.

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

- Image analysis
- Visualization
- Computer graphics
- Image processing
Problem solving using image analysis: fundamental steps

- Image acquisition
- Preprocessing, enhancement
- Segmentation
- Feature extraction, description
- Classification, interpretation, recognition

Knowledge about the application

**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

Computer vs. human

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

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

Why automated/computerized image analysis?

- Fast
- Objective
- User Independent
- Accurate
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

Sensors
- Pointscanner
- Linescanner
- Arrayscanner
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
Expressed differently

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

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

Two dimensional image.

Digitization

- To represent the continuous value in a computer, it needs to be digitized.
- Spatial sampling - Discretizing a continuous function in terms of coordinate value
- 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.

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>$[0, 16.2 \times 10^6]$</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 Image

3 channels, two dimensional image.

3D 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)?

Resampling, grey-level interpolation

- Nearest neighbour, NN
- Bilinear, interpolation from four closest neighbours.

Re-sampling:

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 1/4 of its size.

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

Next Lecture: pointwise operators

- Histograms, contrast/brightness, transfer function, image arithmetics etc.
- GW: 2.6.1-2.6.4, 3.1-3.3

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.

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, imagsc to view images/matrices
- For, while if
- +, -, *, ./, .^2 etc.
- Scripts and functions