Computer Assisted Image Analysis
Lecture 1 – Introduction

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Swedish University of Agricultural Sciences
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Course Homepage

Course homepage: Studentportalen—Computer Assisted Image Analysis

- Schedule
- Teacher contact information
- Computer exercise instructions
- ...

Centre for Image Analysis
Swedish University of Agricultural Sciences
Uppsala University
Twitter

Follow us on Twitter @imagecba

• Additional info related to the course
• Expect both serious and funny posts
• Twitter is *not* the official channel for course information
Course Literature

- (Digital Image Processing Using MATLAB, by Gonzales and Woods)

Book homepage:
www.imageprocessingplace.com
Teachers

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Swedish Society for Automated Image Analysis
www.ssba.org.se

- Free membership for students
- Newsletter (PDF)
- Annual symposium
- Annual summer school (3-4 days)
- Member of IAPR
Organisations

International Association for Pattern Recognition
www.iapr.org

- Newsletter
- Conferences
- Journals
Course Arrangement

• 12 lectures
• 3 computer exercises (1-2 students per group)
  • Introduction to digital image analysis
  • Segmentation
  • Classification
• Written exam
• (Course Pub)
Learn how to work with an image in **MATLAB**.

- Histogram, filtering, arithmetics, FFT etc.
- Report done orally during lab session
- Otherwise hand in a written report

Good to idéa to start before the scheduled time.
Segmentation and analysis of circular objects using MATLAB Image Processing Toolbox.

- Combine functions to segment and analyse image of coins
- No “perfect solution”
- Written lab report
Segment real image regions using classification in MATLAB.

- Different statistical methods will be tried
- Thresholding vs Maximum-Likelihood classification
- Using colour images
- Written lab report
Introduction

What is a digital image?

rat.png

Rat nose

```
>> 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
```
Why Digital Image Analysis?

Human
- Identification
- Recognition
- See and describe relations
- Interpretation using experience

Computer
- Measuring absolute values
- Perform calculations
- Never gets tired
- Cheap
- Fast
- Objective
Perception and Objectiveness

Which inner square is the brightest?

How much is dark and bright respectively?
Perception and Objectiveness

Which inner square is the brightest?

How much is dark and bright respectively?
Application Examples
Agricultural and Environmental
Application Examples
Medical and Biomedical
Problem Solving Using Image Analysis

Fundamental steps

Low level
- Problem
- Image acquisition
- Preprocessing

Intermediate level
- Segmentation
- Representation
- Knowledge base

High level
- Classification
- Result
Image Processing vs Image Analysis

Difference in Terminology

Image Processing

Image Analysis

- Blue eyes
- 8cm ears
- Greek flag
Course Contents

• Digitization
• Pointwise operations
• Local neighbourhood operations
• Fourier transform (FFT)
• Segmentation
• Mathematical morphology
• Object description and representation
• Image restoration
• Colour
• Classification
• Image coding and compression
Electromagnetic Spectrum
Other Image Acquisition modalities

- Acoustic Imaging
- Electron Microscopy (TEM and SEM)
Creating a Digital Image

Illumination source

Scene element

Imaging system
Creating a Digital Image

Illumination source

Scene element

Imaging system

Image plane
Creating a Digital Image

Illumination source

Scene element

Imaging system

Image plane

Output
Sensors

- Point scanner
- Line scanner
- Array scanner
Digital Images

A 2D grayscale image $f(x, y)$
The value of $f(x, y)$ is the intensity, or graylevel, at position $(x, y)$. When an image is digitized it is sampled in

- **SPACE** $(x, y)$: image sampling
- **AMPLITUDE** $f(x, y)$: graylevel quantization

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Spatial Sampling
Spatial 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** (short for picture element) in 2D and **voxel** (short for volume element) in 3D. It is usually square (cubic) but can also have other shapes, e.g. rectangular or hexagonal grids.
• 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 dots per inch (dpi) = pixels per 2.54 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.
Graylevel Quantization

256

32

8

2
Graylevel Quantization

256

128

64

32

16

8

4

2
Methods for Quantization (in Amplitude)

- Uniform (linear) - the intensities of the object are mapped directly to the graylevels of the image.
- Logarithmic - higher intensity resolution in darker areas (the human eye is logarithmic).
Common Quantization Levels

Image values when using integers, \( f(x, y) \in [0, 2^n - 1] \).

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<th>Interval</th>
<th>Comment</th>
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<td>( n = 1 )</td>
<td>([0, 1])</td>
<td>“binary image”</td>
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<tr>
<td>( n = 5 )</td>
<td>([0, 31])</td>
<td>what the human can resolve locally</td>
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<tr>
<td>( n = 8 )</td>
<td>([0, 255])</td>
<td>1 byte, very common</td>
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<td>( n = 16 )</td>
<td>([0, 65535])</td>
<td>common in imaging systems</td>
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<tr>
<td>( n = 24 )</td>
<td>([0, 16.2 \times 10^6])</td>
<td>common in colour images ((3 \times 8 \text{ bit for RGB}))</td>
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Choice of 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 graylevel resolution)?
Resampling, Graylevel Interpolation

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

Original image

Rotation with NN interpolation

Rotation with bilinear interpolation
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 high to be correctly represented when the image is subsampled to \( \frac{1}{4} \) of its size.

This image was scanned from a magazine, resulting in a pattern due to the frequency of the raster in the printing.
The Nyquist–Shannon Sampling Theorem

• The Nyquist–Shannon Sampling Theorem is a fundamental theorem in image analysis.

• 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.

Review Questions

• What is the difference between image processing and image analysis?
• Spatial sampling vs. graylevel quantization?
• What is the difference between nearest neighbour and bilinear interpolation?
• How often should you sample with respect to the smallest detail that needs to be resolved?
• What is aliasing?