Computer Vision

1

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

2

Literature

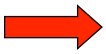


Image Processing, Analysis and Machine Vision (3. Ed.)
M. Sonka, V. Hlavac, R. Boyle, Thomson 2008

Grundlagen der Bildverarbeitung
K.D. Tönnies, Pearson Studium, 2005

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

Digitale Bildverarbeitung
B. Jähne, 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

3

Website

The website for this course can be reached via

http://kogs-www.informatik.uni-hamburg.de/~neumann/BV-WS-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 before the lectures.

4

Exercises

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

5

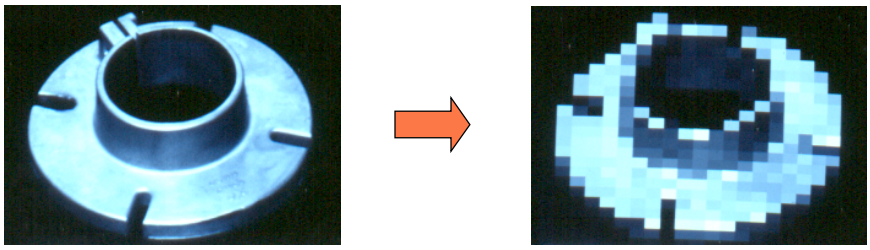
Why Study Image Processing, Image Analysis and Image Understanding?

- 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

6

What is "Image Processing"?

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



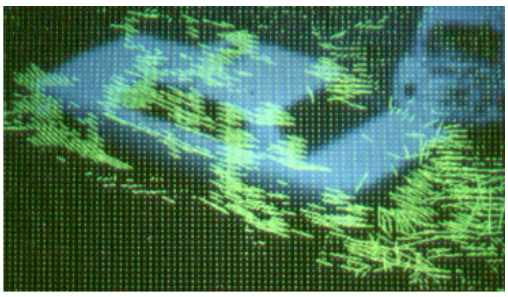
512 columns x 574 rows

32 columns x 35 rows

7

What is "Image Analysis"?

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



computation of displacement vectors

8

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. ..."

9

Image Understanding is Silent Movie Understanding

Buster Keaton
"The Navigator" (1924)

Silent movie understanding requires more than object recognition:

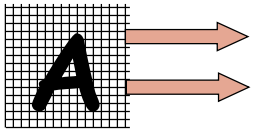
- **common sense**
- **emotionality**
- **sense of humour**

} **consequences for vision system architecture**

10

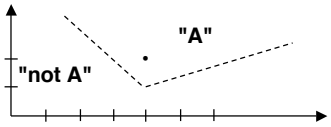
What is "Pattern Recognition"?

- 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



$x_1 = 4.2$

$x_2 = 2.7$



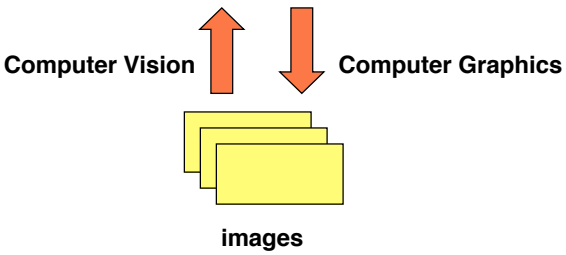
$\underline{x} = [\ 4.2 \ \ 2.7\ ]$

"The unknown object is an A"

11

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



12

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**

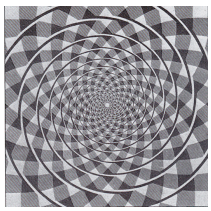
Computer Vision aims at engineering solutions, but research is interested in biological vision:

- **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.**

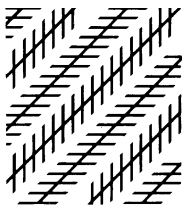
Caution: Mimicking biological vision does not necessarily provide the best solution for a technical problem.

13

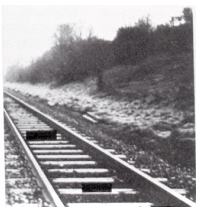
Geometry in Human Vision

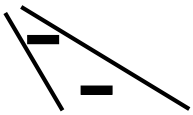


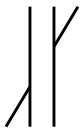
Frasers Spiral



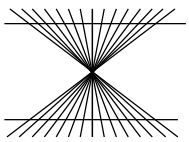
Zöllner´s Deception



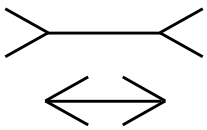




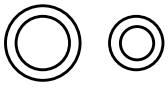
Poggendorf
1860



Hering
1861



Müller-Lyer
1889

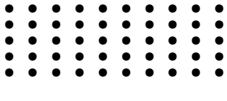


Delboeuf
1892

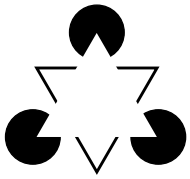
Do we want a vision system to perceive like humans?

14

Human Object Perception



Grouping preferences



Kanizsa´s triangle

Camouflage

The dalmatian

15

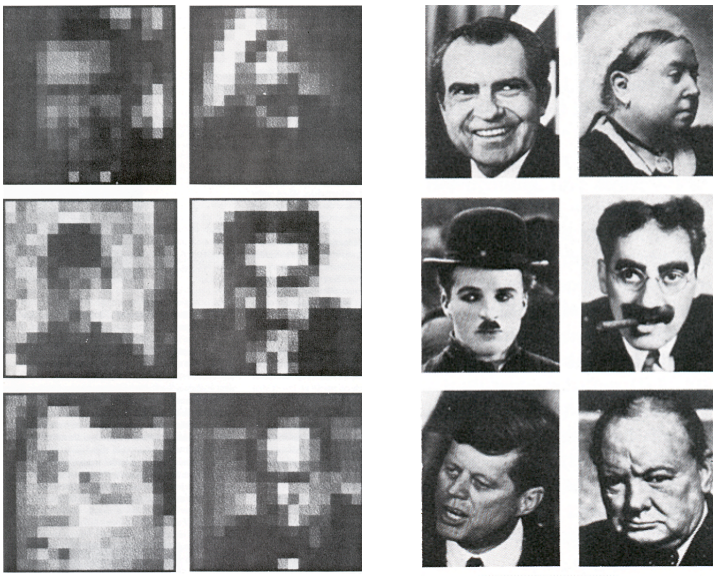
Human Character Recognition

CATS + DOGS

HEAVEN + EARTH

16

Human Face Recognition



Richard Nixon

Queen Victoria

Charlie Chaplin

Graucho Marx

John F. Kennedy

Winston Churchill

17

Complexity of Natural Scenes

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

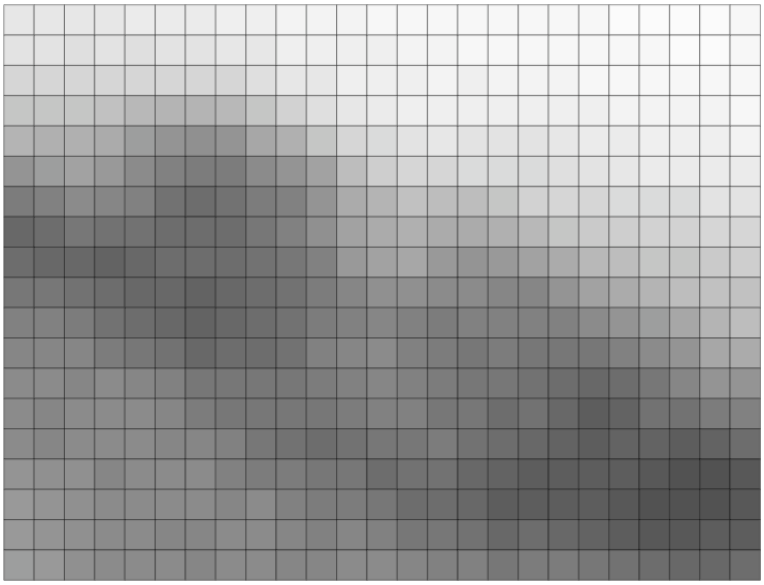
18

The Computer Perspective on Images

226	228	229	230	232	231	235	236	240	241	244	245	247	246	248	249	249	248	250	250	251	251	251	251	250
223	225	220	222	217	224	223	228	228	236	236	239	240	243	244	246	247	249	248	247	249	249	251	251	250
209	210	209	209	206	206	208	209	217	226	229	237	237	239	241	240	242	243	243	246	247	248	248	249	249
189	190	187	181	175	169	168	173	190	204	219	230	232	236	237	237	236	237	238	238	241	242	243	244	247
168	164	164	157	142	134	129	133	152	164	188	208	215	224	226	224	224	225	227	232	235	238	239	240	242
135	145	148	137	123	111	107	109	122	131	147	177	197	206	209	213	211	213	220	223	227	231	233	234	235
105	112	122	119	111	96	90	95	106	115	134	157	168	181	179	180	189	201	207	210	212	214	215	221	224
89	94	100	98	97	91	90	94	101	112	126	148	158	162	157	158	163	174	188	195	197	201	204	209	210
94	89	86	84	88	93	91	93	98	103	115	136	146	151	138	135	138	147	159	174	179	186	190	195	199
102	100	95	90	88	88	81	87	94	99	108	119	129	128	122	121	119	118	131	147	157	169	176	182	184
112	115	108	98	91	87	83	89	91	98	109	115	118	111	106	110	112	111	112	120	134	145	153	169	176
117	117	117	106	103	98	89	94	94	99	111	117	121	112	105	104	105	102	101	104	112	124	135	152	157
125	120	118	121	118	113	101	101	101	101	107	112	119	115	105	102	101	99	92	87	91	104	119	133	135
124	116	122	124	120	117	106	104	102	100	102	107	112	111	104	100	94	96	86	78	82	95	99	105	112
125	119	124	121	121	117	116	112	101	98	94	98	101	103	107	97	91	87	81	78	80	83	78	81	92
132	128	126	119	122	121	120	115	109	106	100	101	93	95	95	88	82	78	77	78	75	71	67	65	71
139	131	127	123	123	122	122	119	120	115	106	109	103	93	94	86	79	78	77	78	73	68	67	69	70
136	134	127	121	120	119	117	121	121	117	110	119	111	104	102	98	87	91	89	84	78	74	74	76	77
142	138	130	125	120	121	119	122	120	116	116	124	122	117	113	110	103	106	105	102	96	90	89	89	92

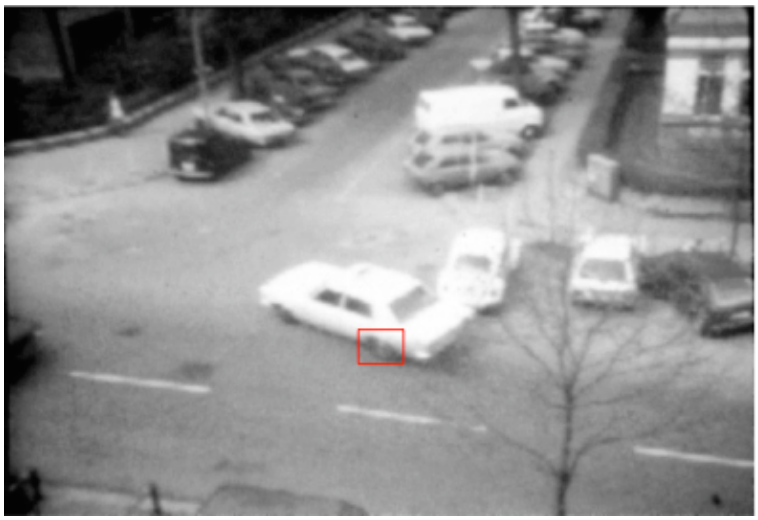
19

Greyvalues of the Section



20

Street Scene Containing the Section



21

Computer Vision as an Academic Discipline

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

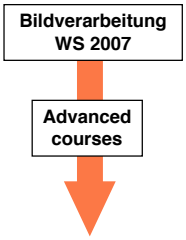
There exists a large body of research results to build on.

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



22

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

23

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

24

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

25

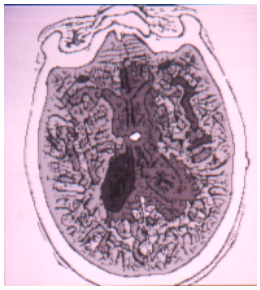
Image Retrieval

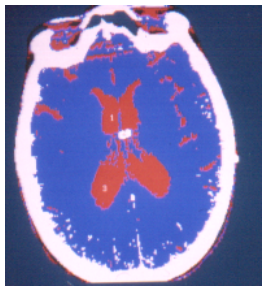
Which of the stored images
matches the example image?

26

Example: Medical Image Analysis

classification of materials in tomographic images of the human head

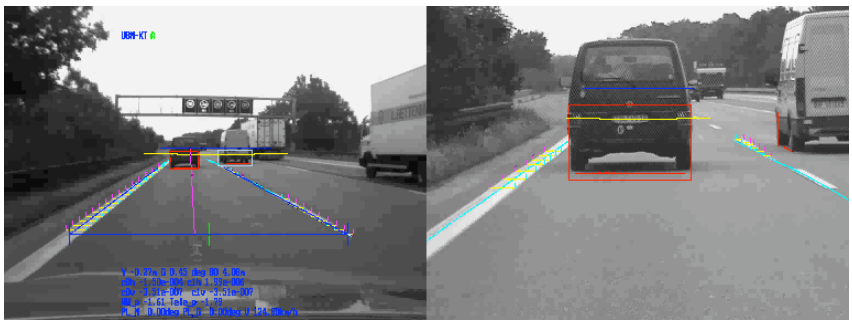




27

Example: Driver Assistance

Dickmanns 1996: Autonomous navigation on highways



28

Example: Monitoring

Hongeng 2003: Criminal acts recognition

29

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

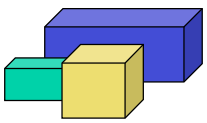
space missions, aerial image processing

Character recognition

=> pattern recognition paradigm

Blocksworld, restricted domains

Roberts 1965: 2D => 3D



Natural scenes with motion

Nagel 79: Digitization and analysis of traffic scenes

Visual agents

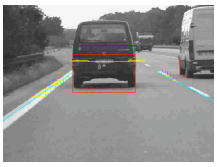
Bajcsy 1988: Active Vision

30

History of Computer Vision (2)

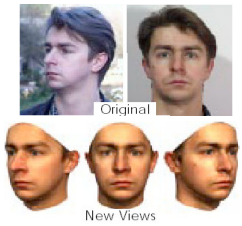
Visual driver assistance

Dickmanns 1996: Autonomous navigation on highways



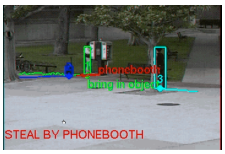
Recognizing faces

Bülthoff 2002: Modelling faces for recognition



Motion tracking and event recognition

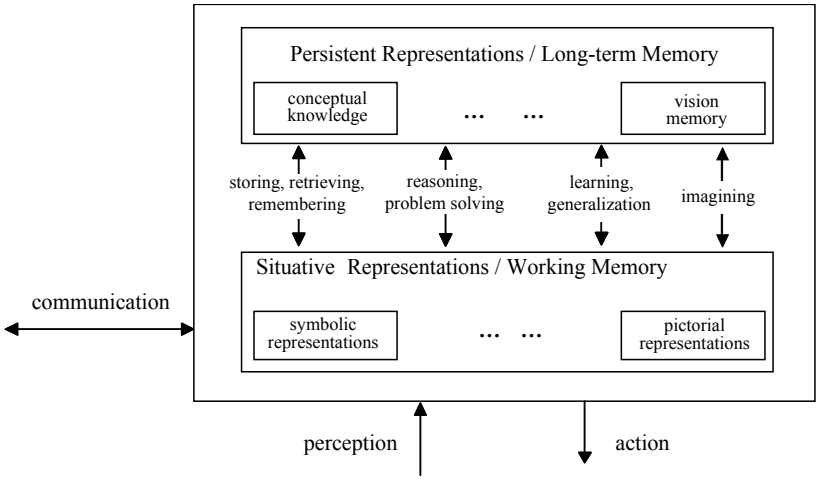
Hongeng 2003: Criminal act recognition



31

Computer Vision at KOGS (1)

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

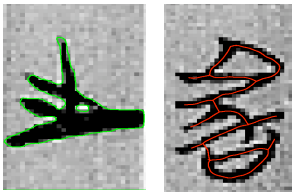


32

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**

33