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Basic Algorithms for Digital Image Analysis: a course

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Topics of the Course

- **Introduction**: Tasks and applications of image analysis
- **Image enhancement**: Point and neighbourhood processing
- **Template matching**
- **Feature detection**: Edges, corners, lines
- **Image segmentation**: Thresholding and region-based methods
- **Processing of binary images**: Medial axis, distance transforms, thinning and skeletons
- **Morphological processing**
- **Shape analysis**

Lecture 1: Introduction

Tasks and applications of image analysis

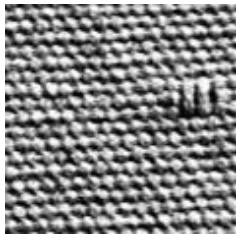
- Applications of image analysis
- Example: Industrial object recognition
- Computer vision, image processing and analysis
  - Digital image
  - Entities of computer vision
  - Steps of object recognition: general case
  - Why is computer vision difficult?
  - Relation between computer graphics and image analysis
- About this course: Recommended literature

Applications of Image Analysis

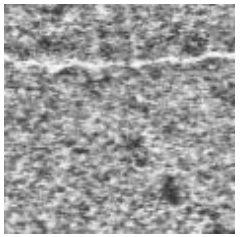
	Applications	Domains
1	Mail sorting, label reading, supermarket-product billing, bank-check processing, text reading, interpretation of technical drawings	Document processing
2	Tumour detection, measurement of size and shape of internal organs, chromosome analysis, blood cell count	Medical image analysis
3	Part identification on assembly lines, defect and fault inspection	Industrial automation
4	Recognition and interpretation of objects in scene, motion control and execution through visual feedback	Robotics
5	Map making from photographs, synthesis of weather maps	Cartography
6	Finger-print matching, face recognition, gait analysis, other biometric measurements, for example, ear, iris	Forensics, security

	Applications	Domains
7	Face expression analysis, eye motion tracking, gesture recognition	Man-machine interact
8	Tracking of cars and people, analysis of events and activities	Surveillance
9	Scene reconstruction from multiple views and video, photorealistic models	Virtual reality
10	Image and video content based retrieval, indexing, representation and coding of shape, texture and motion	Multimedia databases
11	Target detection and identification, guiding of helicopters and aircraft in landing, guidance of remotely piloted vehicles, missiles and satellites from visual cues	Radar imaging
12	Multispectral image analysis, weather prediction, classification and monitoring of urban, agricultural, and marine environments from satellite images	Remote sensing

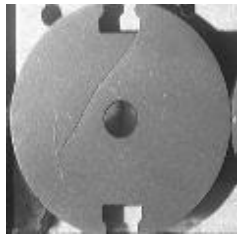
bottle inspection



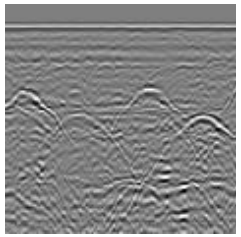
textile defect



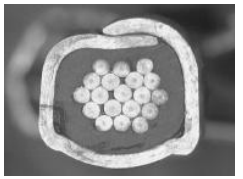
stone crack



ferrite core



soil (ultrasonic)



cable cross-section

Typical images: Industrial inspection, quality control.

indoor

outdoor

statue (Peter I)

ikon (painting)

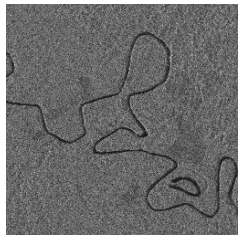
logo

fingerprint

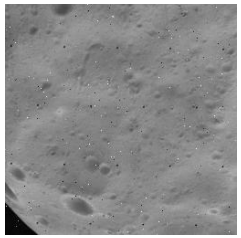
Typical images: Indoor/outdoor scenes, image databases.

Aerial, stereo (Pentagon)

'Aerial', model board



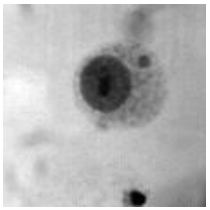
Aerial, river



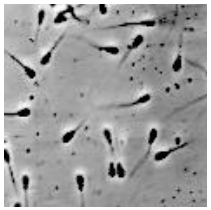
Cosmic, Phobos

Typical images: Remote sensing.

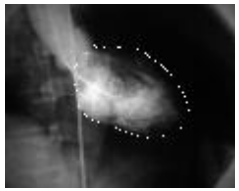
cells



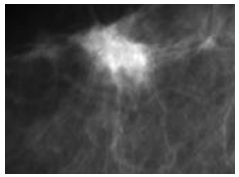
radiology



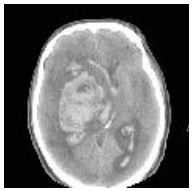
spermatozoa



heart

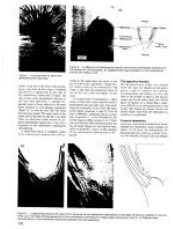


mammogram (breast)

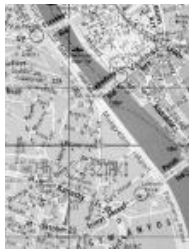


MRI tomography (brain)

Typical images: Biomedical applications.



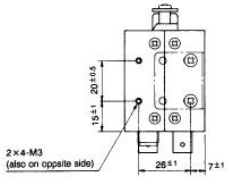
journal page



map

handwriting

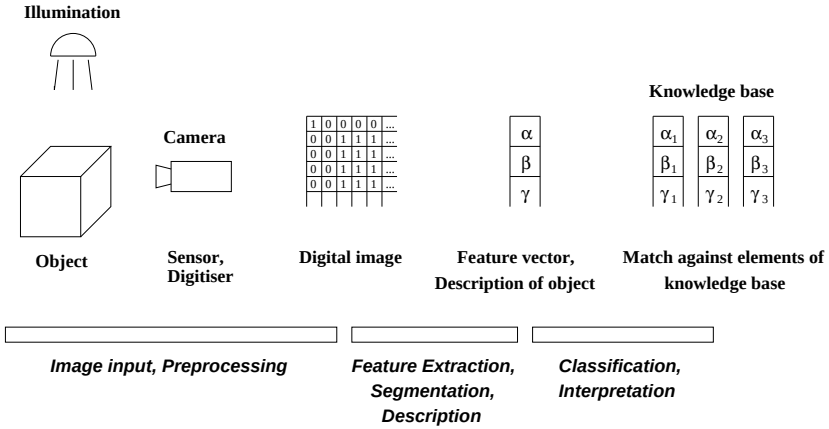
bank receipt



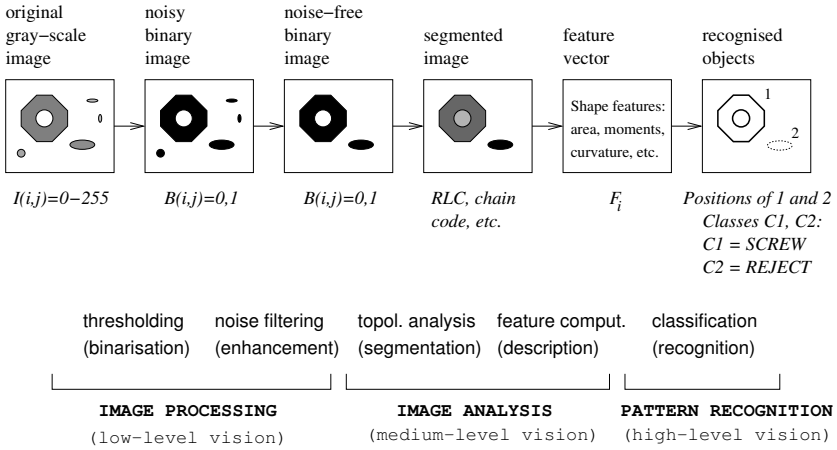
technical drawing

Typical images: Documents.

Example: Industrial object recognition



Framework of an industrial object recognition system.



Main steps of industrial object recognition.

Computer Vision, Image Processing and Analysis

Goal of computer vision: Provide methods for solving **automation tasks related to processing of visual information**, including:

- **Detection and recognition** of known objects
- Obtaining **geometric models** of unknown objects
- Computing **position and orientation** of objects
- Measurement of **spatial properties** of objects (distances, sizes, etc.)
- Measurement of object **motion**
- Measurement of surface **texture and colour**

Digital image

Image is a spatial representation of an object, a 2D or 3D scene, or another image:

- **Intensity image**: $I(r, c)$ is proportional to radiant electromagnetic energy reflected by object surface and received by sensor.
- **Range image**: $I(r, c)$ is a function of line-of-sight distance between (r, c) and an object in 3D world.
- **Tactile sensors**: $I(r, c)$ is proportional to sensor deformation caused by surface at (r, c).
- **Symbolic image**: $I(r, c)$ is a label, index, or symbol associated with some category, e.g. colour, thematic land use, soil type, rock type, etc.

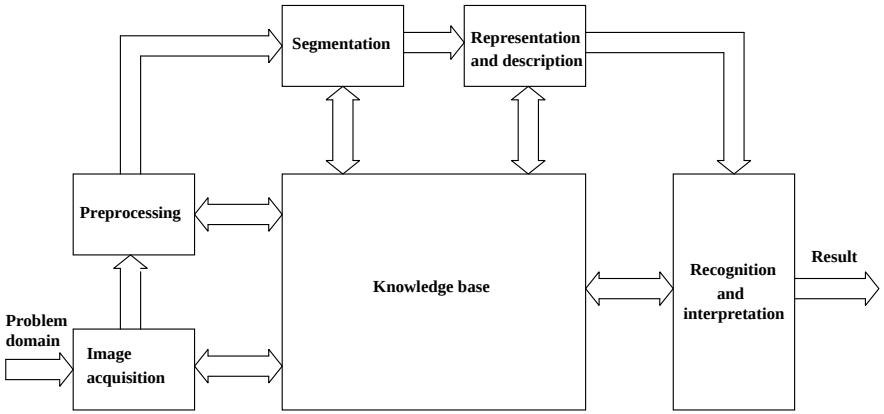
Entities (units) of computer vision

- **Unit of observation** is pixel: value of $I(r, c)$ discretised to a certain number of grades (e.g. 255)
- **3D object feature**: point, line segment, surface patch
- **2D image feature**: point, line segment, region
- Correspondence between object features and image features
- Relation between object features
- Relation between image features
- Sensor position/orientation
- Object position/orientation

Steps of object recognition: general case

- **Image formation** (sensors, illumination, surface reflection models, etc.)
- **Enhancement**: Image is composed of informative pattern modified by non-informative variations. Enhance informative pattern based on image data.
  - Examples: noise filtering, geometric correction
- **Feature-based segmentation**: Informative pattern is arrangement of *features*. Each feature is a set of connected pixels. Assign features to pixels.
  - Examples: thresholding, edge detection

- **Region-based segmentation**, or grouping: Collect together pixels belonging to the same feature and form *regions* or other entities (e.g., lines).
  - Examples: connected component analysis, edge linking
- **Region description**: Compute properties of regions. Measure spatial/topological relations between regions/entities.
  - Examples: areas, centroids, orientations, dimensions, distances
- **Matching**: Interpret the image by establishing correspondences between the measured entities and a scene model.
  - Example: Recognising a letter based on its measured elements



Block diagram of an image analysis system.

Why is computer vision difficult?

Inherent problem of computer vision: Units of observation (pixels) are not units of analysis.

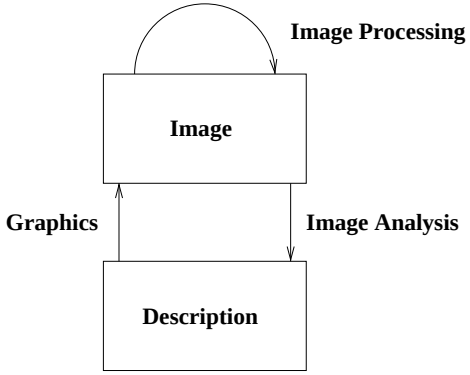
- By itself, pixel gives no information related to **tasks** of image analysis.
  - Given: pixel values $I(r, c)$
  - Desired result: Count **chairs** in the room

Additional problems:

- Noisy, incomplete, missing input data with outliers.
  - Physical measurements!
- Often, no satisfactory mathematical model is available for image features.
  - How to formalise what we see?

Relation between computer graphics and image analysis

- **Computer graphics**: Inputs mathematical description, outputs image
  - Direct problem, **synthesis**
- **Image analysis**: Inputs image, outputs mathematical description
  - Reverse problem, **analysis**
  - **More difficult**
- **Image processing**: Inputs image, outputs another image



Relation between computer graphics, image processing and image analysis.

About this course

This course is devoted to basic tools of image processing and analysis.

- **2D image processing and analysis** considered: low- and medium-level vision
- **No 3D computer vision**, no stereo
- **No high-level** tasks (classification, structural methods)
- **No motion** analysis, no sequences: single image only
- **No image formation**, no colour
- Minimum of theory
- Accent on understanding and use of methods
- Description sufficient for **implementation**

Literature used in this course

1. E.Trucco, A.Verri, "Introductory Techniques for 3-D Computer Vision", Prentice Hall, 1998.
2. R.Klette, P.Zamperoni, "Handbook of Image Processing Operators", J.Wiley and Sons, 1996.
3. I.Pitas, "Digital Image Processing Algorithms", Prentice-Hall, 1993.
4. R.C.Gonzales, R.E.Woods, "Digital Image Processing", Addison-Wesley, 1993.
5. R.M.Haralick, L.G.Shapiro, "Computer and Robot Vision", Addison-Wesley, volumes I-II, 1992-1993.
6. A.K.Jain, "Fundamentals of Digital Image Processing", Prentice-Hall, 1989.
7. Álló G., "A Digitális Képfeldolgozás Alapproblemái", Akadémiai Kiadó, 1989.

Other recommended literature

1. M.Sonka, V.Hlavac, R.Boyle, "Image Processing, Analysis and Machine Vision", Chapman and Hall, 1999.
2. B.Jähne, "Digital Image Processing", Springer, 1997 or later edition.
3. W.K.Pratt, "Digital Image Processing", J.Wiley and Sons, 1992.
4. A.Rosenfeld, A.C.Kak, "Digital Picture Processing", Academic Press, volumes I-II, 1982.

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