

Computer Vision



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IMAGE PROCESSING FOR MULTIMEDIA APPLICATIONS

Introduction

The digitized image and its properties

Data structures for image analysis

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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

Literature



Image Processing, Analysis and Machine Vision
M. Sonka, V. Hlavac, R. Boyle
Chapman & Hall 1993 / 1998

Digital Image Processing
R.C. Gonzalez, P. Wintz
Addison-Wesley 1987

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

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

For a comparison of CV books see:
www.palantir.swarthmore.edu/~maxwell/vision/spie98/SPIE98.html

Website

The website for this course can be reached via

<http://kogs-www.informatik.uni-hamburg.de/~neumann/BV-SS-2003/>

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 Monday.

Exercises

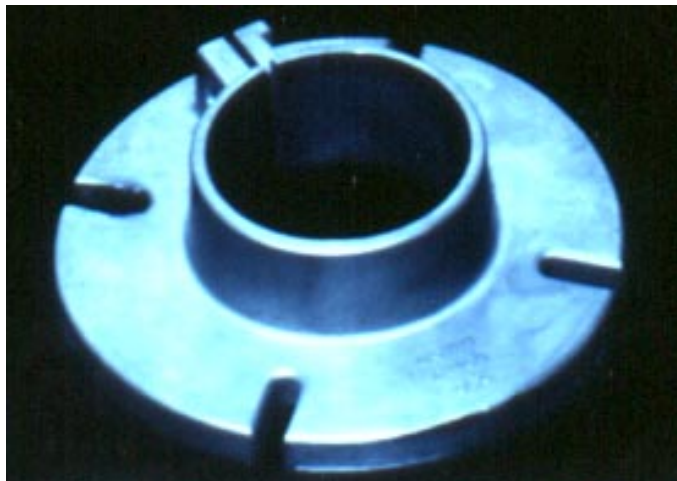
- **Problem sheets related to the current lectures will be handed out every Tuesday.**
- **Written solutions are due on Tuesday the next week.**
- **Solutions will be presented and discussed in class.**
- **Active participation is a prerequisite for thesis work in Computer Vision.**

Why study image processing, image analysis and machine vision?

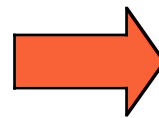
- **Subfield of Computer Science**
- **History of more than 40 years**
- **Rich methodology**
- **Interesting interdisciplinary ties**
- **Exciting insights into human vision**
- **Important applications**
- **Important information modality in the information age**

What is "Image Processing"?

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



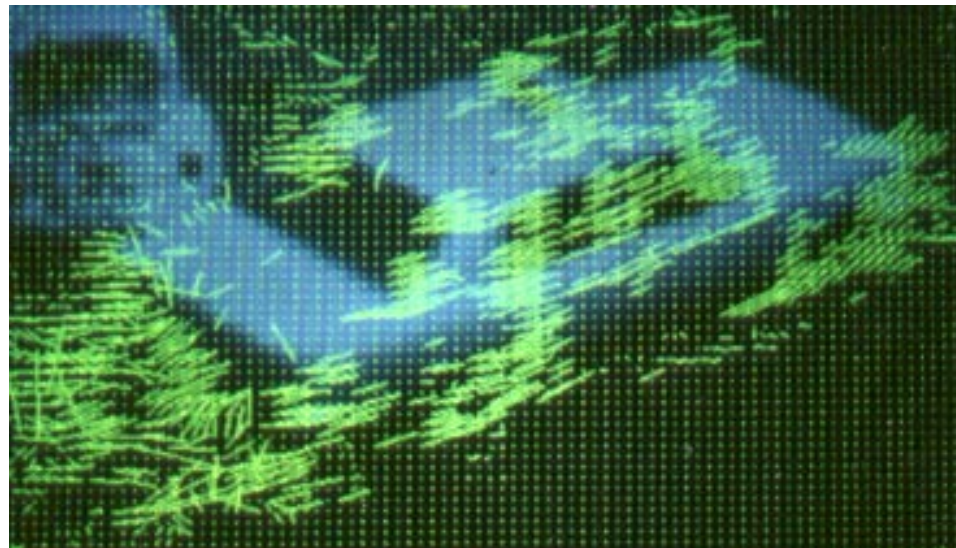
512 columns x 574 rows



32 columns x 35 rows

What is "Image Analysis"?

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



computation of displacement vectors

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. ..."

Image Understanding is Silent Movie Understanding



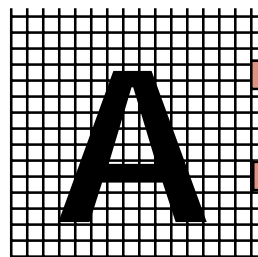
Buster Keaton
"The Navigator" (1924)

Silent movie understanding requires more than object recognition:

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

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

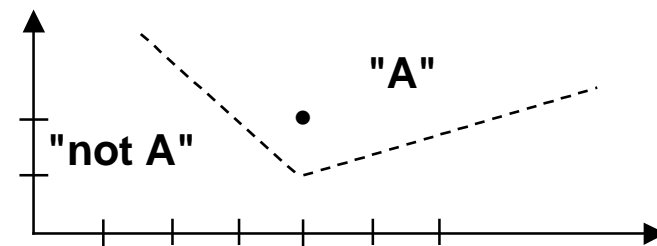


$$x_1 = 4.2$$



$$x_2 = 2.7$$

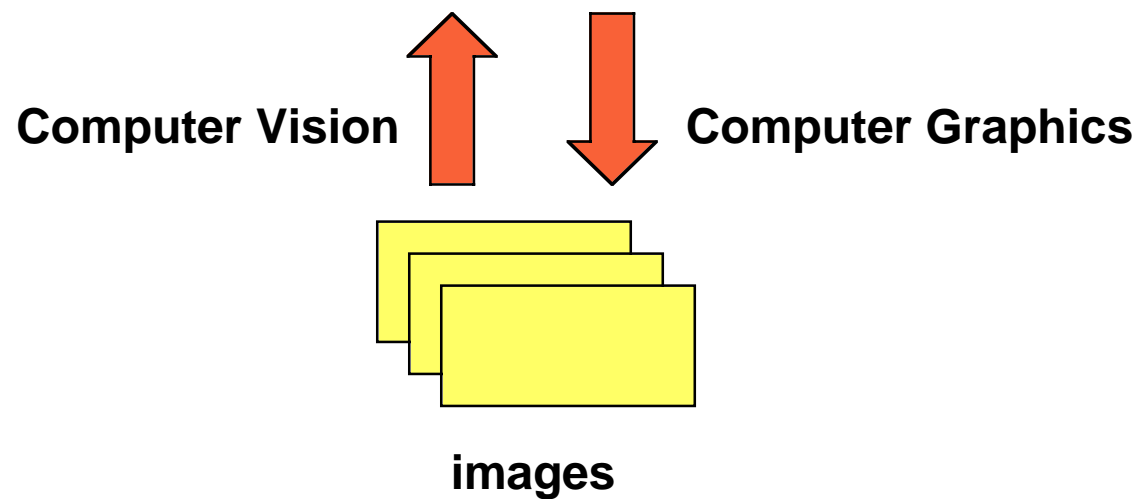
$$\underline{x} = [4.2 \ 2.7]$$



"The unknown object is an A"

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**



Computer Vision vs. Biological Vision

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

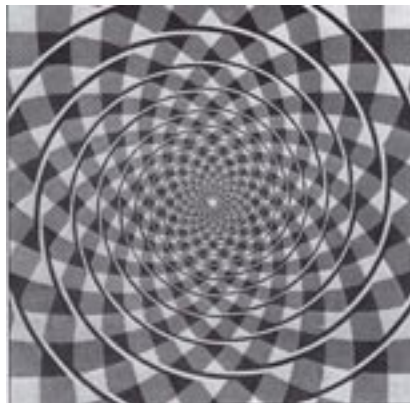
- empirical models which adequately describe biological vision
- describe vision as a computational system

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

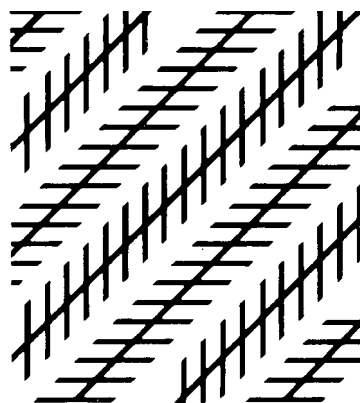
- Biological vision systems have solved problems not yet solved in Computer Vision. They provide ideas for engineering solutions.
- Technical requirements for vision systems often match requirements for biological vision.

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

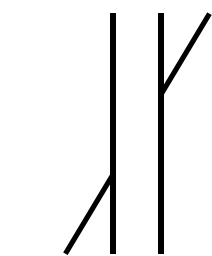
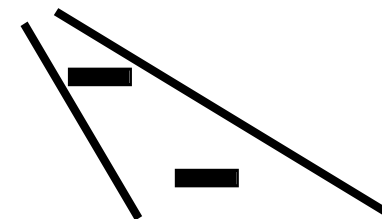
Geometry in human vision



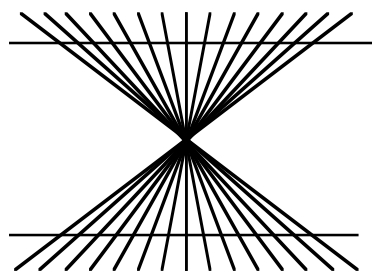
Fraser's Spiral



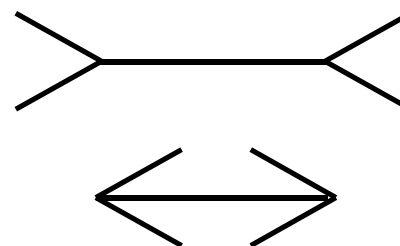
Zöllner's Deception



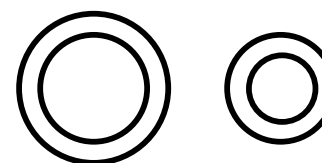
Poggendorf
1860



Hering
1861

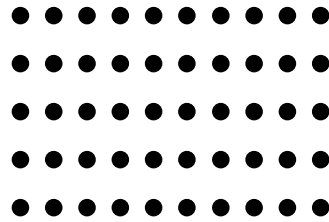
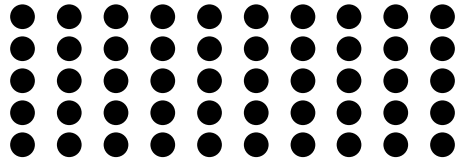


Müller-Lyer
1889

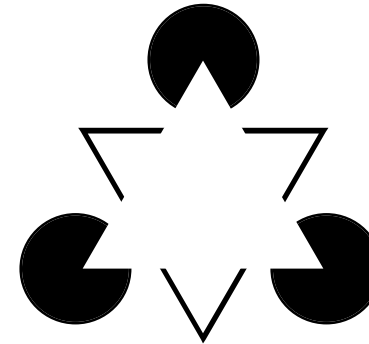


Delboeuf
1892

Human object perception



Grouping preferences



Kanizsa's triangle



Camouflage



The dalmatian

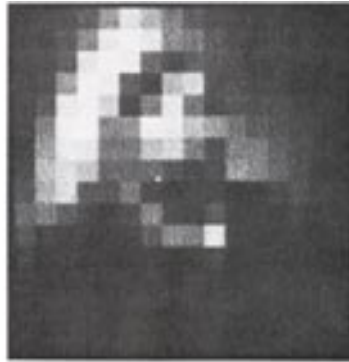
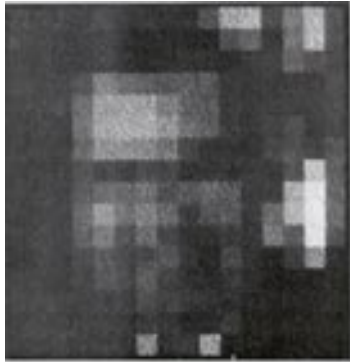
Human character recognition



CATS + DOGS

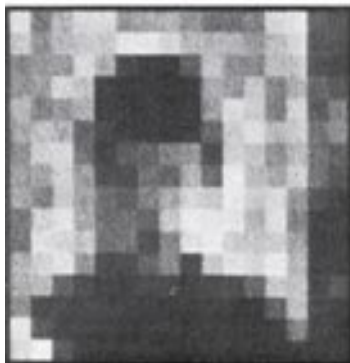
HEAVEN + EARTH

Human face recognition



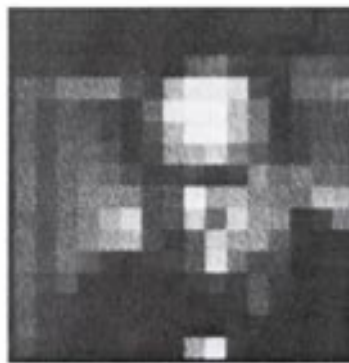
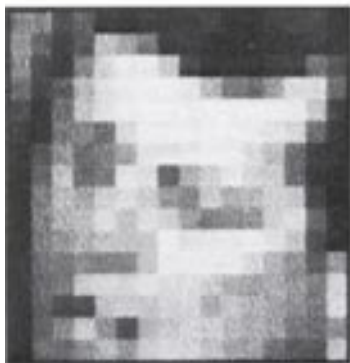
Richard Nixon

Queen Victoria



Charlie Chaplin

Graucho Marx



John F. Kennedy

Winston Churchill

Complexity of natural scenes

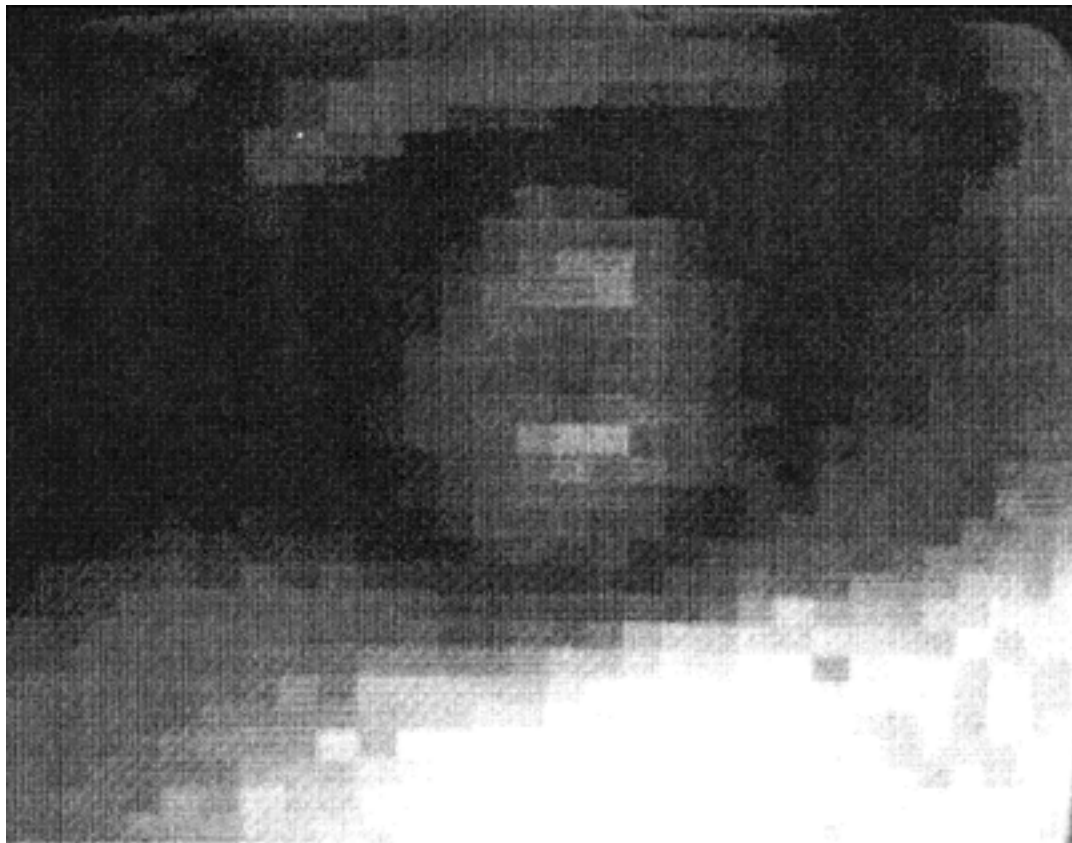


- sky
- clouds
- water
- buildings
- vegetation
- distances
- reflections
- shadows
- occlusions
- context
- inferences

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
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 99 94 101 102 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 81 108 119
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
252 249 247 241 226 177 122 120 116 106 108 110 91 103 93 99 89 88 79 80 72 74 76 65 84 87 109 123
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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 91 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
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235 235 231 228 215 198 165 122 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 95 159 174 175 179 178 180 183 180 179 177 175 174 173 169 168 171 156
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
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Greyvalues of the section



Street scene containing the section



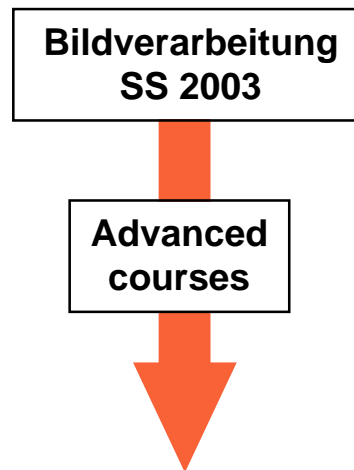
Computer Vision as an academic discipline

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**



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

Important Journals

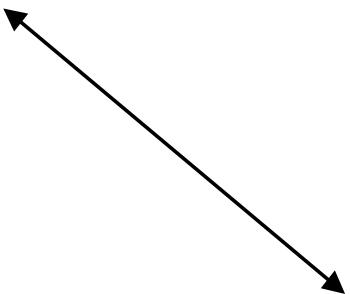
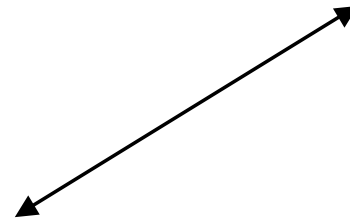
IEEE-PAMI	IEEE Transactions on Pattern Analysis and Machine Intelligence
IVC	Image and Vision Computing
IJCV	International Journal of Computer Vision
CVGIP	Computer Vision, Graphics and Image Processing

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

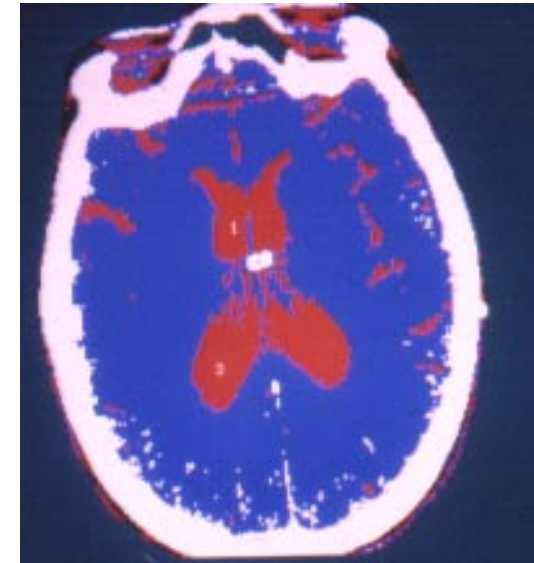
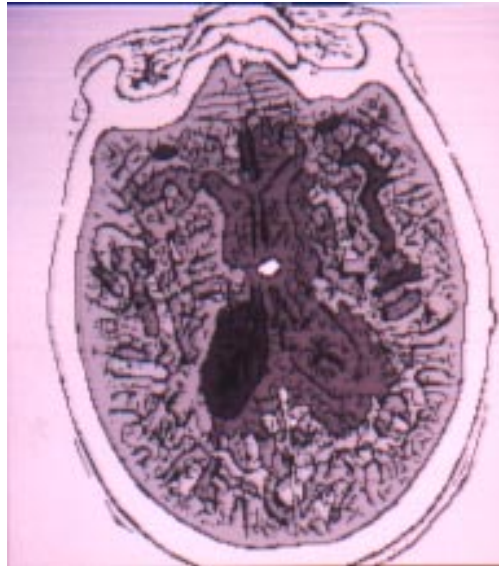
Example-based image retrieval

Which of the stored images matches the example image?



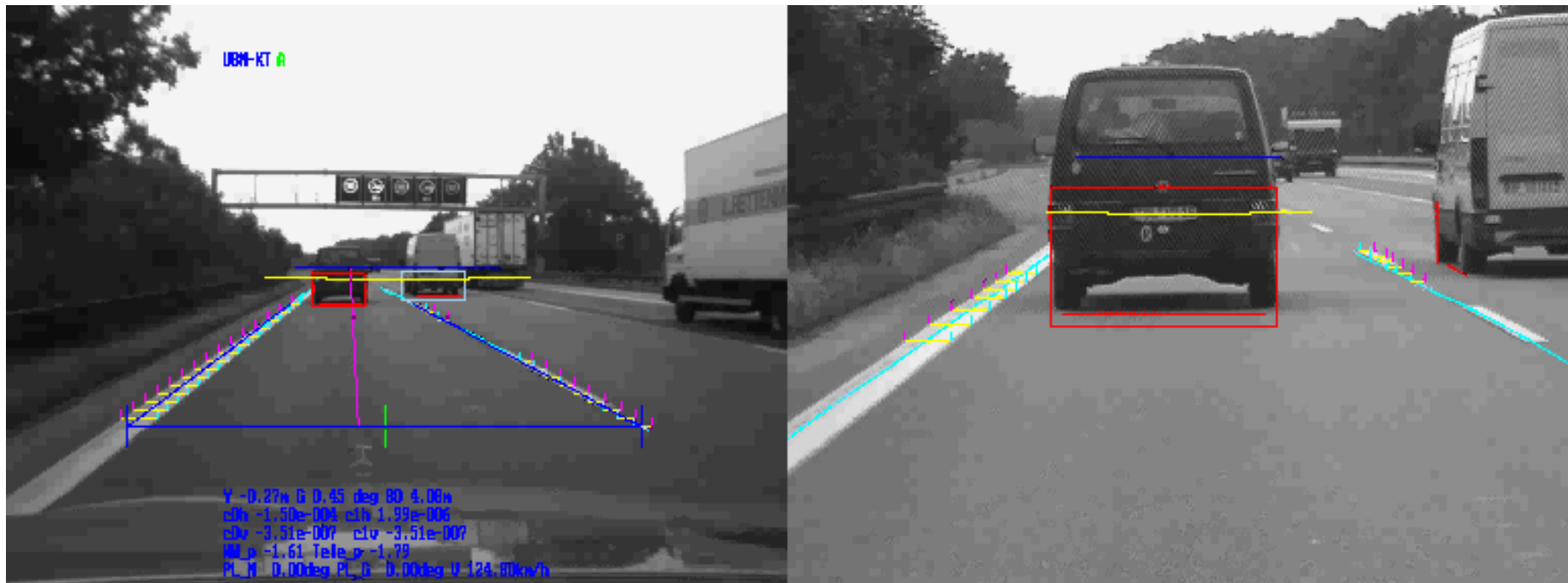
Example: Medical image analysis

classification of
materials in
tomographic images
of the human head



Example: Driver assistance

Dickmanns 1996: Autonomous navigation on highways



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

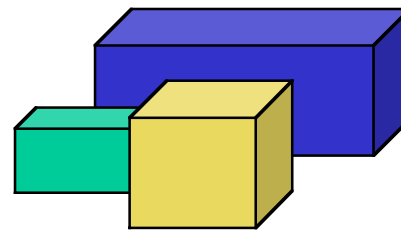
Character recognition

=> pattern recognition paradigm



Blocksworld, restricted domains

Roberts 1965: 2D => 3D



Natural scenes with motion

Nagel 79: Digitization and analysis of traffic scenes



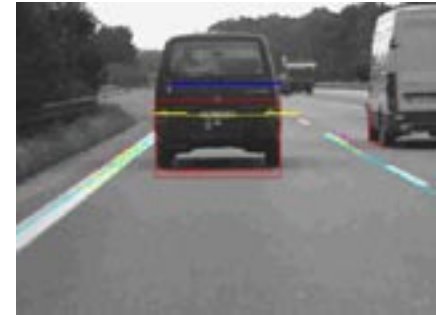
Visual agents

Bajcsy 1988: Active Vision

History of Computer Vision (2)

Visual driver assistance

Dickmanns 1996: Autonomous navigation on highways



Motion tracking

2000: Probabilistic prediction based on particle filtering



Recognizing faces

Bülthoff 2002: Modelling faces for recognition

