

Computer Vision



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Contents

IMAGE PROCESSING FOR MULTIMEDIA APPLICATIONS

- Introduction
- The digitized image and its properties
- Data structures for image analysis
- Image preprocessing
- Image compression

IMAGE ANALYSIS

- Segmentation
- Shape description
- Mathematical morphology
- Texture analysis
- Motion analysis

SEEING AND ACTING

- 3D image analysis
- Object recognition
- Scene analysis
- Knowledge-based scene interpretation
- Probabilistic scene interpretation

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Literature

Computer Vision - A Modern Approach
D.A. Forsyth, J. Ponce, Prentice-Hall 2003

Digital Image Processing
R.C. Gonzalez, R.E. Woods, Prentice-Hall 2001



Image Processing, Analysis and Machine Vision
M. Sonka, V. Hlavac, R. Boyle, Chapman & Hall 1993

Digitale Bildverarbeitung
B. Jahne, Springer 1997

Computer Vision
R. Klette, A. Koschan, K. Schluns, Vieweg 1996

Computer and Robot Vision, Vol. I+II
R. Haralick, L.G. Shapiro, Addison-Wesley 1993

Robot Vision
B.K.P. Horn, MIT Press 1986

Computer Vision
D.H. Ballard, C.M. Brown, Prentice-Hall 1982

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Website

The website for this course can be reached via

<http://kogs-www.informatik.uni-hamburg.de/~neumann/BV-SS-2007/>

You will find

- a PDF copy of the slides
- the problem sheets for the exercise sessions
- useful information related to the course.

The website will be updated each week on Thursday.

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Exercises

- Problem sheets related to the current lectures will be usually handed out every Thursday.
- Solutions - either as answer texts or program documentations - are due on Thursday the next week.
- Solutions will be presented and discussed in class.
- Active participation is a prerequisite for thesis work in Computer Vision.

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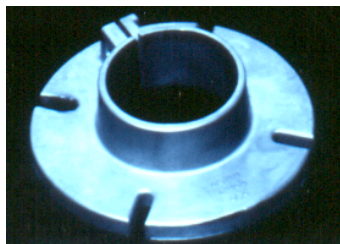
Why Study Image Processing, Image Analysis and Image Understanding?

- Subfield of Computer Science
- History of more than 40 years
- Rich methodology
- Interesting interdisciplinary ties
- Exciting insights into human vision
- Important applications
- **Important information modality in the information age**

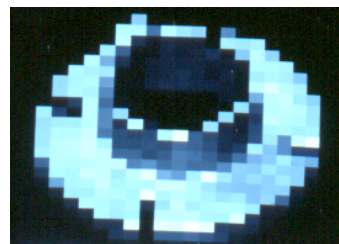
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What is "Image Processing"?

- Transforming images as a whole
- "Bildverarbeitung" in a narrow sense
- E.g. change of resolution, high pass filtering, noise removal



512 columns x 574 rows

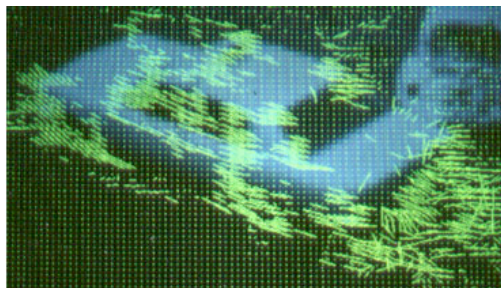


32 columns x 35 rows

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What is "Image Analysis"?

- Computing image components and their properties
- "Bildanalyse"
- E.g. edge finding, object localization, motion tracking



computation of displacement vectors

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What is "Image Understanding"?

- Computing the meaning of images
- "Bildverstehen"
- E.g. object recognition, scene interpretation, vision and acting



"Ein heller Opel biegt von der Hartungstraße in die Schlüterstraße ein. Er wartet, bis ein Fußgänger die Hartungstraße überquert hat. Auf der Schlüterstraße steht ein heller Ford vor der Ampel an der Hartungstraße. Ein Fußgänger geht auf dem Gehweg rechts neben der Schlüterstraße in Richtung Hartungsstraße. ..."

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Image Understanding is Silent Movie Understanding



Buster Keaton
"The Navigator" (1924)

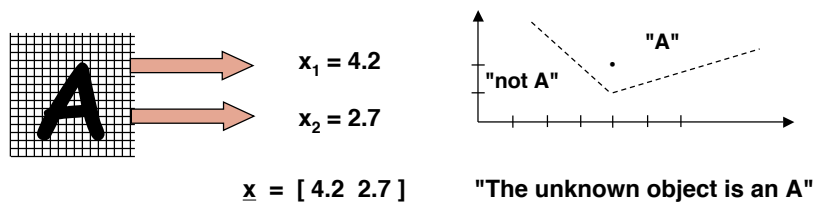
Silent movie understanding requires more than object recognition:

- common sense
 - emotionality
 - sense of humour
- } consequences for vision system architecture

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What is "Pattern Recognition"?

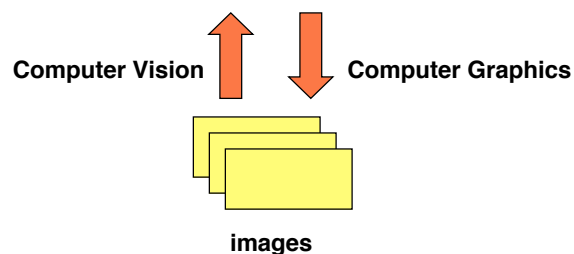
- In the narrow sense: object classification based on feature vectors
- In the wide sense: similar to Image Analysis
- "Mustererkennung"
- E.g. character recognition, crop classification, quality control



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What is "Computer Vision"?

- General term for the whole field, including Image Processing, Image Analysis, Image Understanding
- Same as Machine Vision ("Maschinensehen")
- Image Processing ("Bildverarbeitung") in the wide sense



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Computer Vision vs. Biological Vision

Cognitive Science ("Kognitionswissenschaft") investigates vision in biological systems:

- empirical models which adequately describe biological vision
- describe vision as a computational system

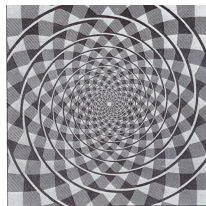
Computer Vision aims at engineering solutions, but research is interested in biological vision:

- Biological vision systems have solved problems not yet solved in Computer Vision. They provide ideas for engineering solutions.
- Technical requirements for vision systems often match requirements for biological vision.

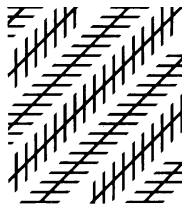
Caution: Mimicking biological vision does not necessarily provide the best solution for a technical problem.

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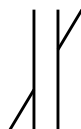
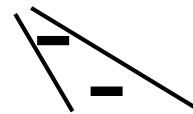
Geometry in Human Vision



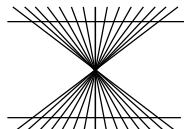
Fraser's Spiral



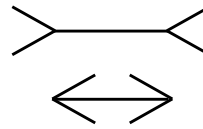
Zöllner's Deception



Poggendorf
1860



Hering
1861



Müller-Lyer
1889

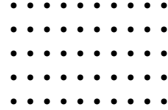
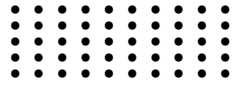


Delboeuf
1892

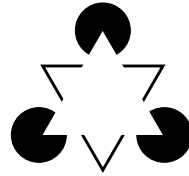
Do we want a vision system to perceive like humans?

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Human Object Perception



Grouping preferences



Kanizsa's triangle



Camouflage



The dalmatian

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Human Character Recognition

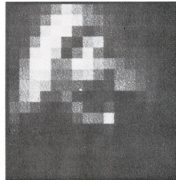
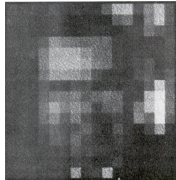


CATS + DOGS

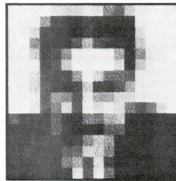
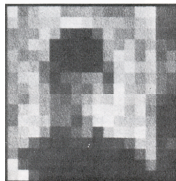
HEAVEN + EARTH

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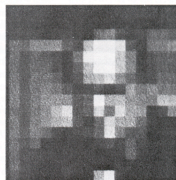
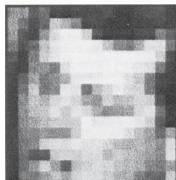
Human Face Recognition



Richard Nixon
Queen Victoria



Charlie Chaplin
Graucho Marx



John F. Kennedy
Winston Churchill

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Complexity of Natural Scenes



- sky
- clouds
- water
- buildings
- vegetation
- distances
- reflections
- shadows
- occlusions
- context
- inferences

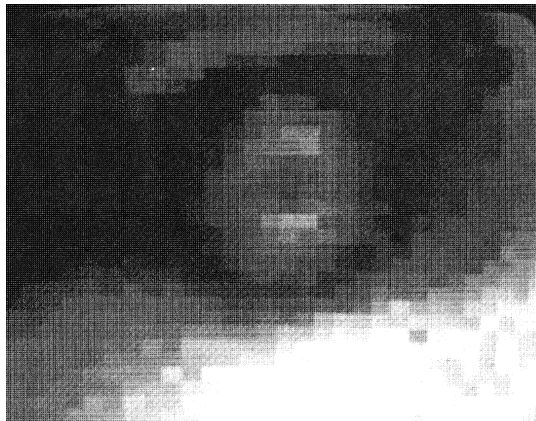
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The Computer Perspective on Images

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232 182 143 151 151 148 148 143 145 139 143 136 139 136 134 132 129 130 126 124 115 116 115 104 109 102 100 101
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212 209 200 188 177 173 174 171 169 165 173 176 180 187 191 192 195 195 201 203 207 210 208 212 201 177 147 143
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Greyvalues of the Section



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Street Scene Containing the Section



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Computer Vision as an Academic Discipline

Computer Vision is an active research field with many research groups in countries all over the world.

There exists a large body of research results to build on.

Studying Computer Vision is a prerequisite for

- the development of state-of-the-art applications
- corporate research
- an academic career

Recent development of Cognitive Vision

- towards robust vision systems
- incorporating spatial and temporal context
- beyond single object recognition

Bildverarbeitung
SS 2007

Advanced
courses

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Important Conferences

ICCV	International Conference on Computer Vision
ECCV	European Conference on Computer Vision
ICPR	International Conference on Pattern Recognition
CVPR	Conference on Computer Vision and Pattern recognition
ICIP	International Conference on Image Processing
DAGM	Symposium der Deutschen Arbeitsgemeinschaft für Mustererkennung

Note: There are many regular conferences and workshops specialized on subtopics of Computer Vision, e.g. document analysis, aerial image analysis, robot vision, medical imagery

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Important Journals

IEEE-PAMI	IEEE Transactions on Pattern Analysis and Machine Intelligence
IVC	Image and Vision Computing
IJCV	International Journal of Computer Vision
CVGIP	Computer Vision, Graphics and Image Processing

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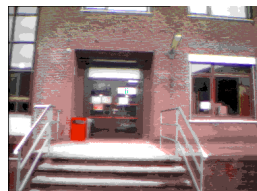
Important Application Areas

- **Industrial image processing**
process control, quality control, geometrical measurements, ...
- **Robotics**
assembly, navigation, cooperation, autonomous systems, ...
- **Monitoring**
event recognition, safety systems, data collection, smart homes, ...
- **Aerial image analysis**
GIS applications, ecological issues, defense, ...
- **Document analysis**
handwritten character recognition, layout recognition, graphics recognition, ...
- **Medical image analysis**
image enhancement, image registration, surgical support, ...
- **Image retrieval**
image databases, multimodal information systems, web information retrieval, ...
- **Virtual reality**
image generation, model construction

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Image Retrieval

Which of the stored images matches the example image?



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Example: Medical Image Analysis

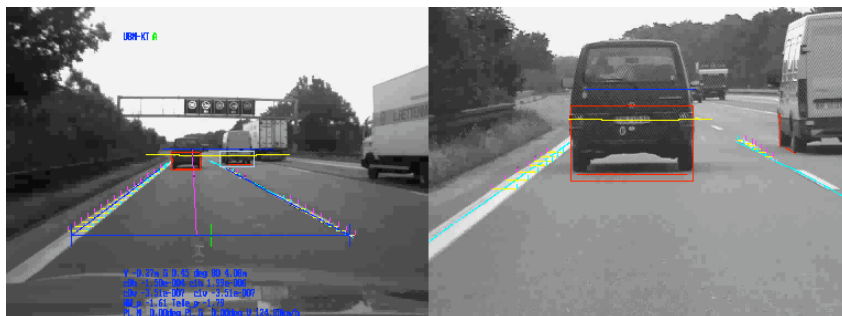
classification of materials in tomographic images of the human head



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Example: Driver Assistance

Dickmanns 1996: Autonomous navigation on highways



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Example: Monitoring

Hongeng 2003: Criminal acts recognition



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History of Computer Vision (1)

A vision of Computer Vision

Selfridge 1955: " ... eyes and ears for the computer"

First image enhancement and image processing applications

space missions, aerial image processing

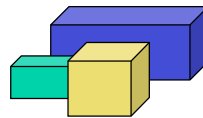
Character recognition

=> pattern recognition paradigm

A A A A A

Blockworld, restricted domains

Roberts 1965: 2D => 3D



Natural scenes with motion

Nagel 79: Digitization and analysis of traffic scenes



Visual agents

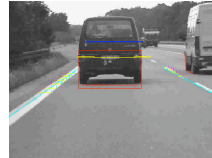
Bajcsy 1988: Active Vision

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History of Computer Vision (2)

Visual driver assistance

Dickmanns 1996: Autonomous navigation on highways



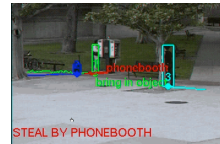
Recognizing faces

Bülthoff 2002: Modelling faces for recognition



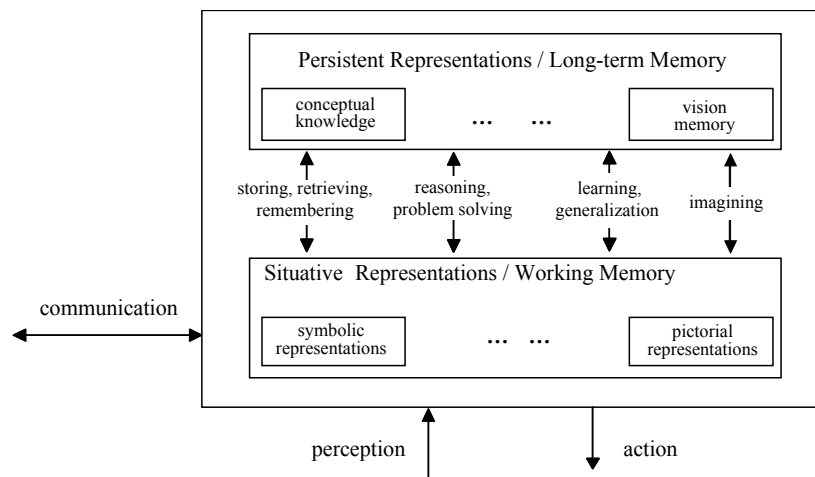
Motion tracking and event recognition

Hongeng 2003: Criminal act recognition



Computer Vision at KOGS (1)

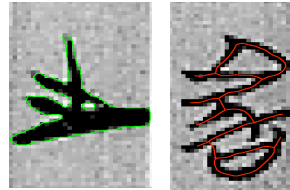
The "grand picture": Vision as part of a cognitive system



Computer Vision at KOGS (2)

Making low-level processes more reliable

- Topology-preserving sampling methods
- Segmentation with subpixel accuracy
- Structural image analysis



Interfacing low-level image analysis and high-level interpretation

- Mapping image features to object categories
- Matching scene hypotheses with evidence
- Connecting quantitative with symbolic descriptions

Knowledge representation for scene interpretation

- Combining logic-based and probabilistic models
- Learning spatial structures

