

Computer Assisted Image Analysis 1

GW 1, 2.1-2.4

Filip Malmberg

Centre for Image Analysis

Department of Information Technology

Uppsala University



Course Overview

9+1 lectures (Filip, Robin, Natasa, Joakim)



5 computer exercises (Tomas, Eva, Nicolas, Elisabeth)

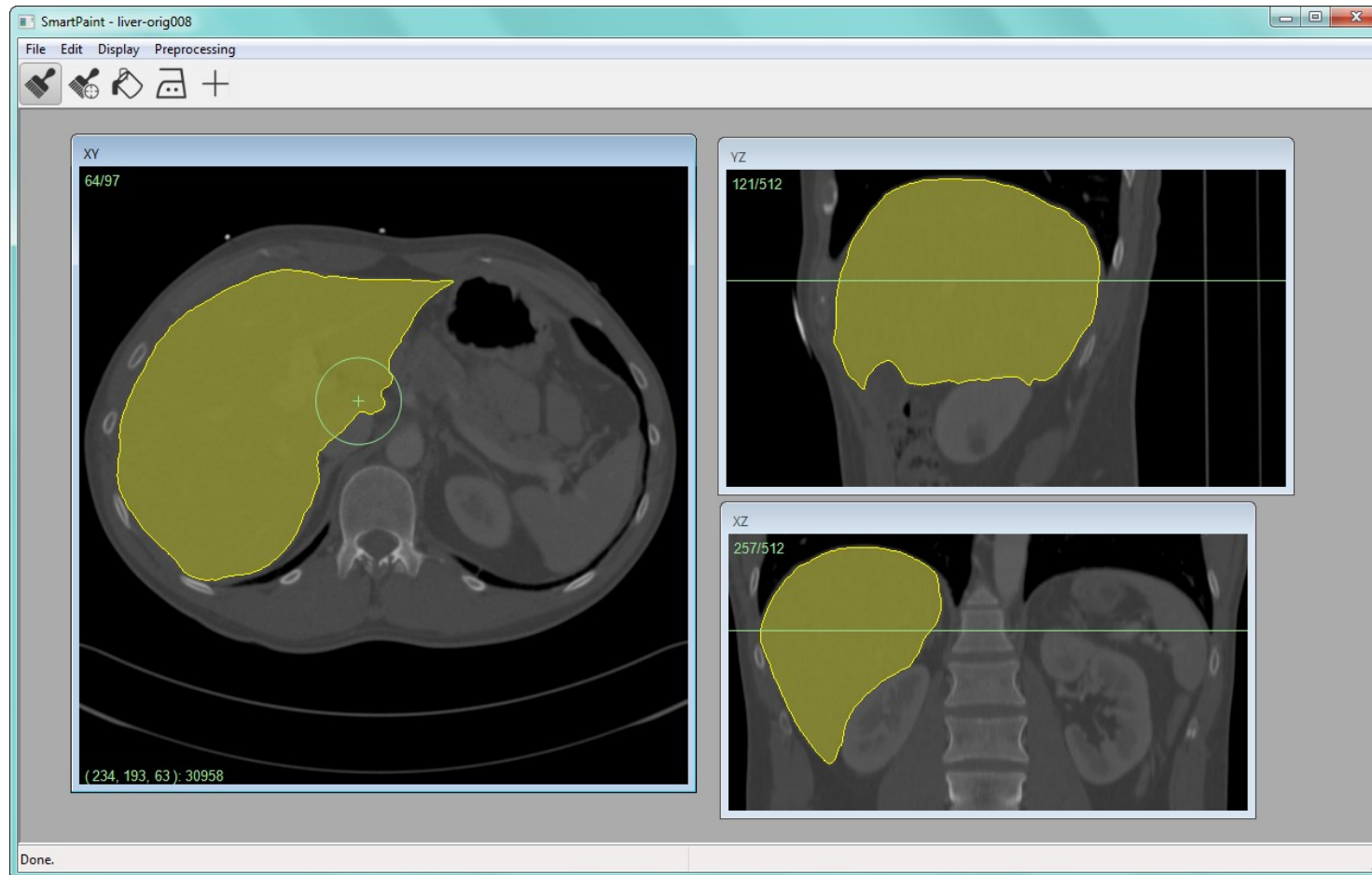


About me

- 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

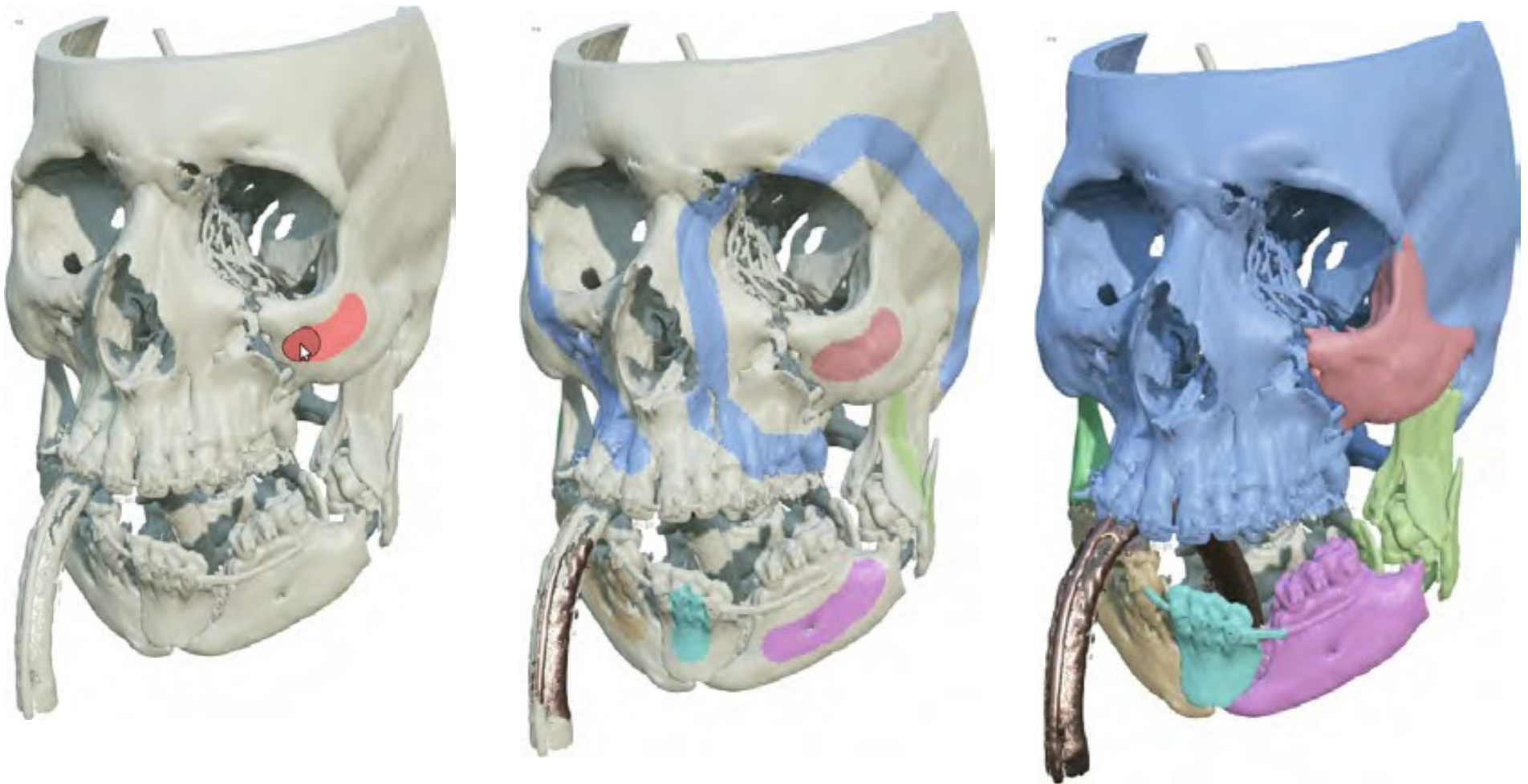


Interactive image segmentation

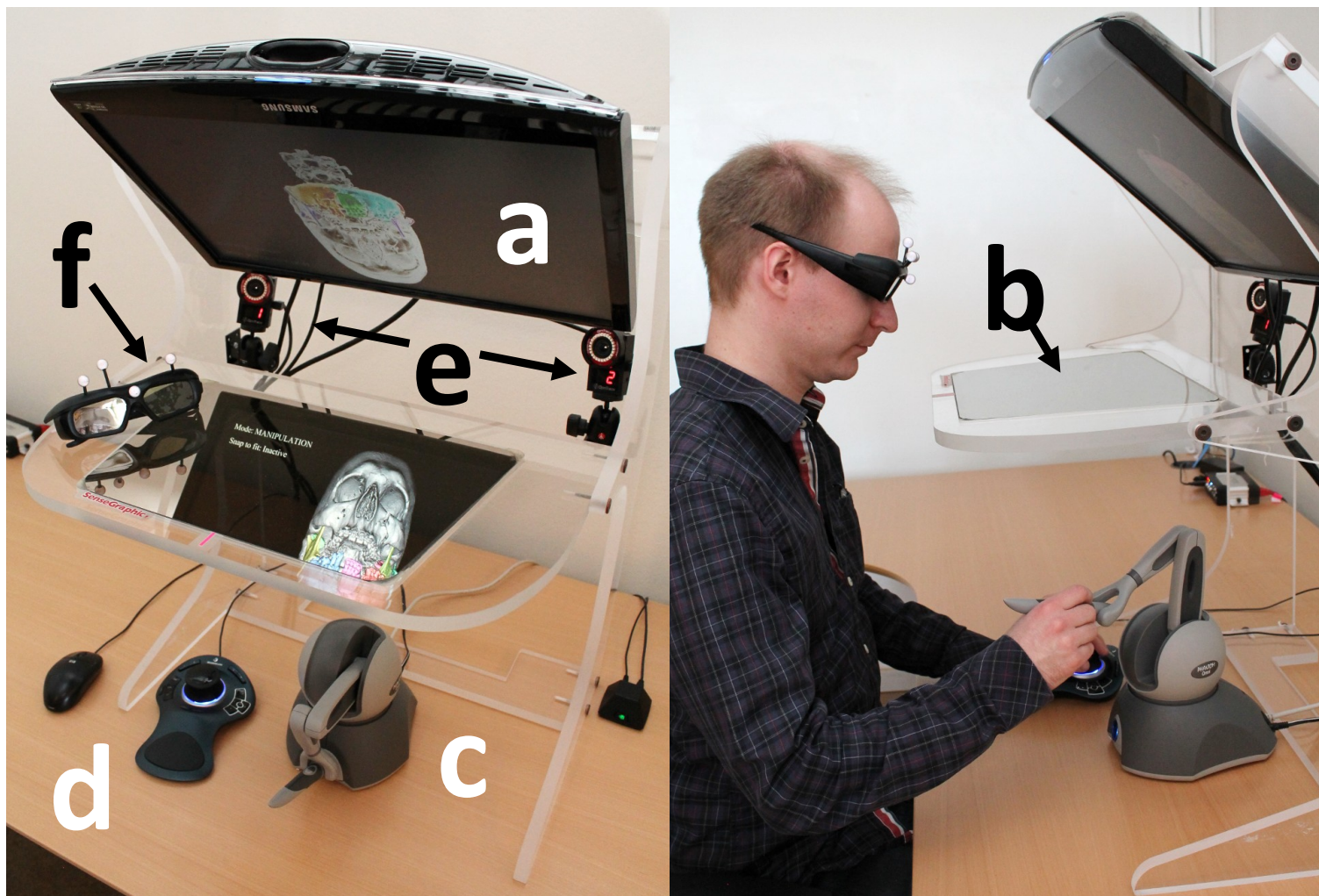


<http://www.cb.uu.se/~filip/SmartPaint/>

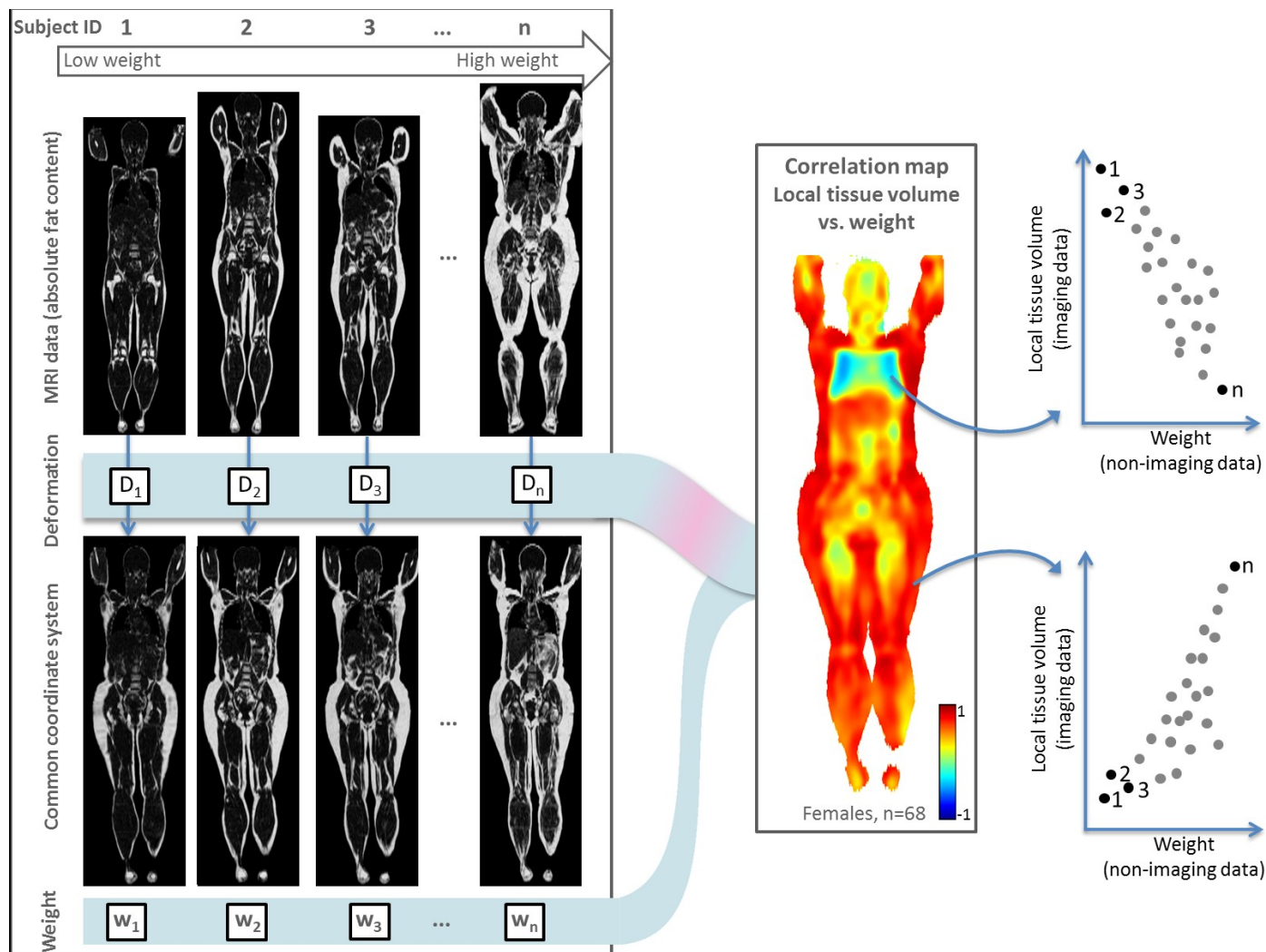
Interactive image segmentation



Virtual surgery planning



Large scale, whole-body MR image analysis



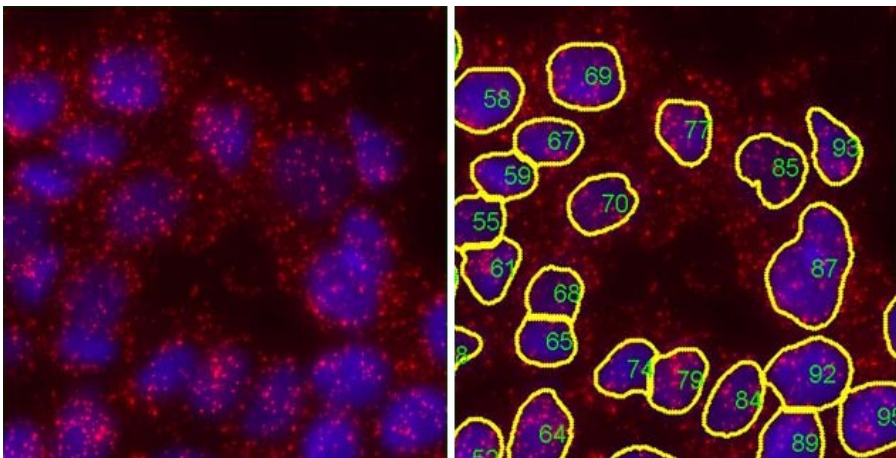
What is image analysis?

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

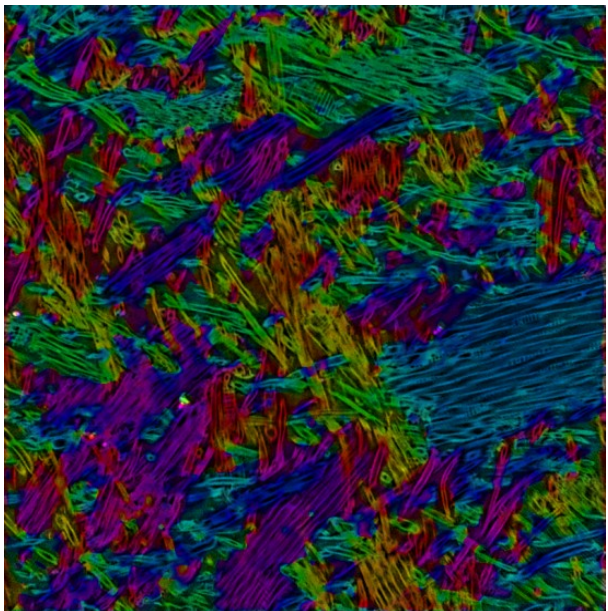
... by means of digital
image processing/analysis techniques.

Image analysis is highly interdisciplinary with foundations in mathematics, signal processing, statistics, computer science ...



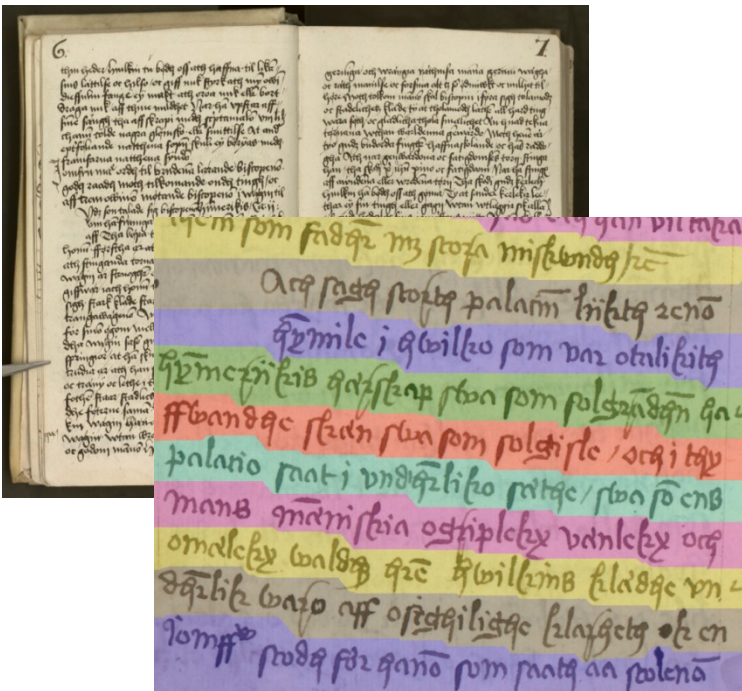


Drug development: How does a drug affect the protein expression in individual cells?



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 and techniques to understand and solve image related problems

Lectures

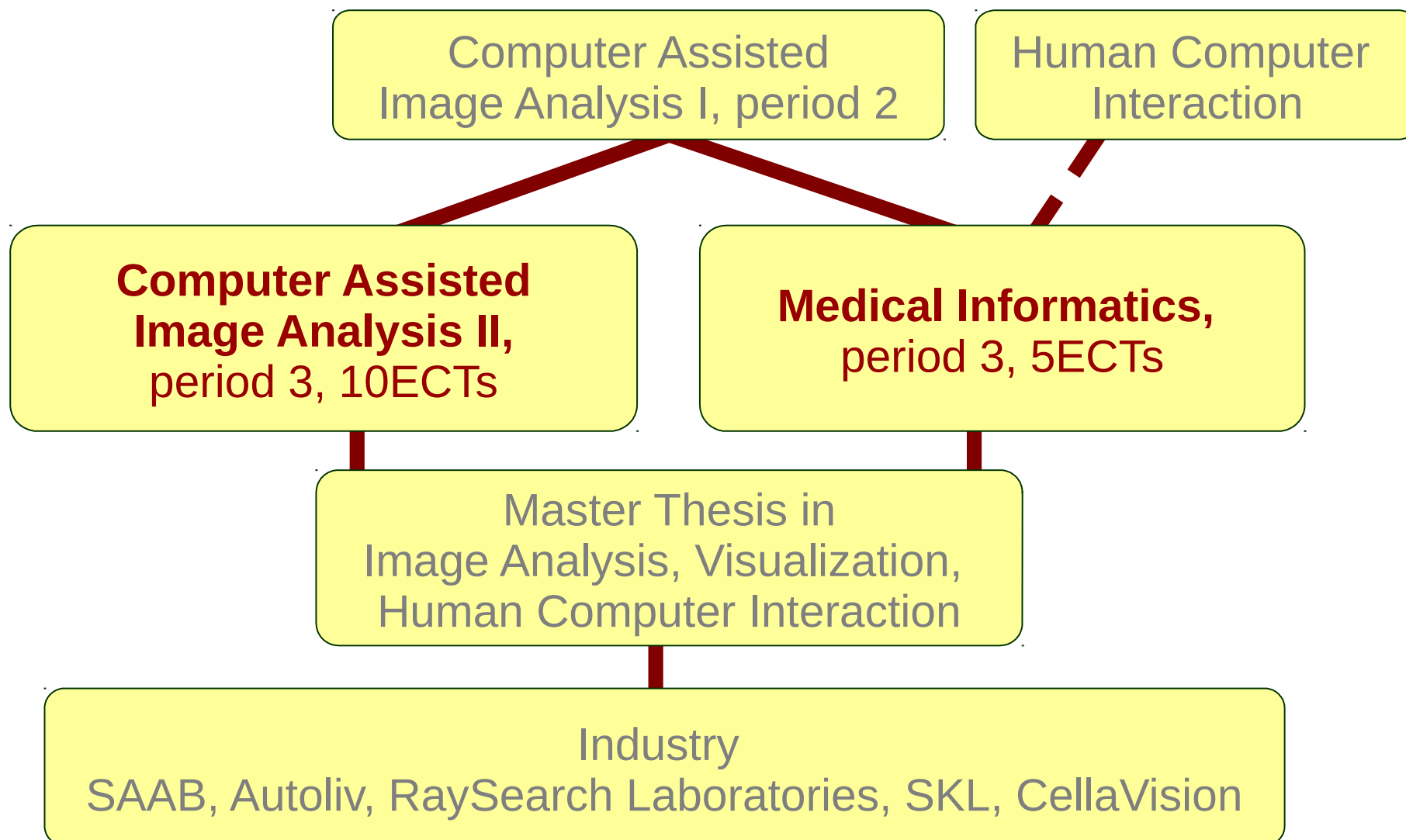
- Introduction
- Pointwise operators
- Filtering
- Filtering 2 (fourier domain)
- Segmentation
- Object Description
- Classification
- Machine learning for image analysis
- Color and compression
- Review

Computer exercises

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



Then what?



Computer Assisted Image Analysis II

Computer Assisted Image Analysis I, period 2

Computer Assisted Image Analysis II, period 3

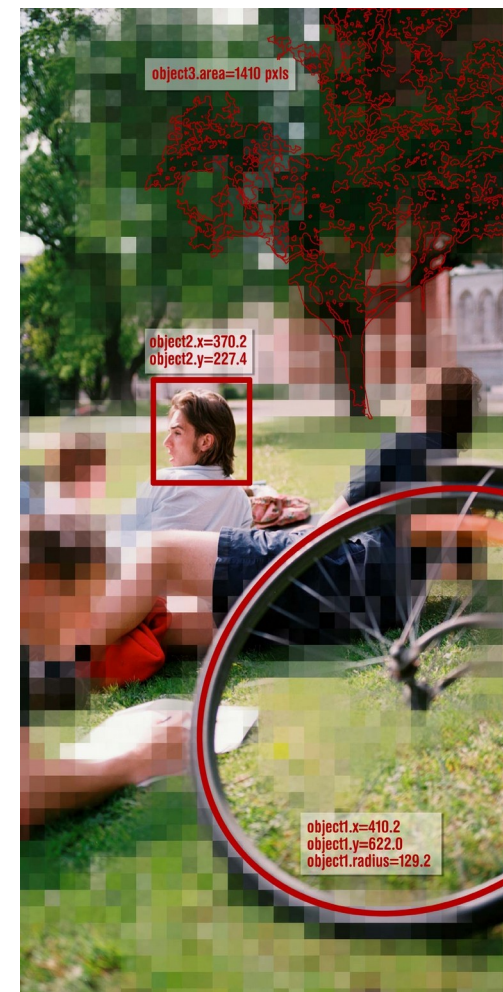
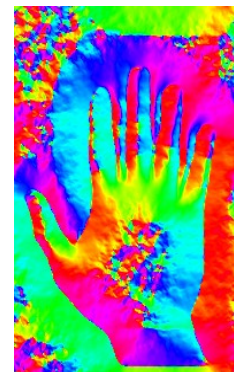
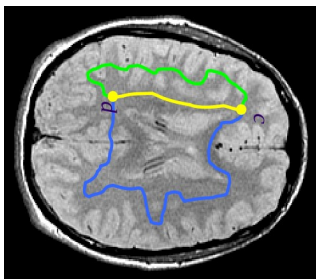
Master Thesis in Image Analysis

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.

Contact:
Natasa Sladoje
natasa.sladoje@it.uu.se

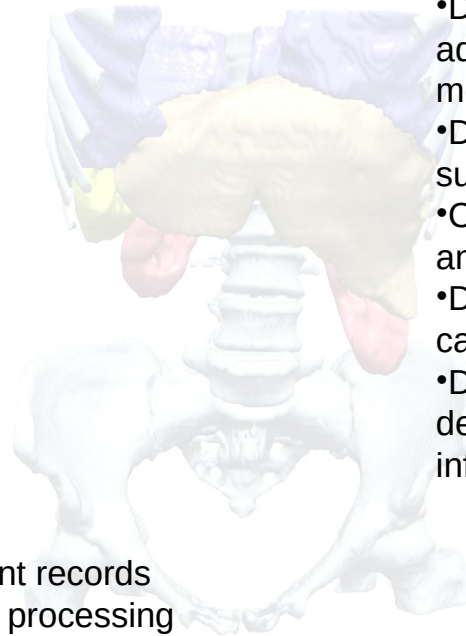


Medical informatics

Computer Assisted
Image Analysis I, period 2

Medical Informatics, period 3

Master Thesis in
Image Analysis, Visualization,
Human Computer Interaction



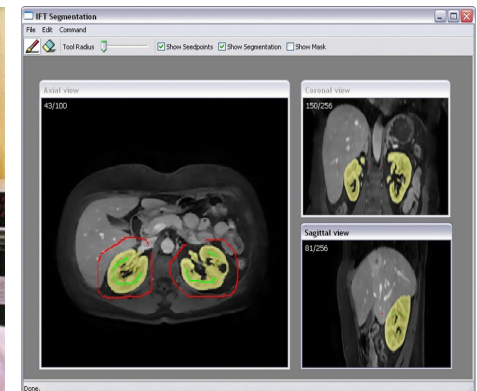
•Learning Goals

- 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.

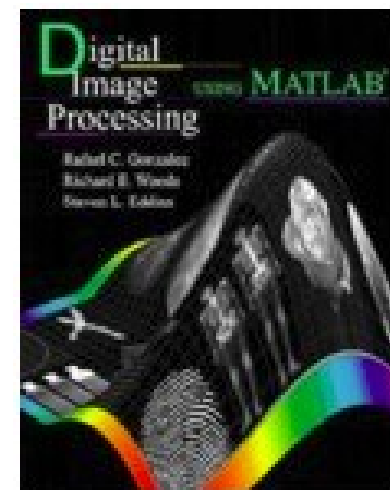
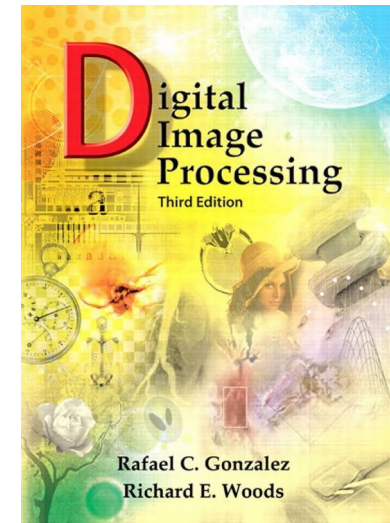


Important info about the exam

- 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
- Gonzalez & Woods: Digital Image Processing, Third edition. (Available locally at Studentbokhandeln, or at various online stores)
- (Digital image processing using matlab)



Swedish Society for Automated Image Analysis, SSBA

www.ssba.org.se

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



SVENSKA
SÄLLSKAPET
FÖR
AUTOMATISERAD
BILDANALYS

SWEDISH
SOCIETY
FOR
AUTOMATED
IMAGE ANALYSIS

MEMBER OF THE
INTERNATIONAL
ASSOCIATION FOR
PATTERN
RECOGNITION

International Association for Pattern Recognition, IAPR

www.iapr.org

- Newsletter
- Conferences
- Journals



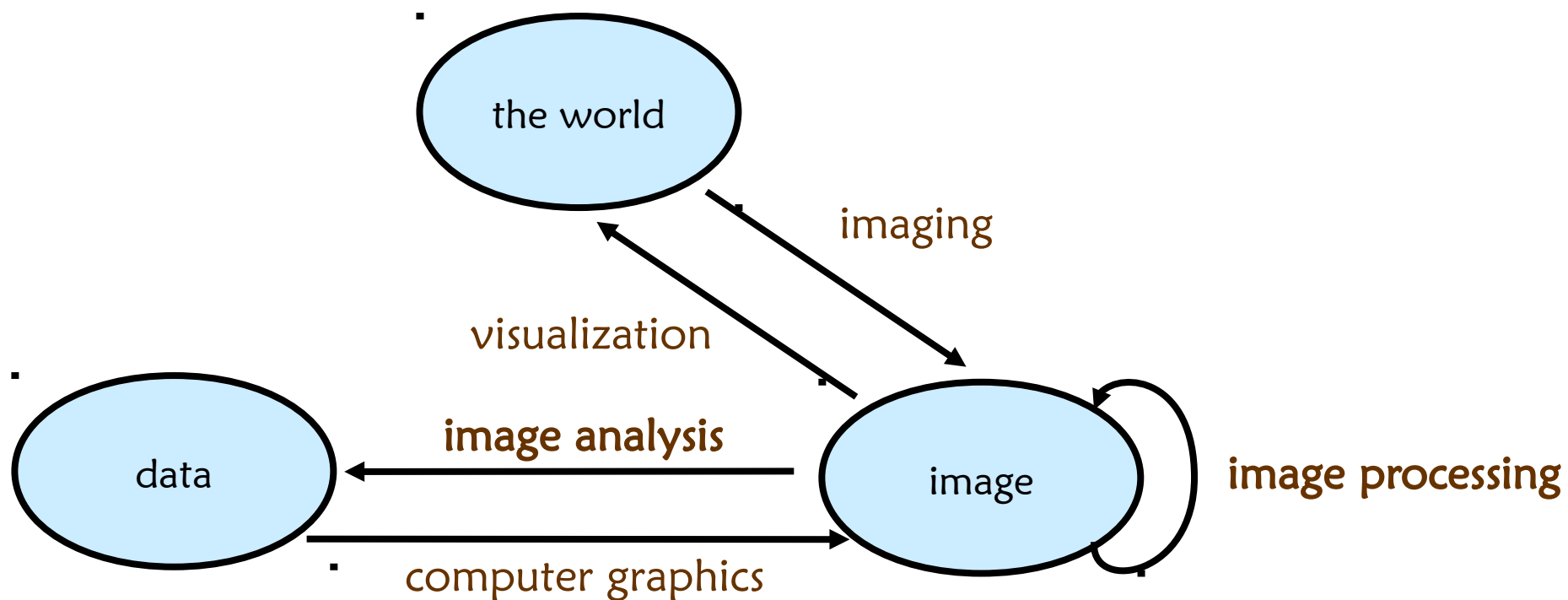
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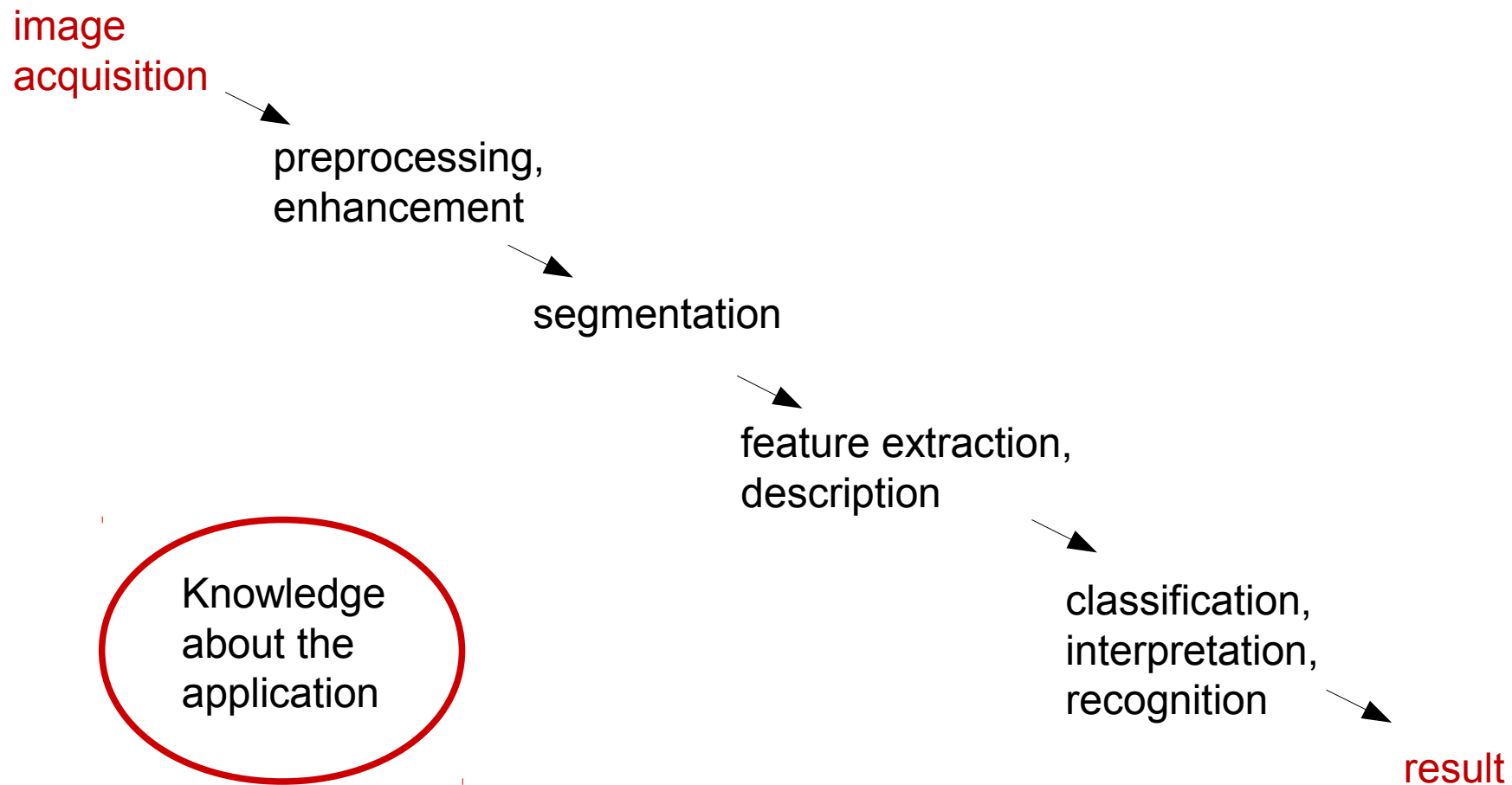


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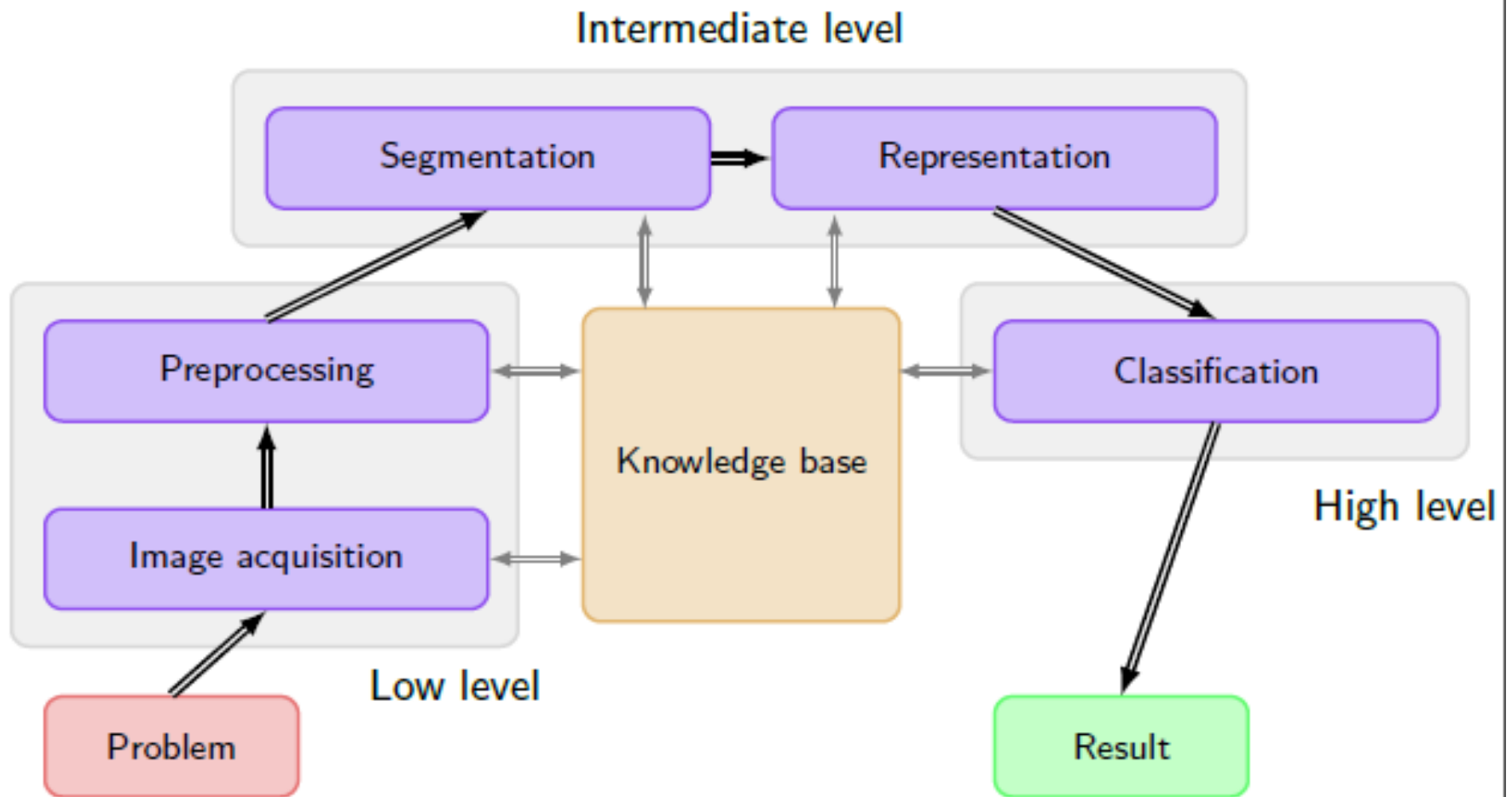
Image processing and analysis



Problem solving using image analysis: fundamental steps

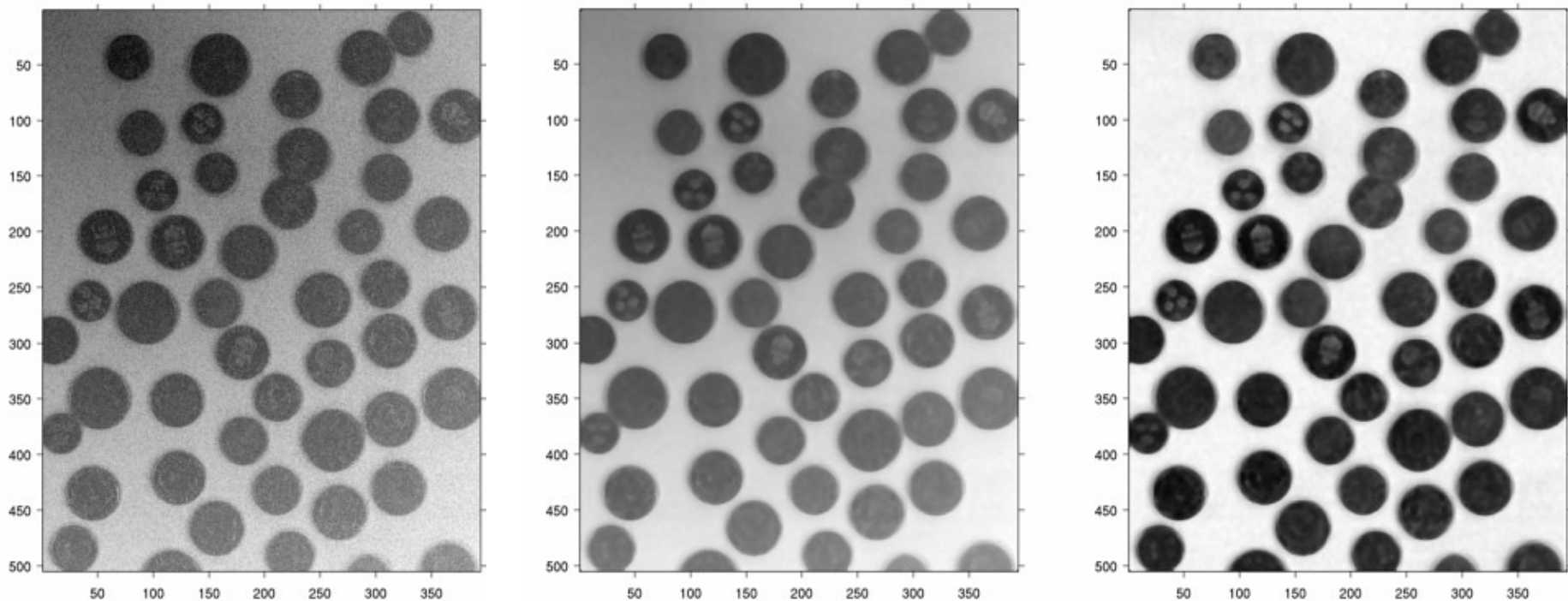


Fundamental steps



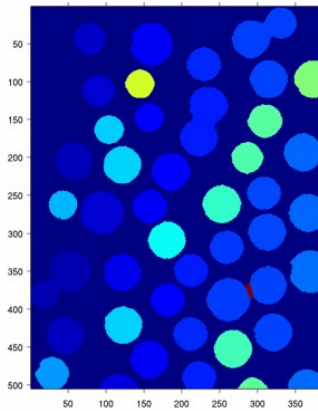
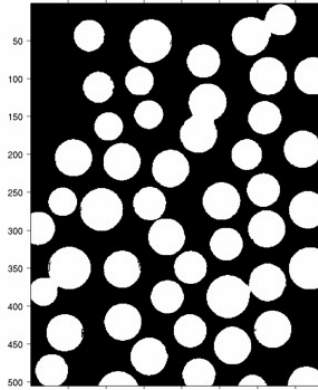
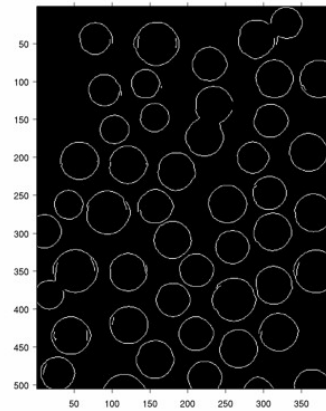
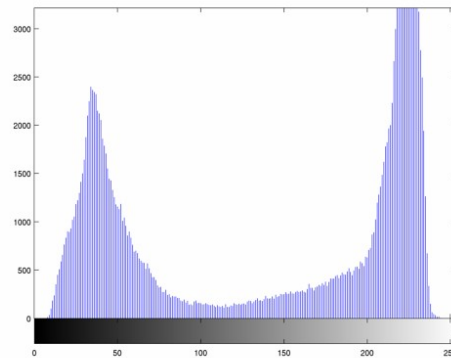
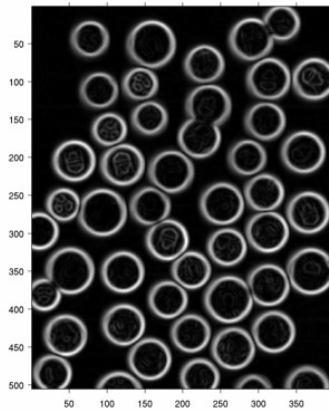
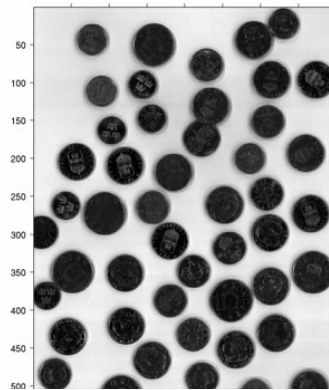
Preprocessing

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



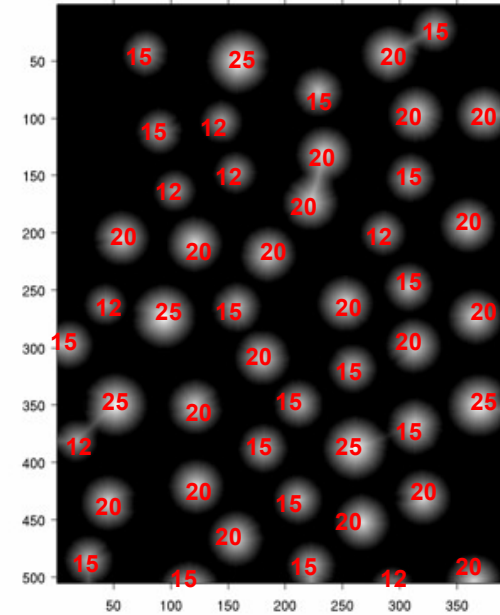
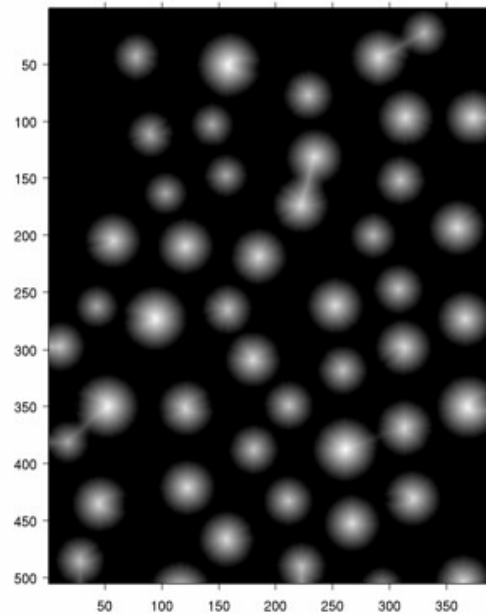
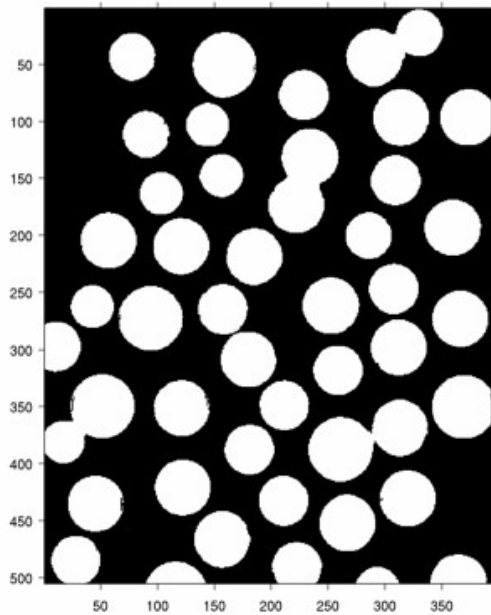
Segmentation

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

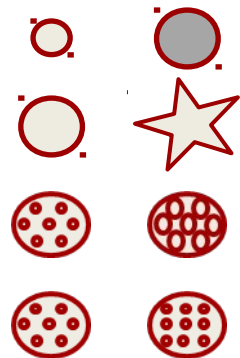
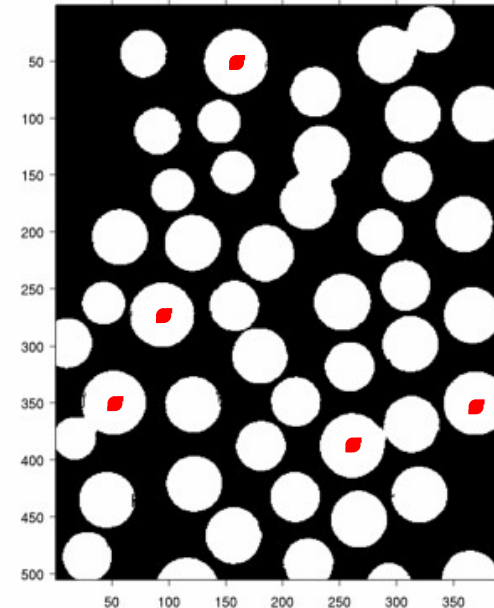
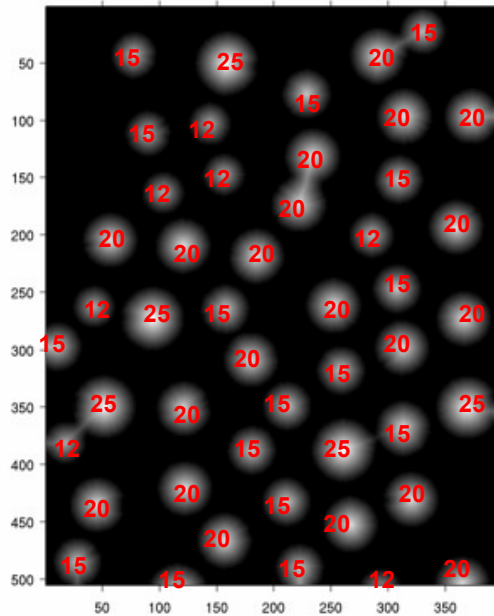


Feature extraction

- Quantitative measures e.g., size, shape, texture...



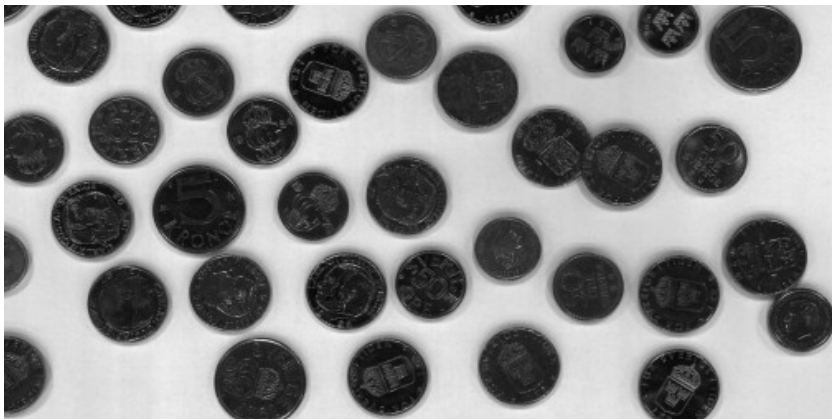
Classification/recognition/interpretation



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



Computers vs. humans



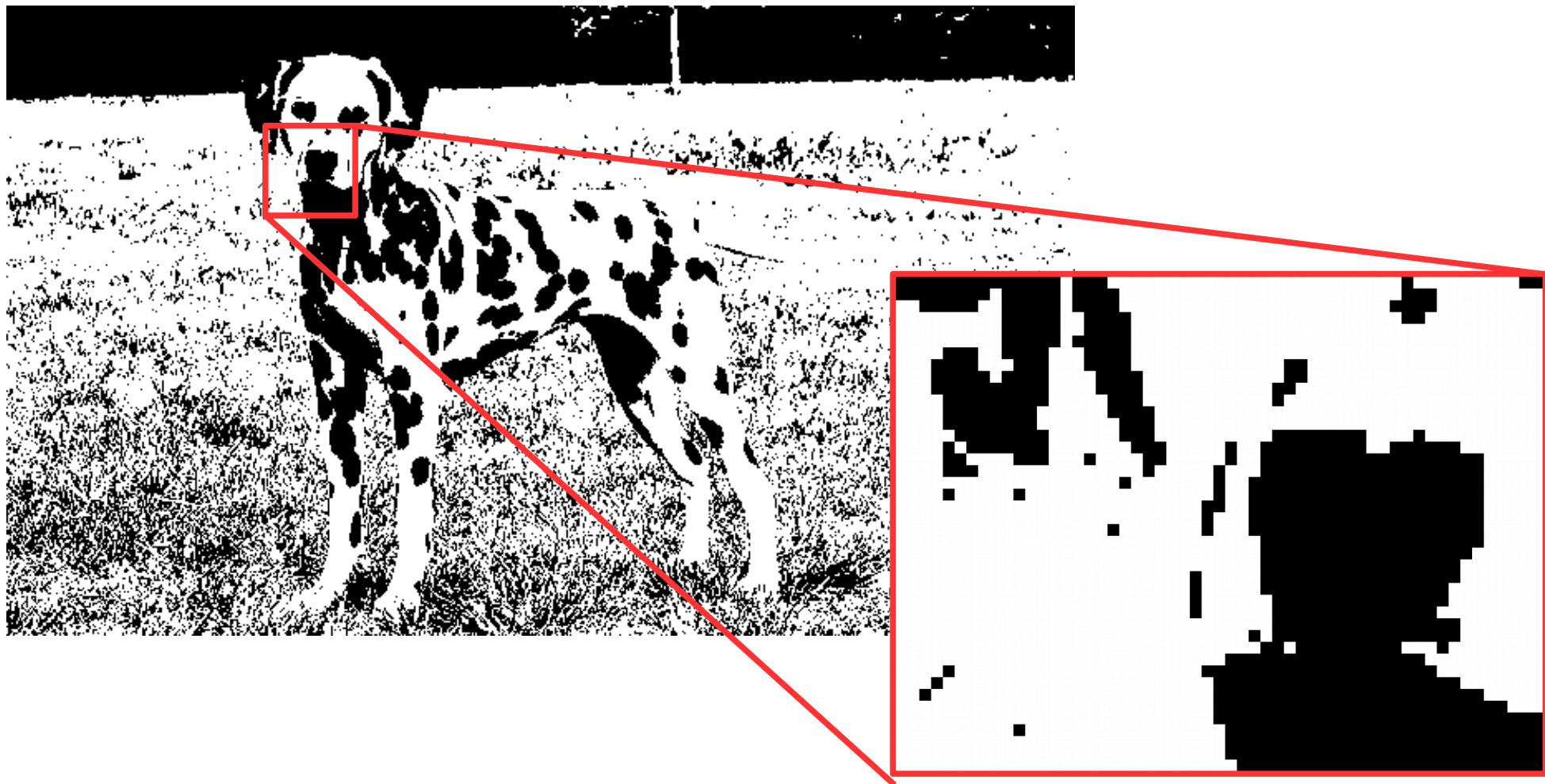
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Computers vs. humans

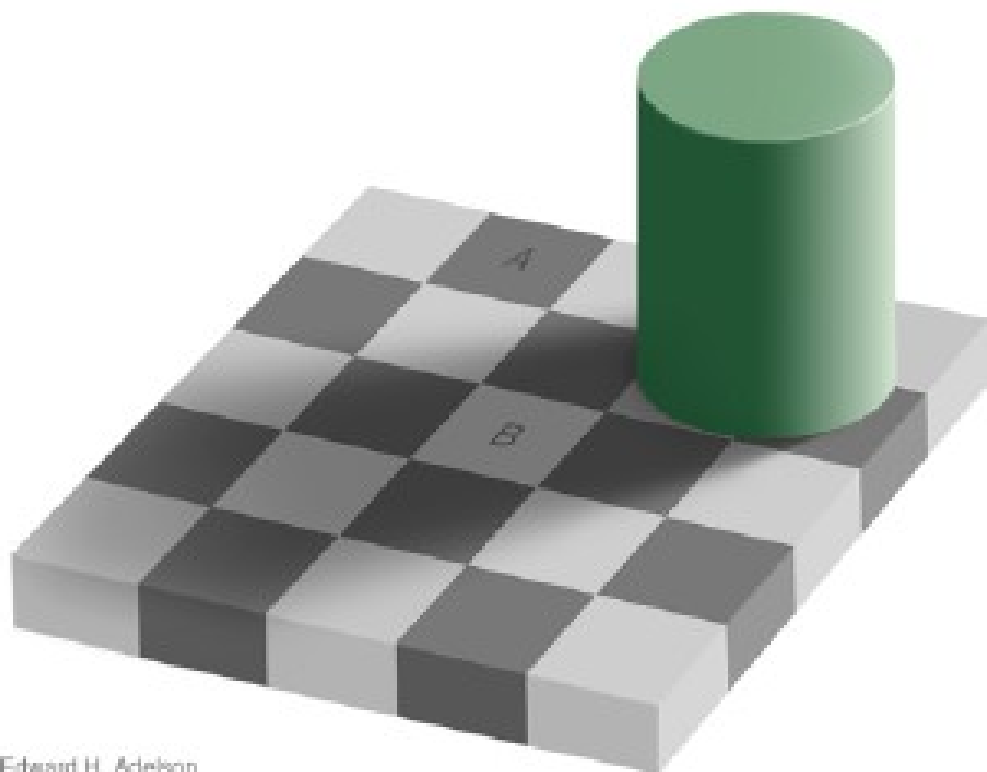


Why automated/computerized image analysis?

- Fast
- Objective
- User Independent
- Accurate

Perception and Objectiveness

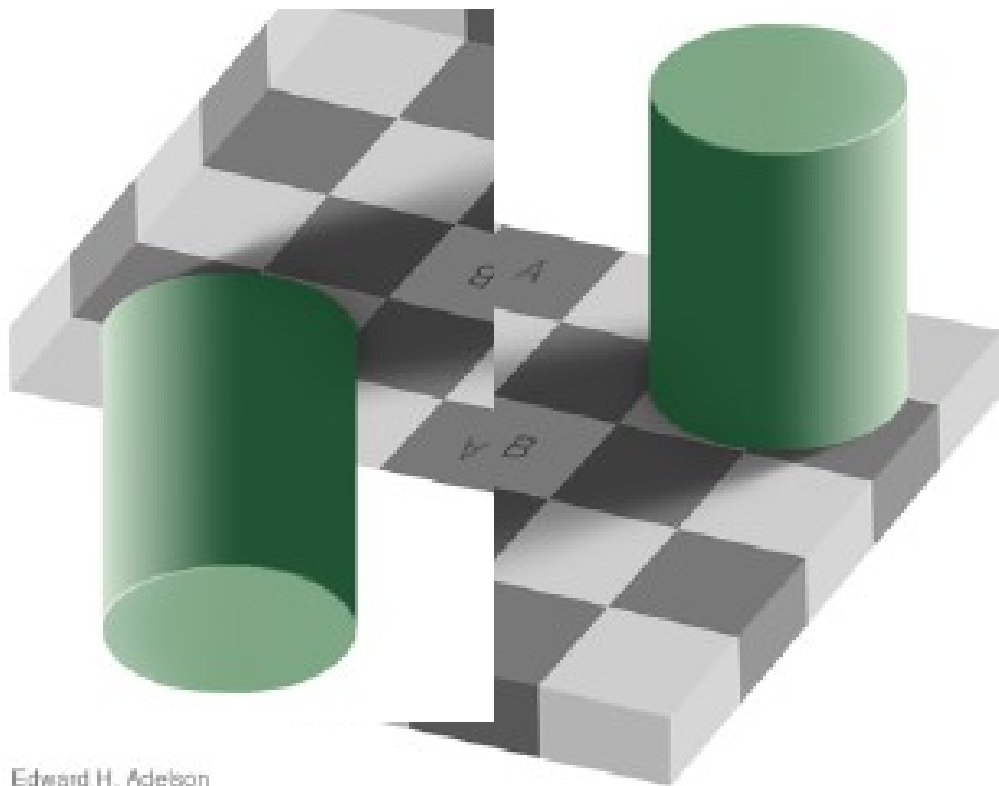
- Which square is brighter: A or B?



Edward H. Adelson

Perception and Objectiveness

- Which square is brighter: A or B?



Edward H. Adelson

Quantification: How much is dark and bright respectively?

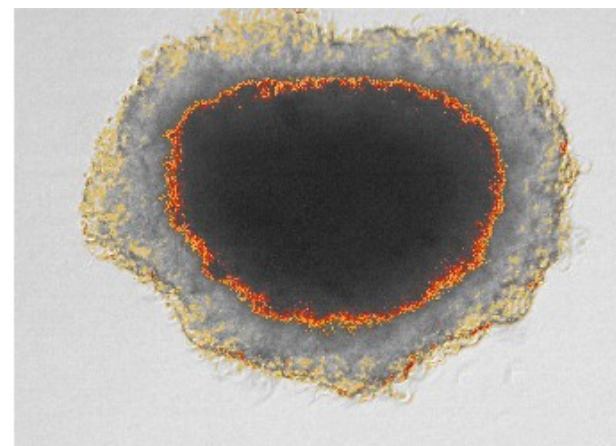
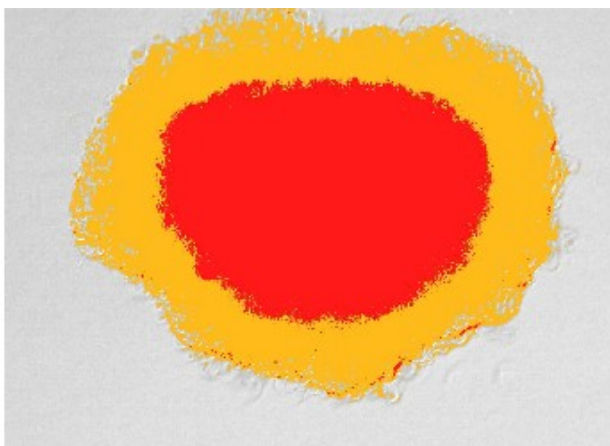
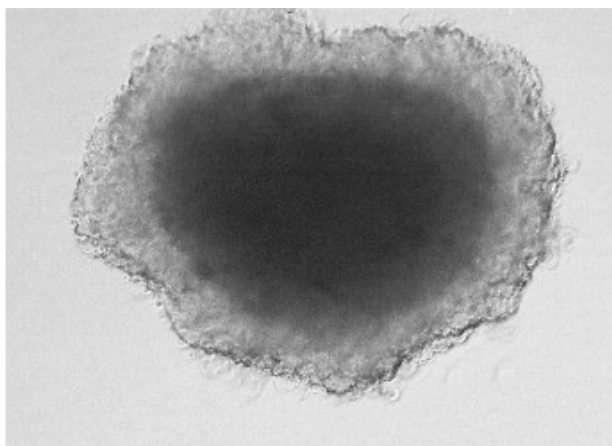
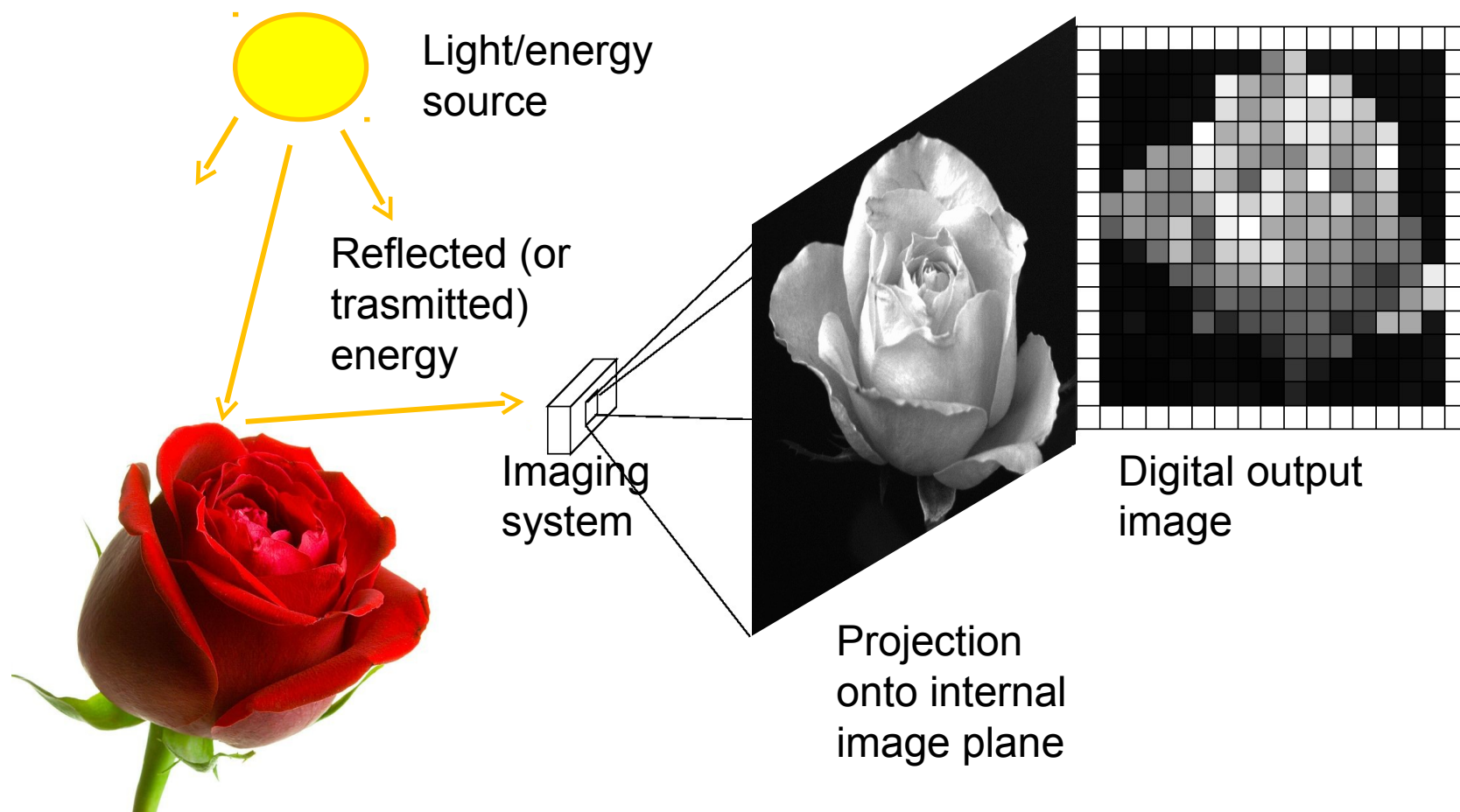
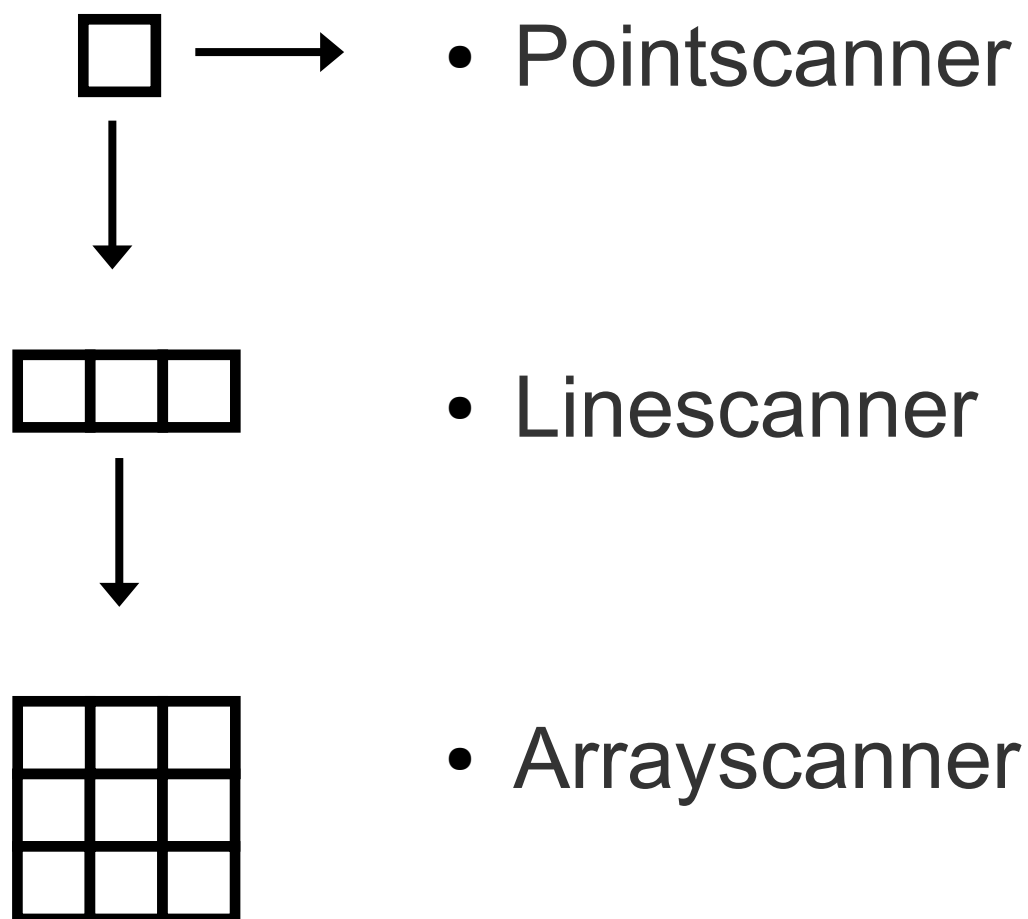


Image formation process



Sensors

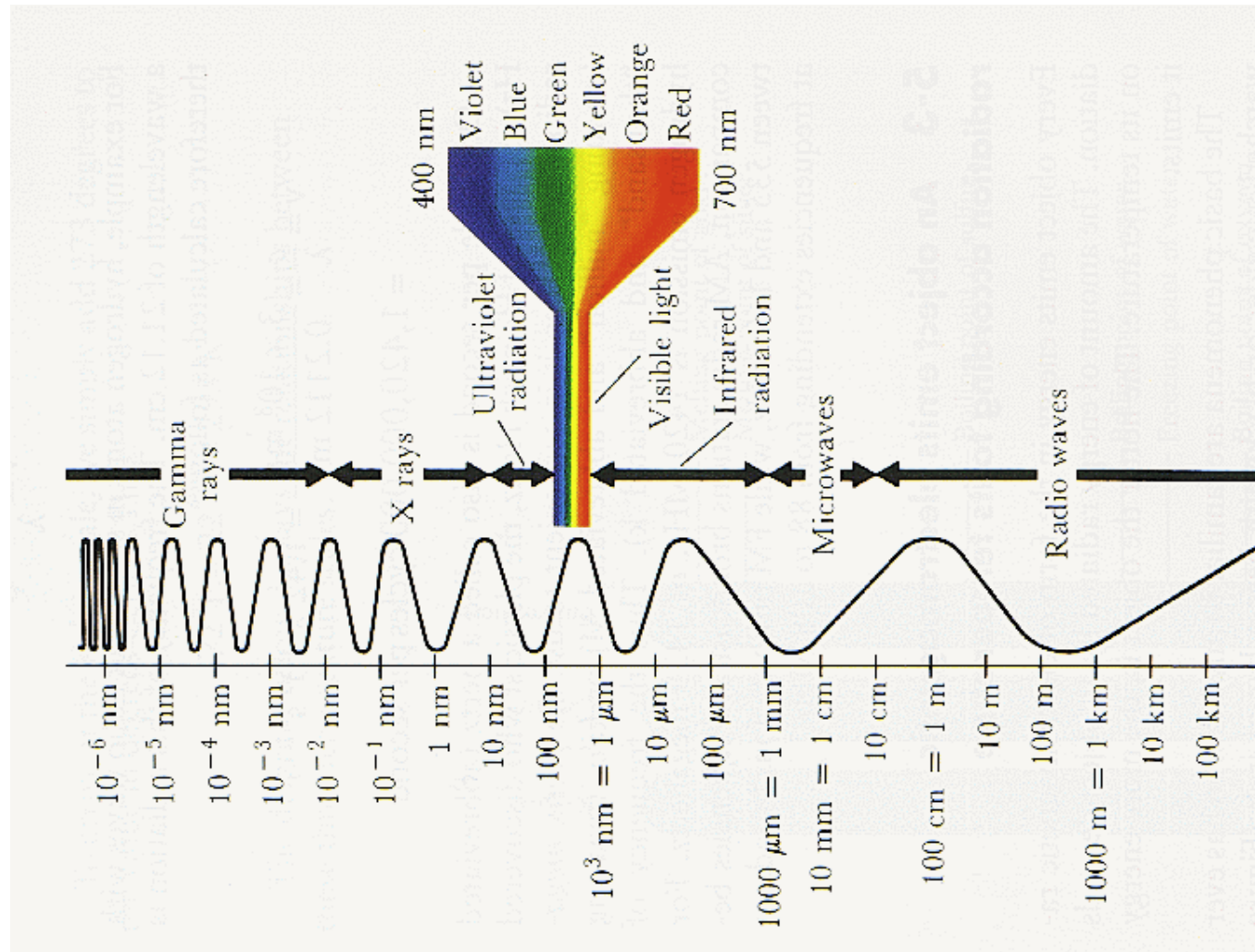


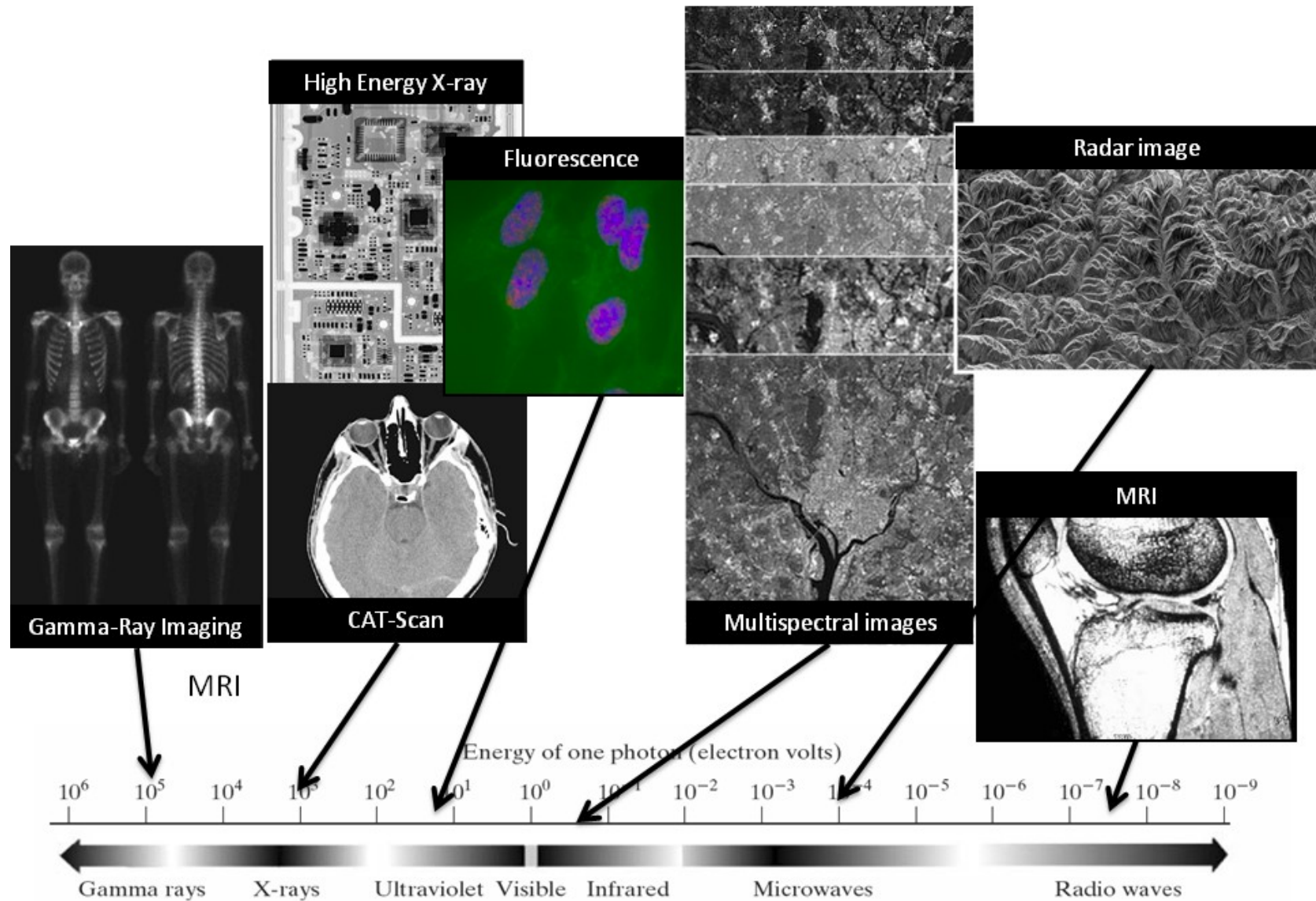
- Pointscanner

- Linescanner

- Arrayscanner

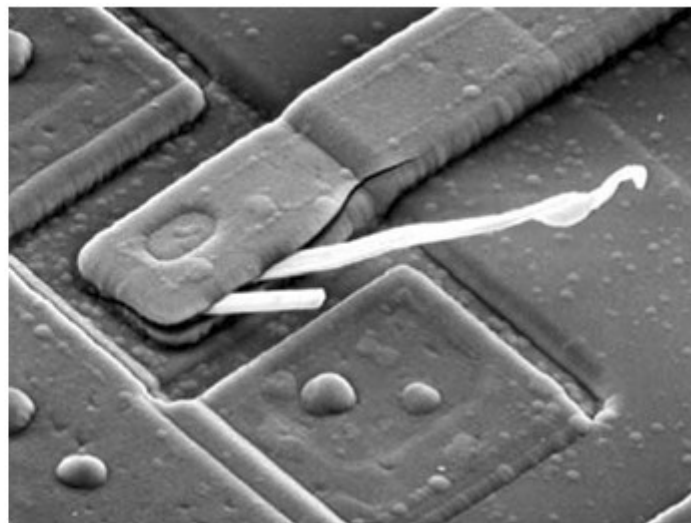
Electromagnetic spectrum





Other common imaging modalities

- Ultrasound, electrons (SEM, TEM)



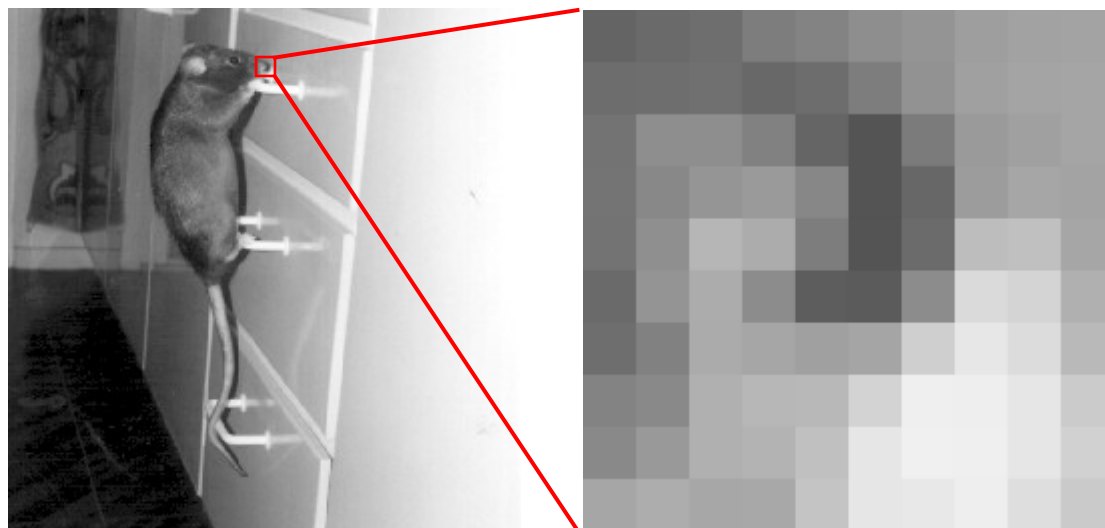
Digital images

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



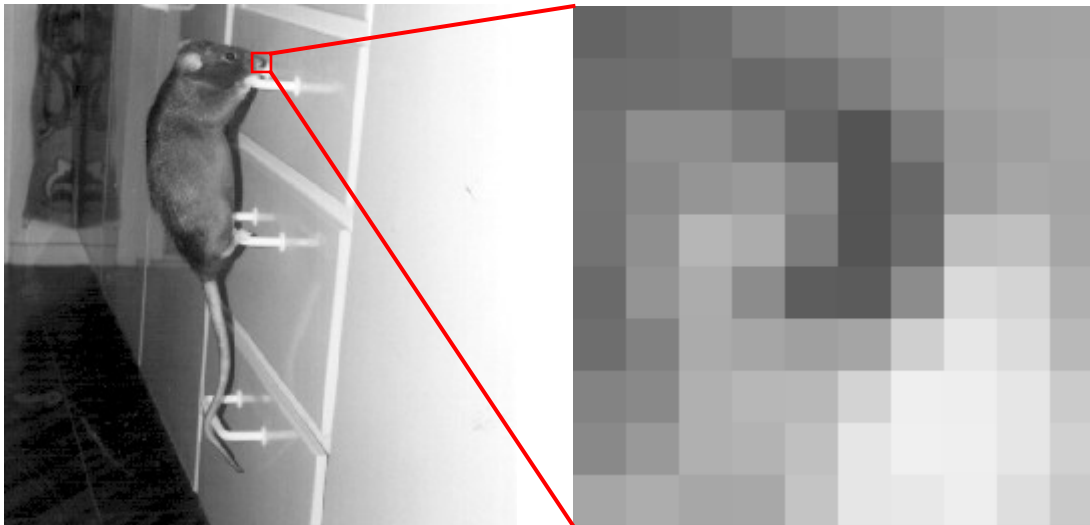
Digital images

- 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

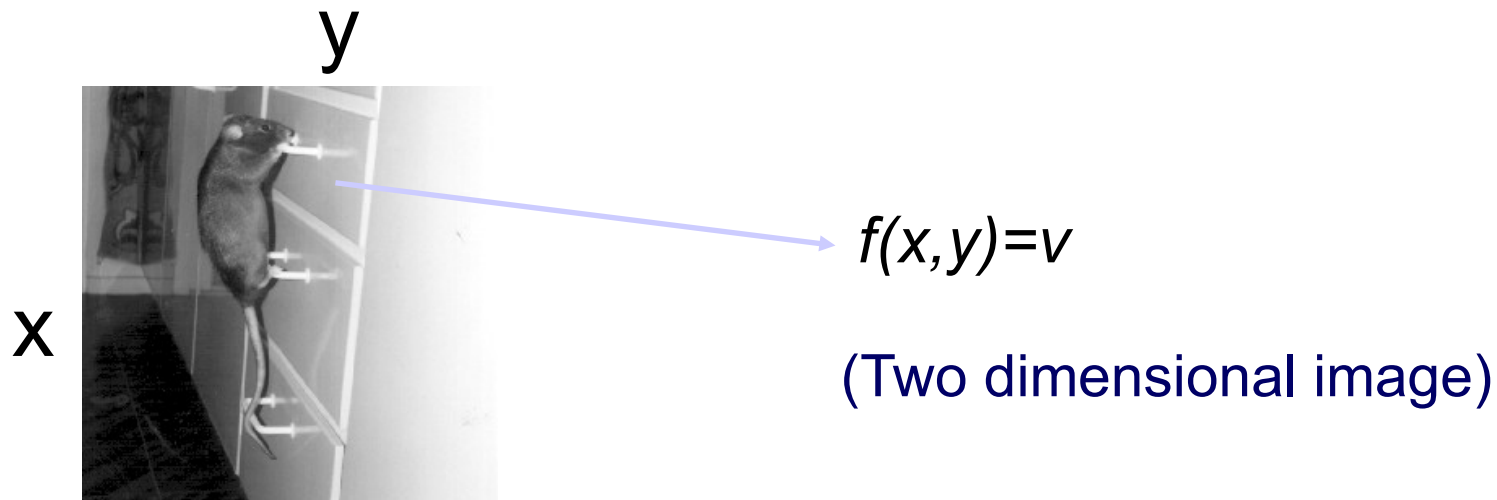


```
>> I = imread('rat.png') ;
>> A = I (26:34 , 125:133)
```

```
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



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

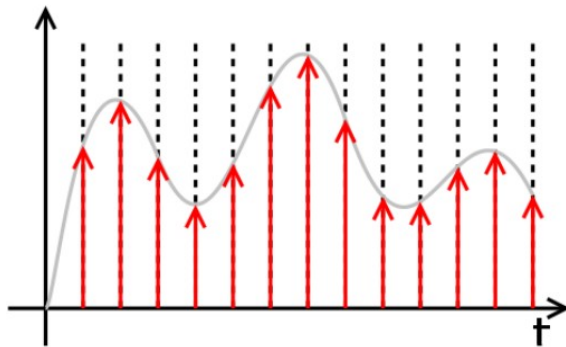
Digitization

- 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

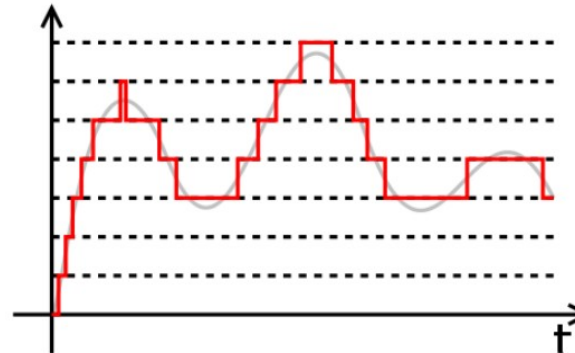


Digitization

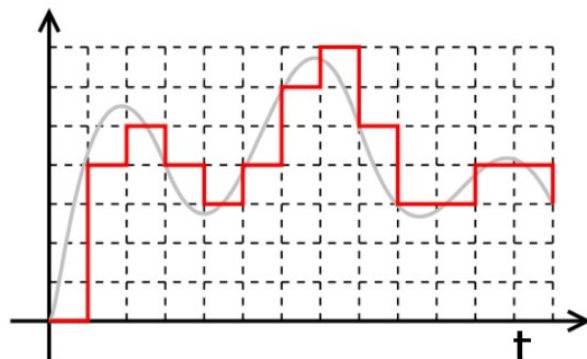
Uniform sampling



Uniform quantization



Digitization



- Sampling rate – spatial resolution
- Quantization - grey level resolution

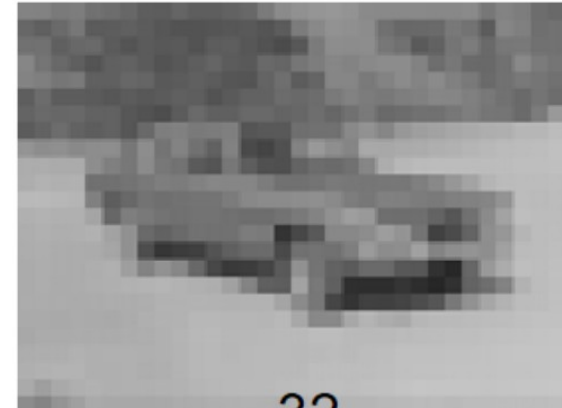
Spatial (x,y) sampling



512



128



32



256



64

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).



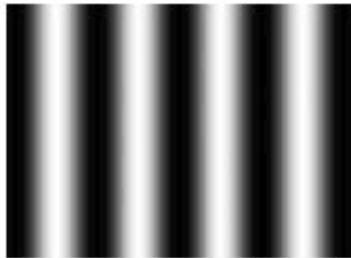
Sampling density and resolution

- 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?)

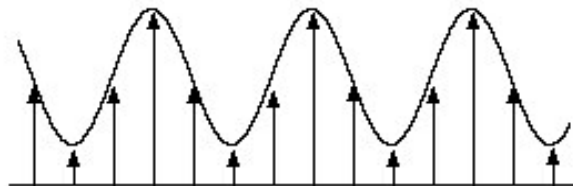


Aliasing when sampling

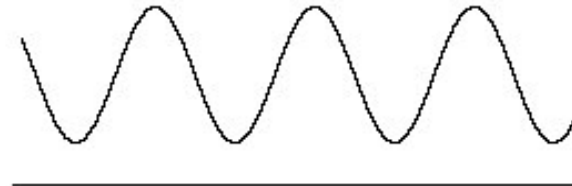
Low frequency input image



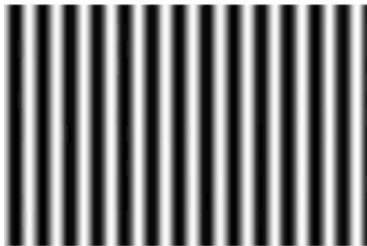
Input image (1-dimension) is correctly sampled



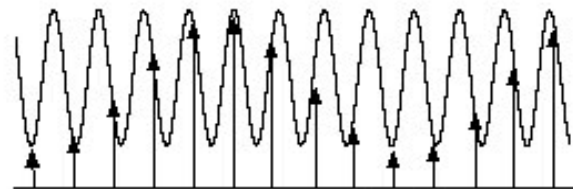
Output image is an accurate representation of the input



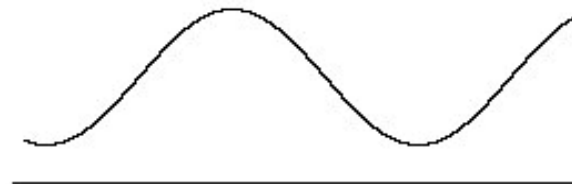
High frequency input image



Input image (1-dimension) is changing too rapidly for correct sampling



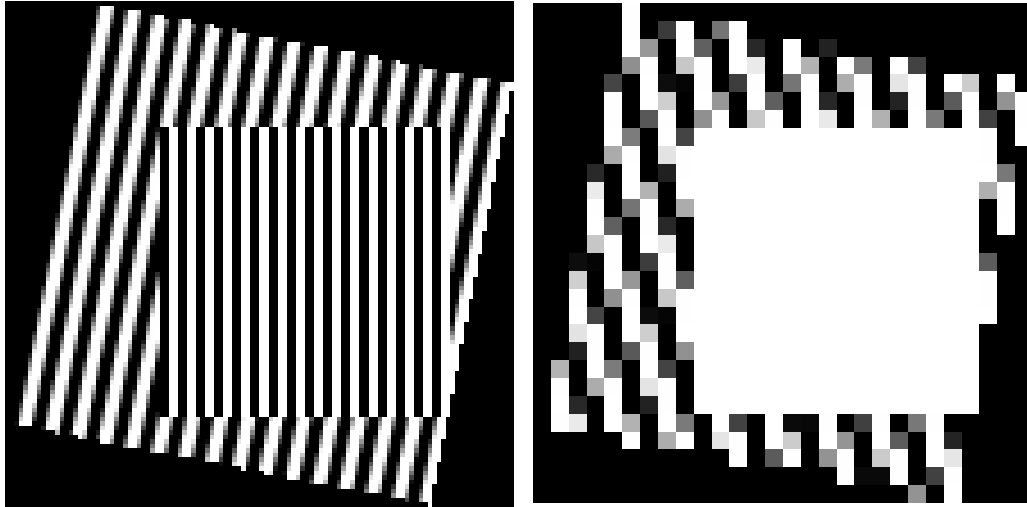
Output image is totally unlike the input



CCD pixels

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 $\frac{1}{4}$ of its size .



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

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.
- Attributed to Harry Nyquist (1889 – 1976) and Claude Shannon (1916 – 2001).
- Avoid aliasing: Remove higher frequencies prior to sampling.



Gray level quantization



256	128	64
32	16	8
4	2	

Common quantization levels

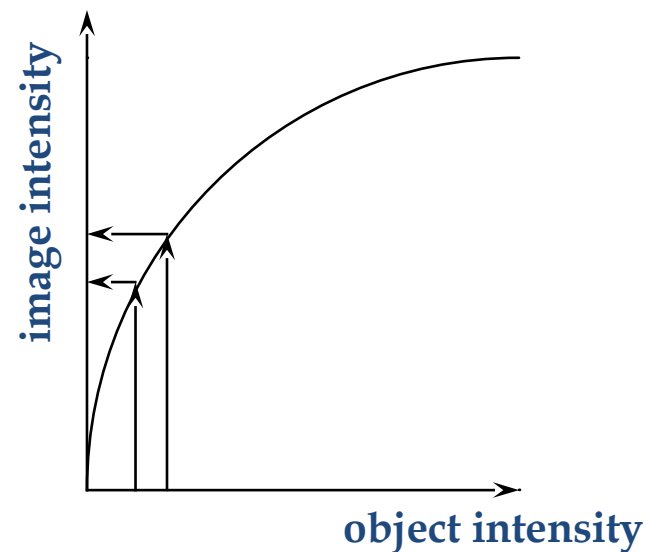
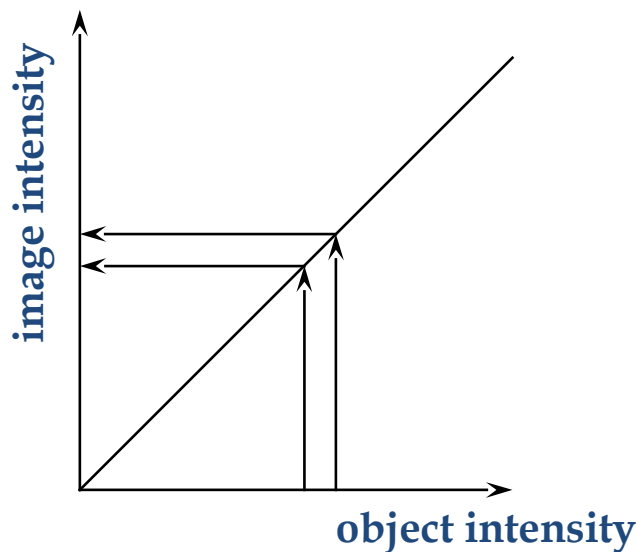
Image values when using integers, in interval $[0, 2^n - 1]$.

Bits	Interval	Comment
$n = 1$	$[0, 1]$	“binary image”
$n = 5$	$[0, 31]$	what the human can resolve locally
$n = 8$	$[0, 255]$	1 byte, very common
$n = 16$	$[0, 65535]$	common in imaging systems
$n = 24$	$[0, 16.2 \times 10^6]$	common for color images (3×8 bit for RGB)

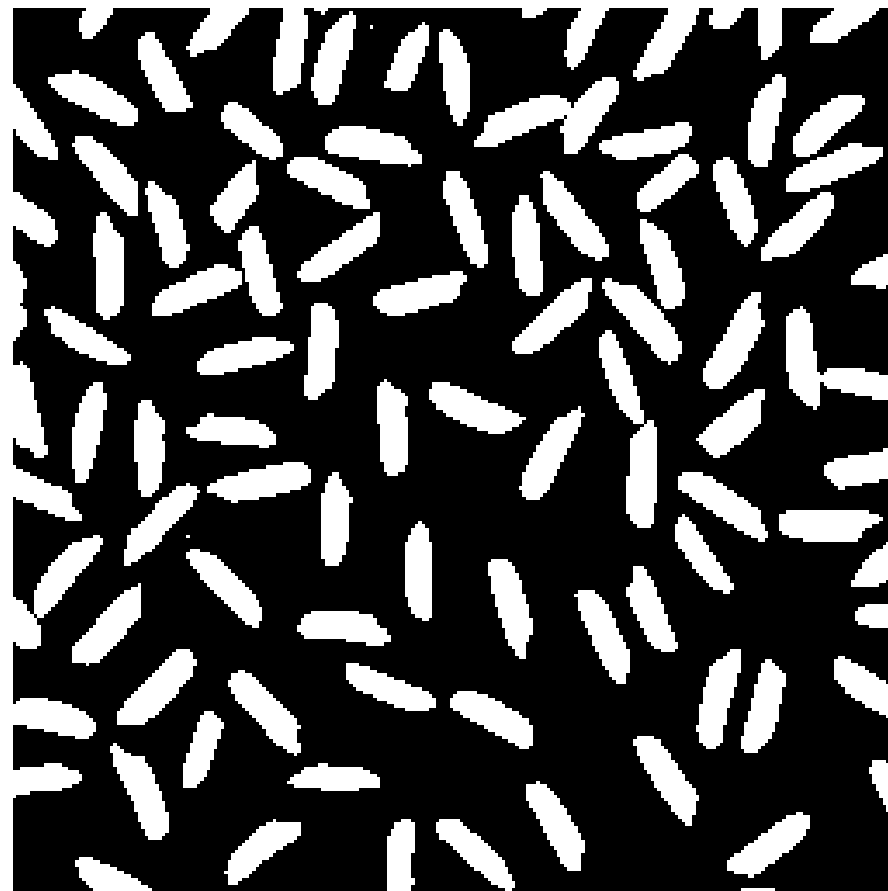


Methods for quantization (in amplitude)

- 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



+



+



=



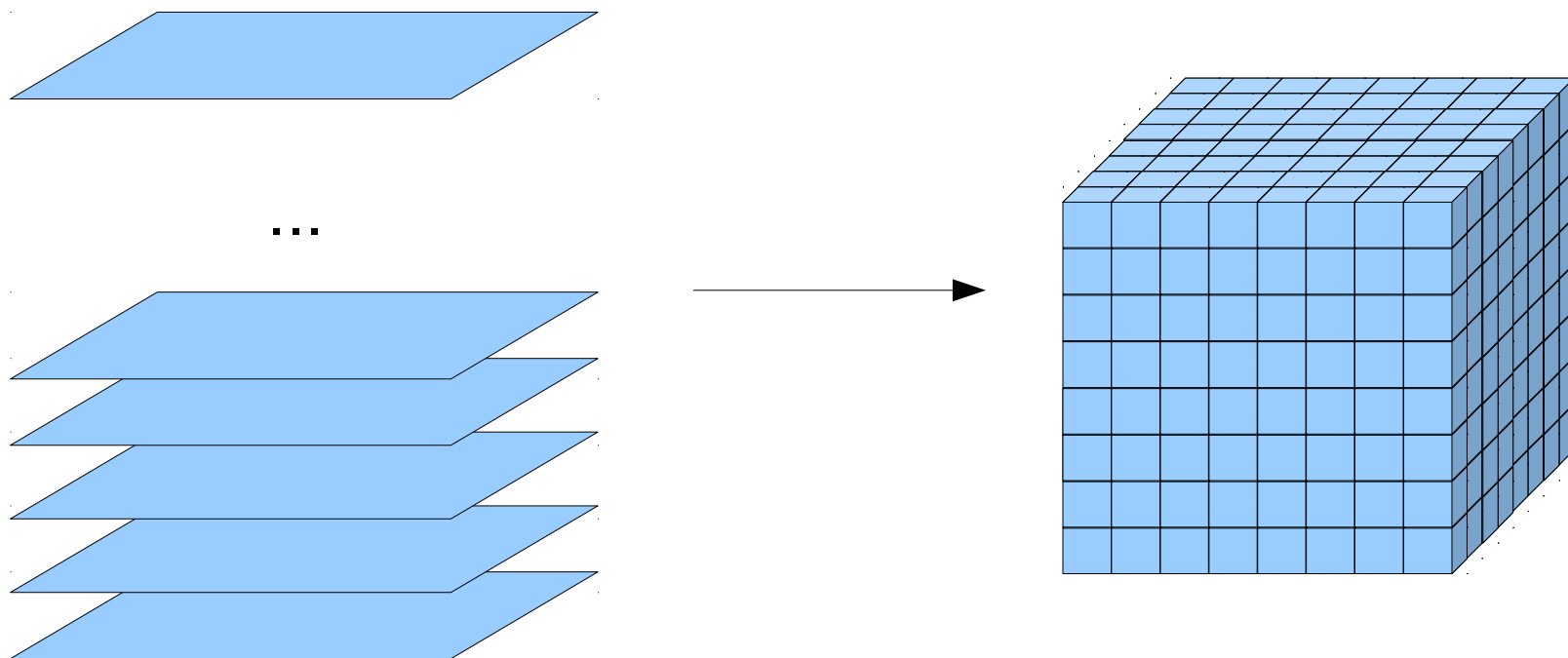
Red

Green

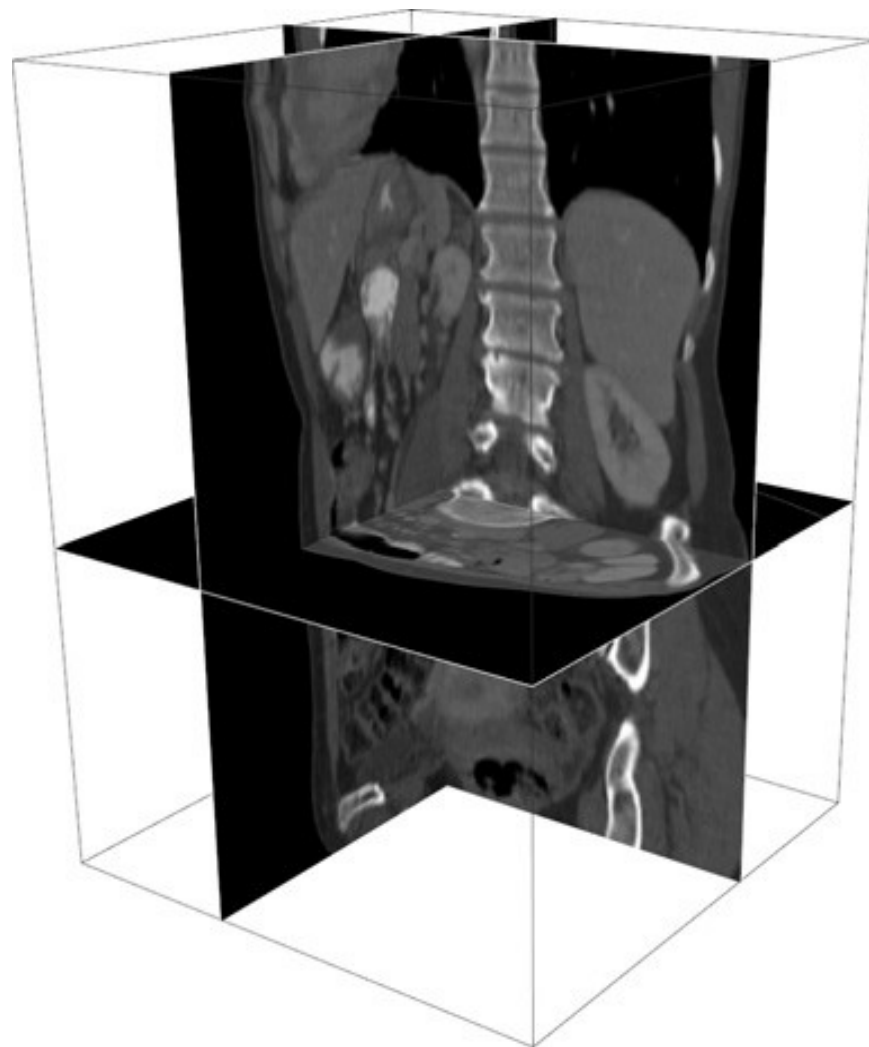
Blue

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)?

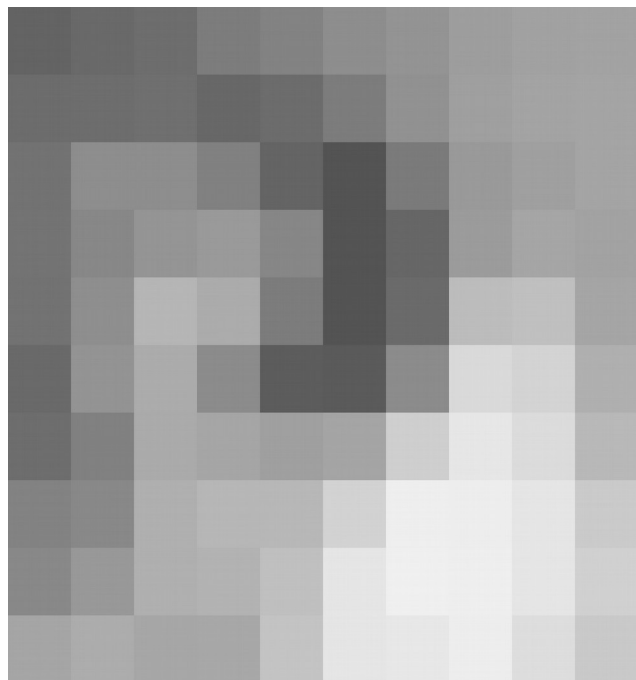


Images and interpolation

- 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

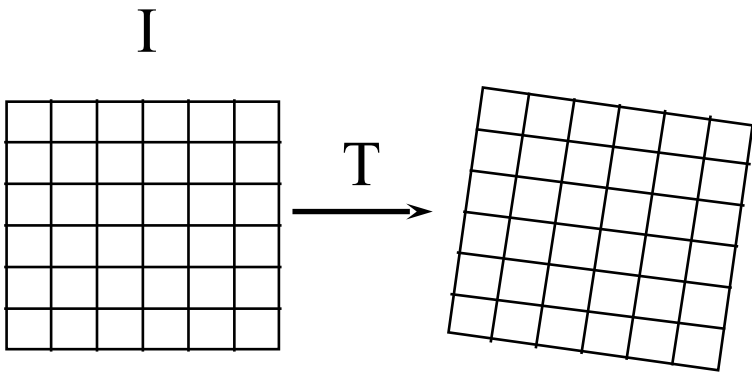


Bi-linear,
Interpolation
from four closest
neighbors

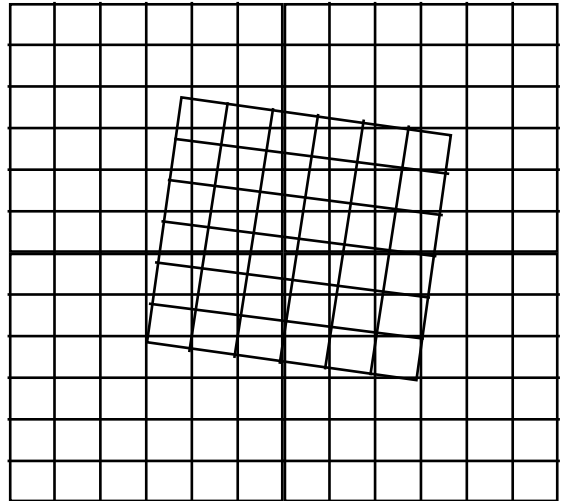


Bi-cubic,
Interpolation from
sixteen closest
neighbors

Resampling, grey-level interpolation



Re-sampling:

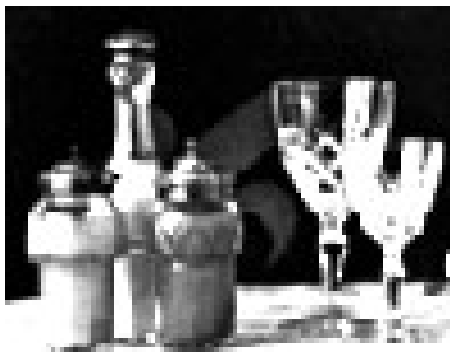


$$I_{\text{transformed}}(p) = I(T^{-1}(p))$$



Generally not an integer coordinate!

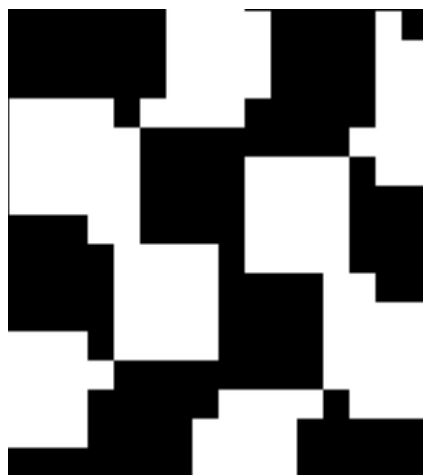
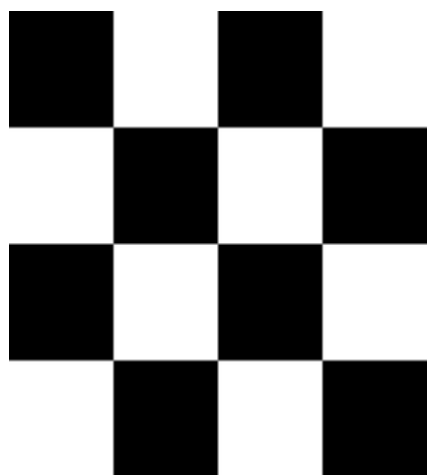
original image



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



Computer Assisted Image Analysis 1

GW 1, 2.1-2.4

Filip Malmberg

Centre for Image Analysis

Department of Information Technology

Uppsala University

