Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

MIN-Fakultät
Fachbereich Informatik
Arbeitsbereich BV

# Image Processing 2 (IP2) – More Advanced Methods

## Lecture 1 – Introduction

Summer Semester 2015

Prof. Dr.-Ing. H. Siegfried Stiehl, BV
Dr. Benjamin Seppke, SAV

# Lessons Learned (IP1)

**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

**SCENE INTERPRETATION**

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

# Lessons Learned (IP1 -> IP2)

**IMAGE PROCESSING FOR MULTIMEDIA APPLICATIONS**

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# Contents (IP2)

**RECAP: LINEAR SYSTEMS THEORY (2 Weeks)**

- Fourier Transform
- Sampling
- Image Formation
- Noise
- Spatial and Frequency Filtering

**LOCAL FREQUENCY ANALYSIS (2 Weeks)**

- Windowed FT
- Gabor Transform
- Wavelet Transform
- JPEG 2000

**VISUAL FEATURE DETECTION (3 Weeks)**

- Differential Geometry
- Scale Space
- Edges
- Structure Tensor and Corners

# Contents (IP2)

***UNIVERSITY HOLIDAYS*** **(1 Week)**

**SCALE INVARIANT FEATURE TRANSFORM (1 Week)**

**REGISTRATION (2 Weeks)**

- Affine and Linear Transforms
- Elastic Transforms

**STATISTICAL PATTERN RECOGNITION (2 Weeks)**

- Bayes' Rule(s)
- Linear and Quadratic Discriminant Functions
- Learning

**ORAL EXAMS (TBA)**

# Lessons Learned (IP1): Key to Success

**ONLY THE – PRIOR TO CLASS – PREPARED WILL EXCEL!**

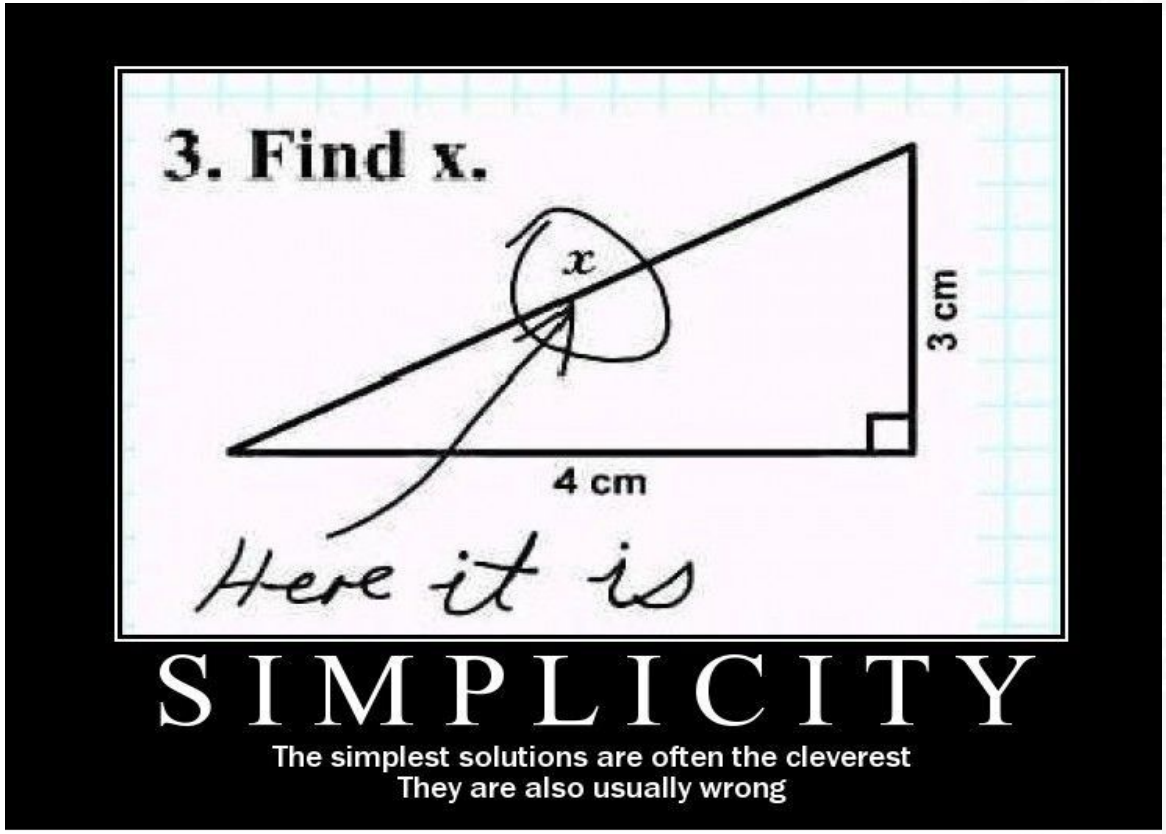
- Get the gist of slides before you enter the classroom!
- Be determined and snoopy – university studies is a privilege!
- Make yourself savvy – capitalize on library ... prior to Wikipedia!
- Ask questions in the class – before it's too late!
- Show respect to lecturers – concentrate and listen!
- Course is not edutainment for media junkies!
- Sleep @ home!

**FORGET ABOUT TED (TECHNOLOGY, ENTERTAINMENT, AND DESIGN)!**

- IP is about theory, methodology, and experiments – rather than tech and more than visual edutainment!
- Don't trust fancy slides alone – listen, annotate, and even take notes!
- Lecturers are neither talking heads nor consultants – but carrier and communicator of knowledge!
- Content is what counts on slides – not appealing design!
- Don't be afraid of math – just master a stony trail!

# Lessons Learned (IP1): Key to Success

**DON'T BE AFRAID OF MATH – JUST MASTER A STONY TRAIL!**



# ... Key to Success (2)

**HOW TO LEARN THE RIGHT WAY!**

- Be interested – well beyond duty!
- Be alert and listen!
- Annotate slides!
- Take notes – don‘t rely on your memory!
- Train the interplay of visual and motor memory for enhancement of learning effect!
- Rework class @ home!
- Join teams – hermits hardly survive!

**NO GOS!**

- Yawning, sleeping, munching, gabbing ... an offense against your fellow students!
- Mailing and surfing!
- Twiddling with mobiles!
- Being bored beyond belief!

**ORAL EXAM ADMIN: STUDIENBÜRO AND SECRETARIATE (hass@informatik.uni-hamburg.de)**

# Literature

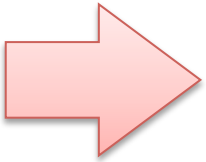
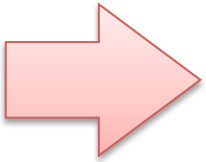


**Image Processing, Analysis and Machine Vision (3. Ed.)**
M. Sonka, V. Hlavac, R. Boyle, Thomson 2008
Grundlagen der Bildverarbeitung
K.D. Tönnies, Pearson Studium, 2005
**Computer Vision - A Modern Approach**
D.A. Forsyth, J. Ponce, Prentice-Hall 2003
**Digital Image Processing**
R.C. Gonzalez, R.E. 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

# Literature



**YOU: Use your brain, eyes, ears, and hands!**

**YOU: Work with your slides – in English .AND. German!**

**YOU: Listen ... annotate and take notes!**

**ME: Using my brain, voice, and hands!**

**ME: Reasoning about slides (and providing literature references)!**

**ME: Rediscovering value of black-/whiteboard and flipchart!**

# Course Website

The website for this course can be accessed via
http://kogs-www.informatik.uni-hamburg.de/~seppke
and will be updated each week before the lecture.

You will find

- a link to PDF copies of the slides*
- a link to problem sheets of the exercises and
- other information related to the course.

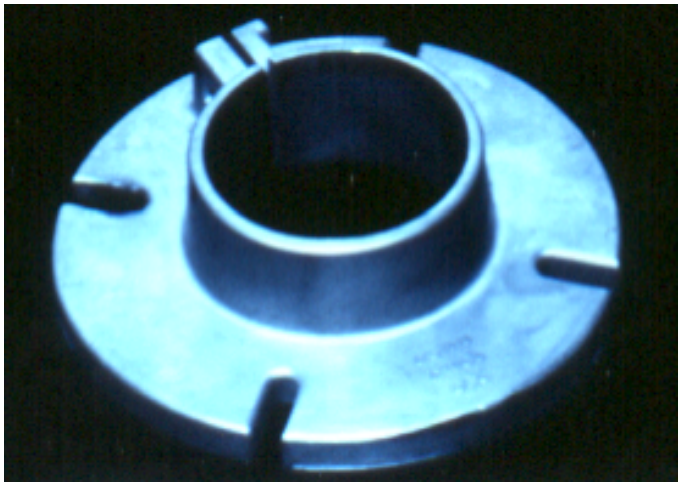
*For personal use only - copying/dissemination prohibited!

# *Recap*: Why Study Image Processing, Image Analysis, and Image Understanding?

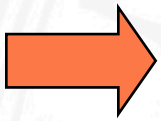
- Subfield of Computer Science
- History of more than 50 years
- Rich methodology
- Interesting interdisciplinary ties
- Exciting insights into human vision
- Important applications
- **Important information modality in the information age**

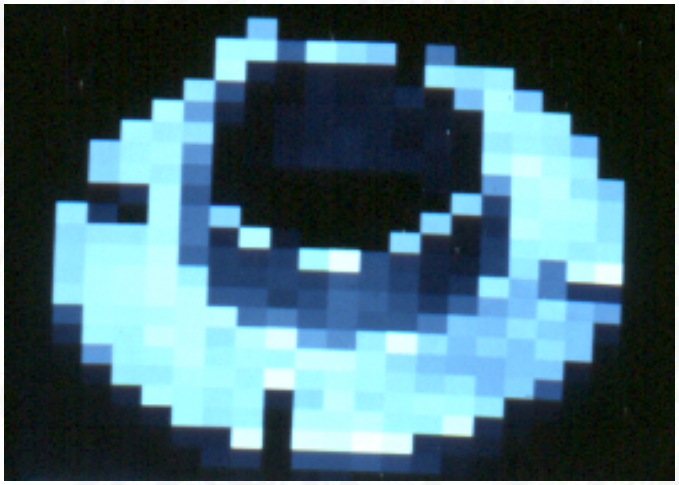
# What is "Image Processing"?

- 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**

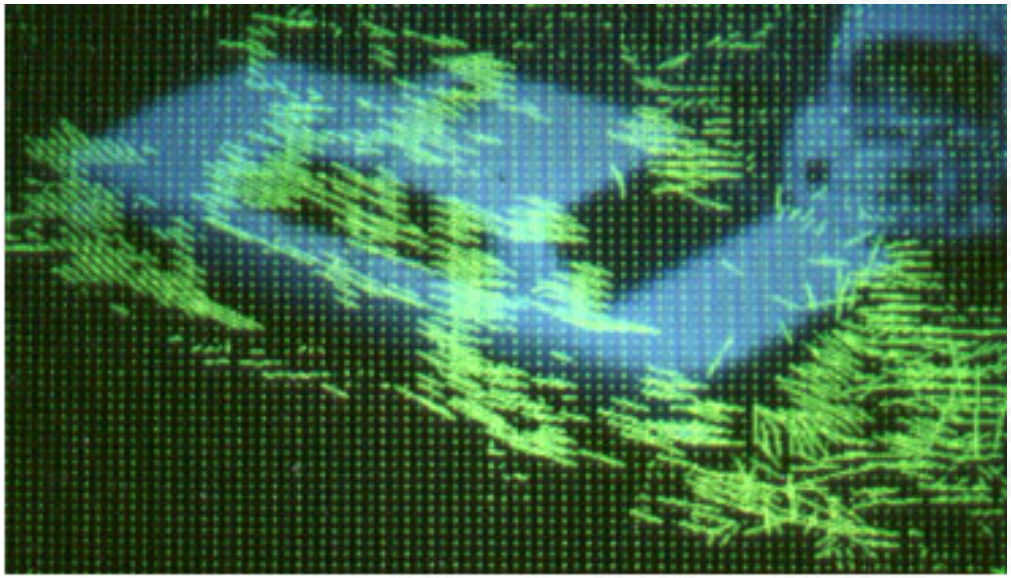




**32 columns x 35 rows**

# 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, natural language description

***"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)**

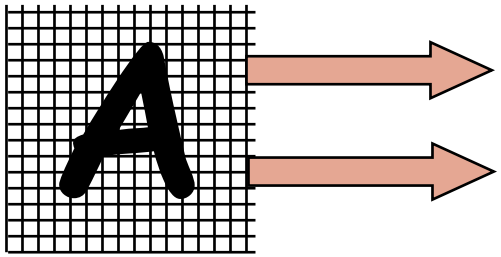
**Silent movie understanding requires more than object recognition:**

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

} **consequences for vision system architecture**

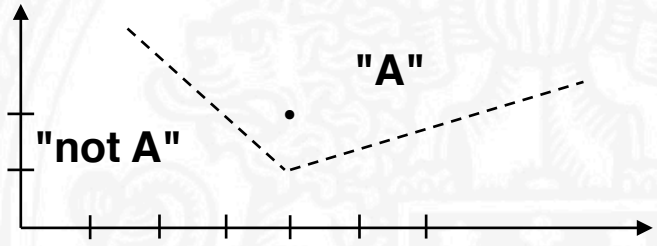
# What is "Pattern Recognition"?

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



$x_1 = 4.2$

$x_2 = 2.7$

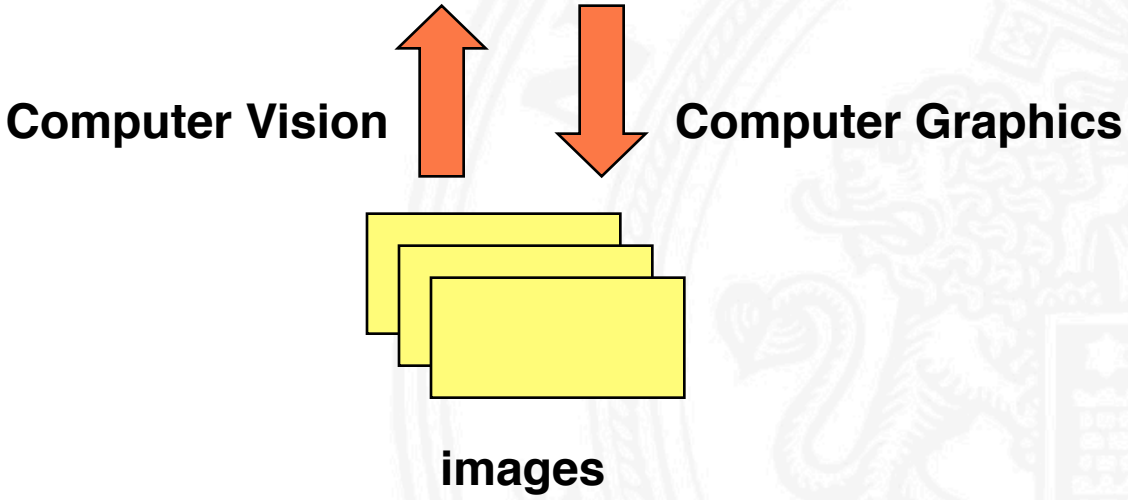



$\underline{x} = [\ 4.2\ ,\ 2.7\ ]^T$

**"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:

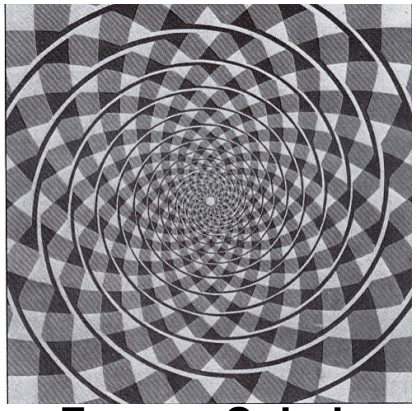
- empirical models which adequately describe biological vision
- describe vision as a computational system

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

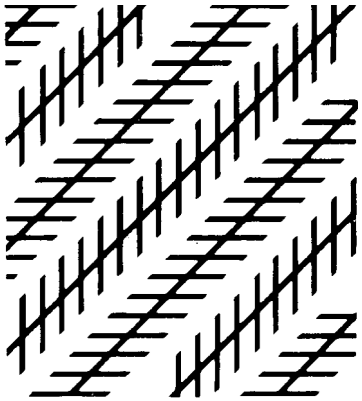
- Biological vision systems have solved problems not yet solved in Computer Vision. They provide ideas for engineering solutions.
- Technical requirements for vision systems often match requirements for biological vision.

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

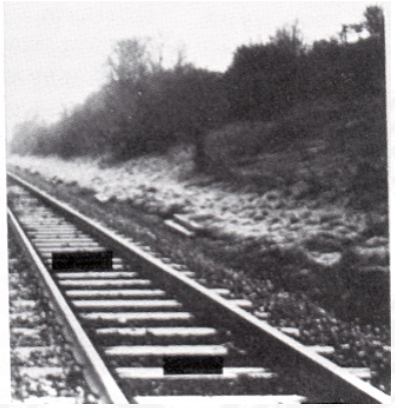
# Geometry in Human Vision

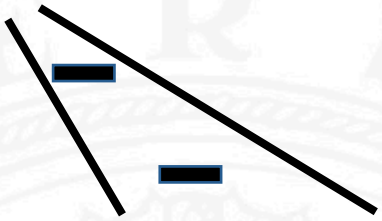


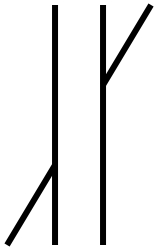
Frasers Spiral



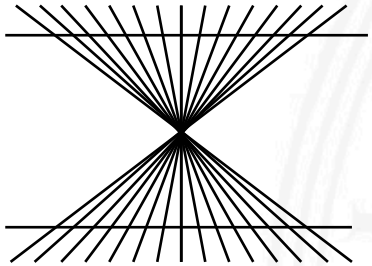
Zöllner´s Deception



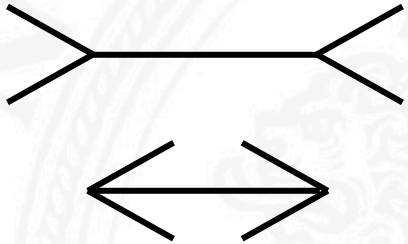




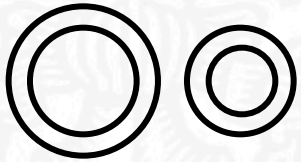
Poggendorf
1860



Hering
1861



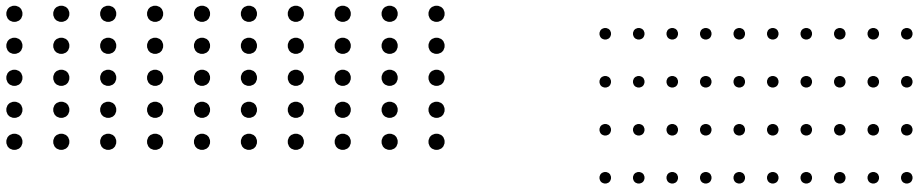
Müller-Lyer
1889



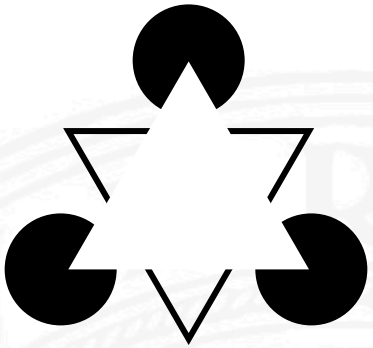
Delboeuf
1892

**Do we want a vision system to perceive like humans?**

# Human Object Perception



Grouping preferences

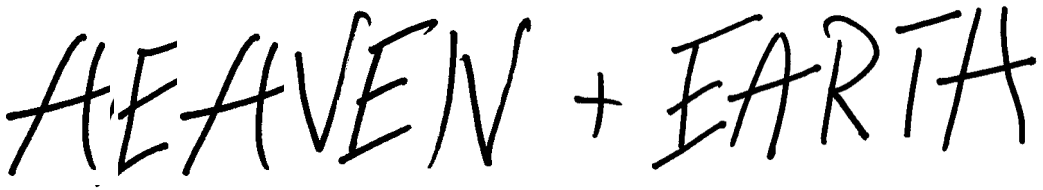


Kanizsa´s triangle

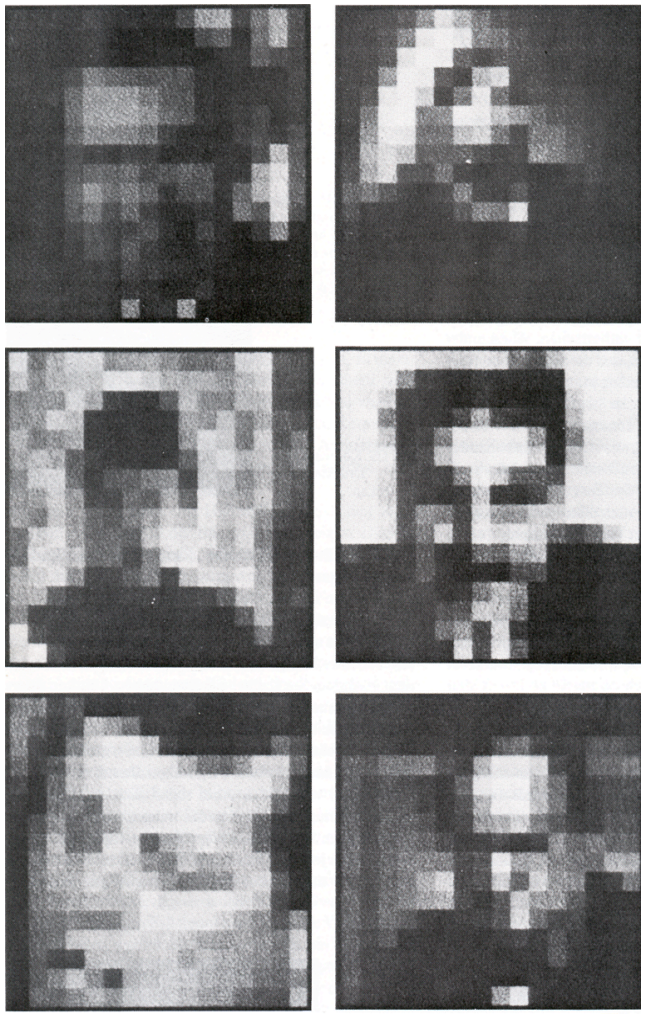
Camouflage

The dalmatian

# Human Character Recognition

# Human Face Recognition



Who is who?

Richard Nixon

Queen Victoria

Charlie Chaplin

Graucho Marx

John F. Kennedy

Winston Churchill

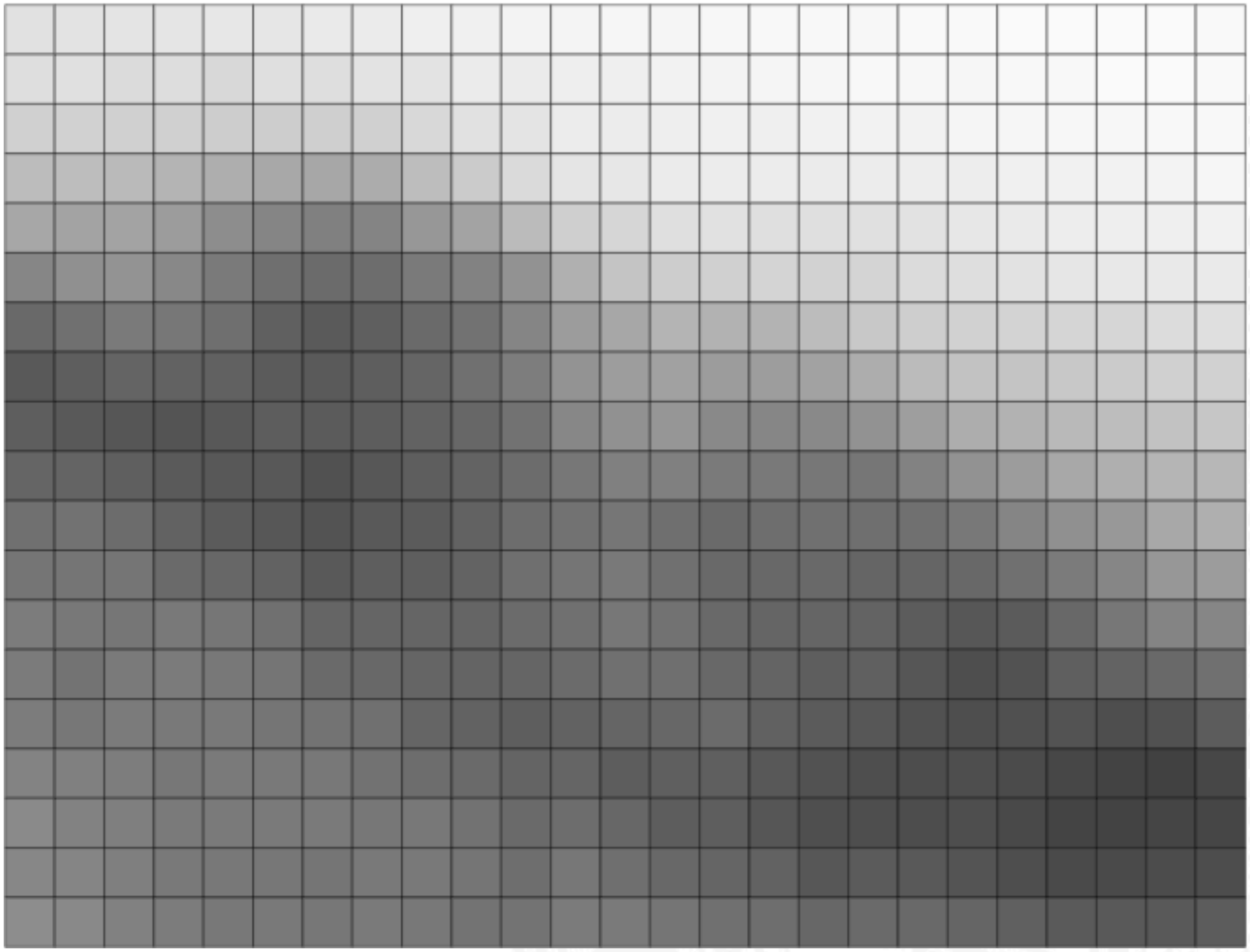
# Complexity of Natural Scenes

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

# The Computer Perspective on Images

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |

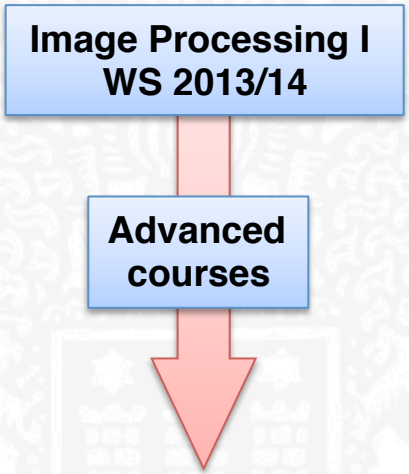
# Greyvalues of the Section



# 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
- Recent developments of Cognitive Vision aim at
  - robust vision systems
  - incorporating spatial and temporal context
  - performance beyond single object recognition



# 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

ICVS International Conference on Computer Vision Systems

GCPR Symposium der Deutschen Arbeitsgem. 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 |
| IJPRAI | International Journal of Pattern Recognition and Artificial Intelligence |
| IVC | Image and Vision Computing |
| IJCV | International Journal of Computer Vision |
| CVGIP | Computer Vision, Graphics and Image Processing |
| MVA | Machine Vision and Applications |
| PR | Pattern Recognition |
| IEEE-IP | IEEE Transactions on Image Processing |

# Important Application Areas I

- **Industrial image processing**
  - process control,
  - quality control,
  - geometrical measurements, ...
- **Robotics**
  - assembly,
  - navigation,
  - cooperation,
  - services,
  - autonomous systems, ...
- **(Local) Monitoring**
  - event recognition,
  - safety systems,
  - data collection,
  - smart homes, ...

# Important Application Areas II

- **Remote Sensing (Air- and Space-borne image analysis)**
  - GIS applications,
  - Ecological issues,
  - Climate research,
  - Defense, ...
- **Document Analysis**
  - Handwritten character recognition,
  - Layout recognition,
  - Grapheme recognition, ...
- **Medical Image Analysis**
  - Image enhancement,
  - Image registration,
  - Surgical support, ...

# Important Application Areas III

- **Image Retrieval**
  - Image databases,
  - Multimodal information systems,
  - Web information retrieval, ...
- **Virtual Reality**
  - Image generation,
  - Model construction
- **Mobile Applications**
  - Automated translations
  - Focus on Face, Shutter on Smile
  - Image filters like Instagram®, ...