

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

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

3

Website

The website for this course can be reached via

<http://kogs-www.informatik.uni-hamburg.de/~neumann/BV-SS-2005/>

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 Friday.

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 prerequisite for thesis work in Computer Vision.

5

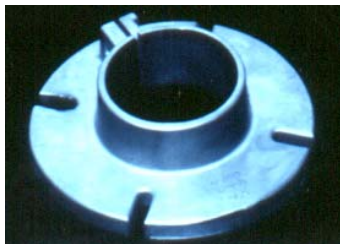
Why Study Image Processing, Image Analysis and Image Understanding?

- 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**

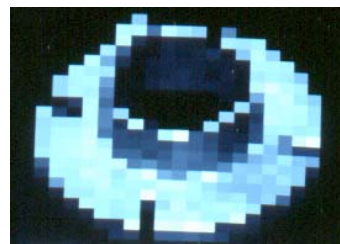
6

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

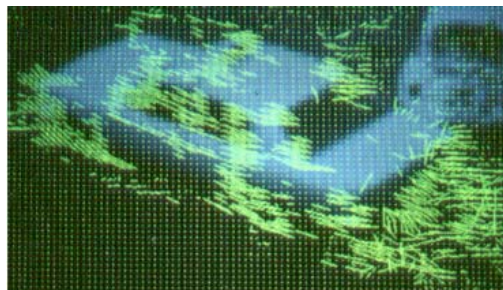


32 columns x 35 rows

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)

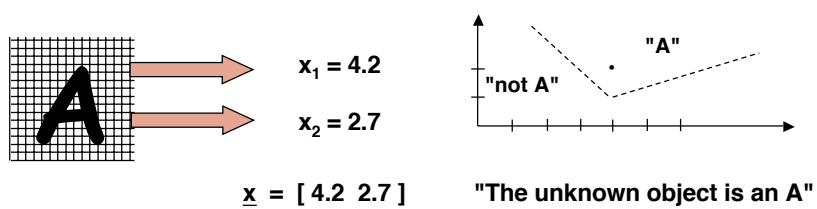
Silent movie understanding requires more than object recognition:

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

10

What is "Pattern Recognition"?

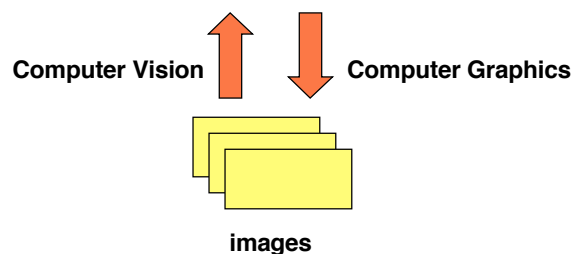
- In the narrow sense: object classification based on feature vectors
- In the wide sense: similar to Image Analysis
- "Mustererkennung"
- E.g. character recognition, crop classification, quality control



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

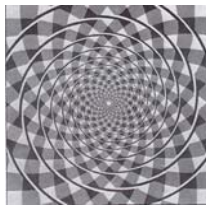
Computer Vision aims at engineering solutions, but research is interested in biological vision:

- **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.**

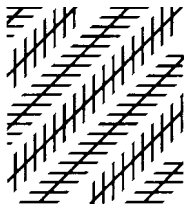
Caution: Mimicking biological vision does not necessarily provide the best solution for a technical problem.

13

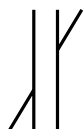
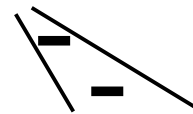
Geometry in Human Vision



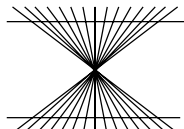
Fraser's Spiral



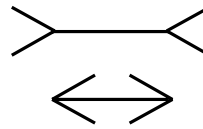
Zöllner's Deception



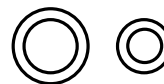
Poggendorf
1860



Hering
1861



Müller-Lyer
1889

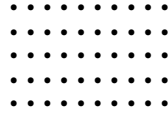


Delboeuf
1892

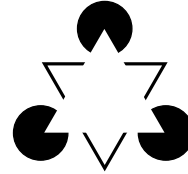
Do we want a vision system to perceive like humans?

14

Human Object Perception



Grouping preferences



Kanizsa's triangle



Camouflage



The dalmatian

15

Human Character Recognition

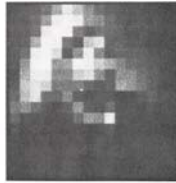
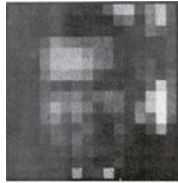


CATS + DOGS

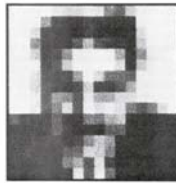
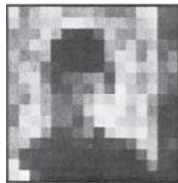
HEAVEN + EARTH

16

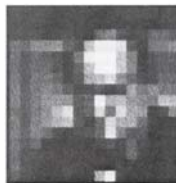
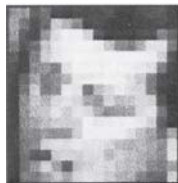
Human Face Recognition



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

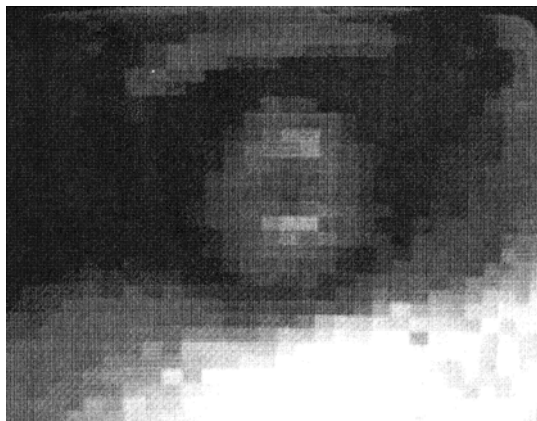
18

The Computer Perspective on Images

```
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
244 218 160 149 145 147 145 143 139 142 140 139 134 134 130 131 125 120 120 116 110 110 107 100 100 97 95 97
246 233 196 145 145 146 141 141 137 134 140 133 133 125 131 125 114 121 116 116 109 101 95 101 97 87 89 91
248 242 222 161 142 140 145 137 138 135 129 127 127 122 124 118 116 113 102 110 99 102 98 94 91 88 91 90
252 246 234 192 143 139 136 134 133 129 131 127 124 121 117 114 111 105 108 95 101 102 86 88 91 84 84 99
252 249 242 215 151 137 134 134 129 126 126 121 120 116 113 111 108 104 99 94 102 93 89 96 79 87 92 112
252 248 242 227 169 134 135 124 122 120 125 121 116 115 105 112 102 99 92 98 93 88 89 74 87 65 97 111
253 246 244 236 192 134 125 123 119 120 118 116 112 107 110 95 104 94 89 96 84 86 79 77 65 79 105 119
252 250 246 238 210 144 126 118 120 115 116 116 98 105 103 102 96 93 91 82 80 79 75 70 82 81 108 111
250 251 247 239 219 161 127 117 117 109 105 107 100 104 99 100 98 79 98 70 75 80 72 65 86 83 113 124
249 249 247 241 226 177 122 120 116 106 108 110 91 103 99 89 88 79 80 72 74 76 65 84 87 109 123
248 249 247 244 238 206 133 121 101 103 94 97 91 87 87 83 83 82 77 78 81 61 73 65 86 99 118 120
247 250 248 244 237 215 149 115 102 105 91 94 80 81 79 83 81 70 71 75 74 71 78 74 76 108 117 119
250 247 246 243 239 218 159 108 100 87 100 88 92 83 85 77 81 63 80 70 63 73 70 78 81 110 120 116
248 245 244 241 239 224 170 113 103 94 89 86 84 83 74 81 68 78 76 66 66 70 73 65 92 108 115 123
248 244 244 242 237 226 179 123 98 94 84 74 88 77 71 76 71 78 68 67 63 72 72 75 94 109 115 124
247 244 245 241 238 221 183 123 95 87 89 73 77 79 71 65 78 56 69 66 62 61 70 69 90 113 118 118
247 246 244 242 236 219 185 120 100 84 82 79 66 67 76 72 69 55 61 56 65 57 70 78 95 106 119 116
246 245 244 241 231 214 190 126 91 86 77 77 72 71 76 60 69 60 57 52 66 55 62 75 87 110 110 117
245 244 244 237 231 221 189 133 97 83 70 73 62 59 77 44 65 66 60 70 51 43 67 75 95 107 116 111
244 244 241 237 230 222 188 133 90 83 77 77 59 78 60 67 62 61 66 72 62 51 62 71 96 105 115 108
242 242 237 236 232 219 187 126 83 79 70 64 58 66 63 67 54 65 51 65 58 54 62 73 77 92 107 94
241 241 238 236 229 216 186 125 85 77 70 66 64 53 63 55 56 53 67 39 52 25 23 9 11 51 66 77
241 239 237 237 228 214 185 127 92 83 64 66 69 62 61 65 32 42 12 7 6 15 65 123 146 160 167 172
240 239 237 236 225 208 178 123 89 67 72 67 49 54 27 10 7 23 103 142 162 167 169 168 171 172 172 178
238 236 236 229 221 203 174 125 77 82 55 33 23 9 79 135 163 173 174 175 174 170 171 167 167 167 169 173
235 235 231 228 215 190 165 122 84 43 14 57 132 166 176 175 179 177 176 178 178 173 169 172 167 168 171 162
231 231 227 223 210 191 163 110 44 95 159 174 175 179 178 180 183 180 179 177 175 175 174 173 169 168 171 156
230 226 225 220 202 187 169 151 175 180 182 177 182 182 183 184 184 184 181 182 181 178 182 179 172 161 160 155
223 224 220 213 198 191 185 186 182 182 178 179 184 185 191 189 189 192 188 192 193 194 192 187 179 161 153 147
220 219 213 203 191 182 181 177 176 173 175 180 182 184 192 192 193 195 200 203 203 206 205 202 192 164 150 151
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
```

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

Bildverarbeitung
SS 2005

Advanced
courses



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

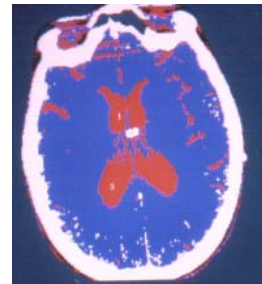
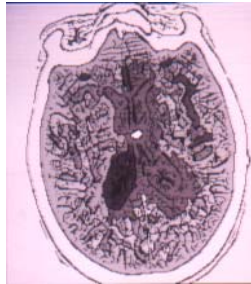
Which of the stored images matches the example image?



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

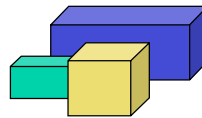
Character recognition

=> pattern recognition paradigm

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

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

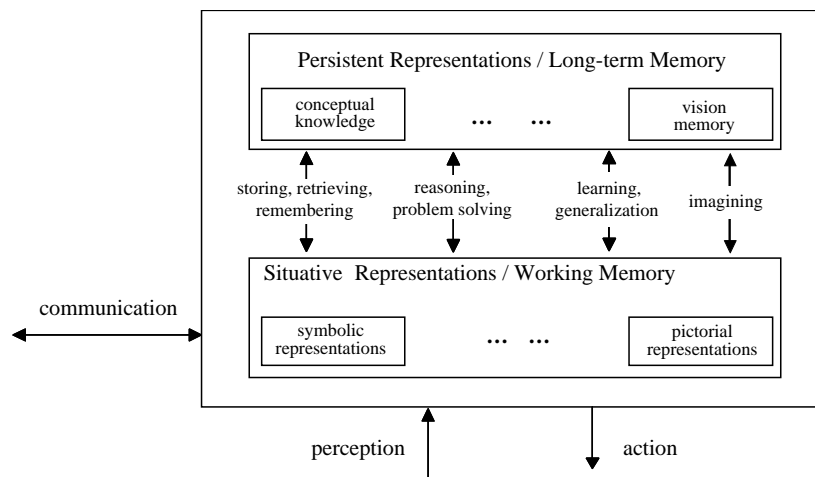
Hongeng 2003: Criminal act recognition



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

33