Foundations of Picture Recognition and Picture Analysis Pattern Recognition

Prof. Dr. H. Burkhardt

Chair of Pattern Recognition and Image Processing

Computer Science Faculty

Albert-Ludwigs-University of Freiburg

Content

Literature for Pattern Recognition:

(1) H. Burkhardt. *Transformationen zur lageinvarianten Merkmalgewinnung*. VDI-Verlag, 1979 (Available at the secretary for 5€ cost price).

(2) H. Schulz-Mirbach. *Anwendung von Invarianzprinzipien zur Merkmalgewinnung in der Mustererkennung*. Dissertation, TU Hamburg-Harburg, Feb. 1995. Reihe 10, Nr. 372, VDI-Verlag

(3) S. Theodoridis und K. Koutroumbas. *Pattern Recognition*. Academic Press, 1999.

(4) R.O. Duda, P.E. Hart und D.G. Stork. *Pattern Classification (Second Edition)*. J. Wiley, 2001.

(5) J. Schürmann. *Pattern Classification*. J. Wiley, 1996.

(6) W.I. Smirnov. *Lehrgang der höheren Mathematik, Bd. II*. Harri Deutsch, 1995.

(7) R.C. Gonzalez und R.E. Woods. *Digital Image Processing*. Addison-Wesley, 1993.

(8) C.M. Bishop. *Neural Networks for Pattern Classification*. Oxford University Press, Oxford, 1995.

(9) M. T. Hagan, H. B. Demuth und M. Beale. *Neural Network Design*. PWS Publishing Company, 1996.

(10) N. Cristianini und J. Shawe-Taylor. *An Introduction to Support Vector Machines*. Cambridge University Press, 2000.

(11) H. Burkhardt und S. Siggelkow. *Invariant features in pattern recognition - fundamentals and applications*. In C. Kotropoulos and I. Pitas, editors, Nonlinear Model-Based Image/Video Processing and Analysis, pages 269-307. John Wiley & Sons, 2001

(12) A.R. Webb. Statistical Pattern Recognition (Second Edition). John Wiley & Sons, 2002

Chapter 1

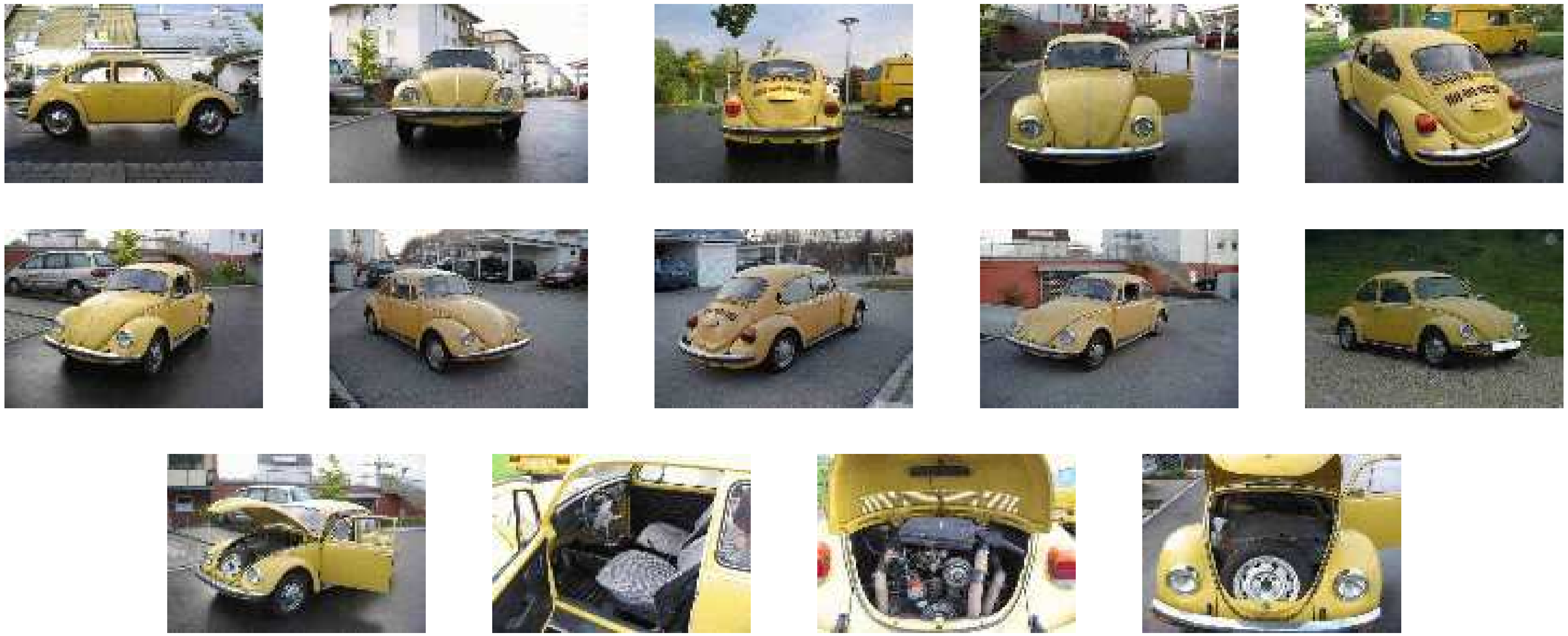
Introduction and Fields of Application

Recognition capacity of man compared to computer

Mankind is extremely capable of classifying patterns (text, language, music, pictures), even for very different forms of appearances of same objects (categories or classes).

- 3D objects appear differently: perspective projection on the retina; occlusions, and due to that only partial views available
- Different presentation of a song: different instruments and due to that different spectrum, pitch, tempi

Category “VW-Beetle”



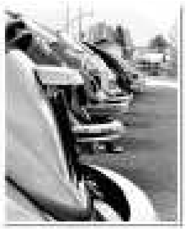
Category “VW-Beetle”









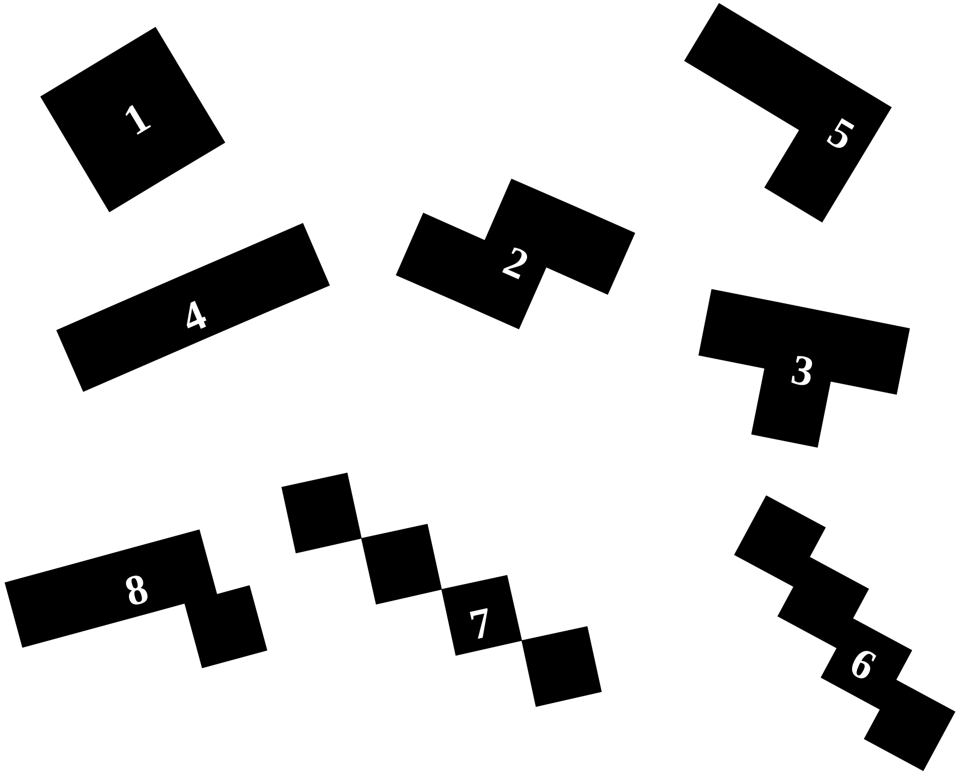


Recognition capacity of man compared to computer

	associative capabilities	combinatorial capabilities
man	***	*
machine	*	***

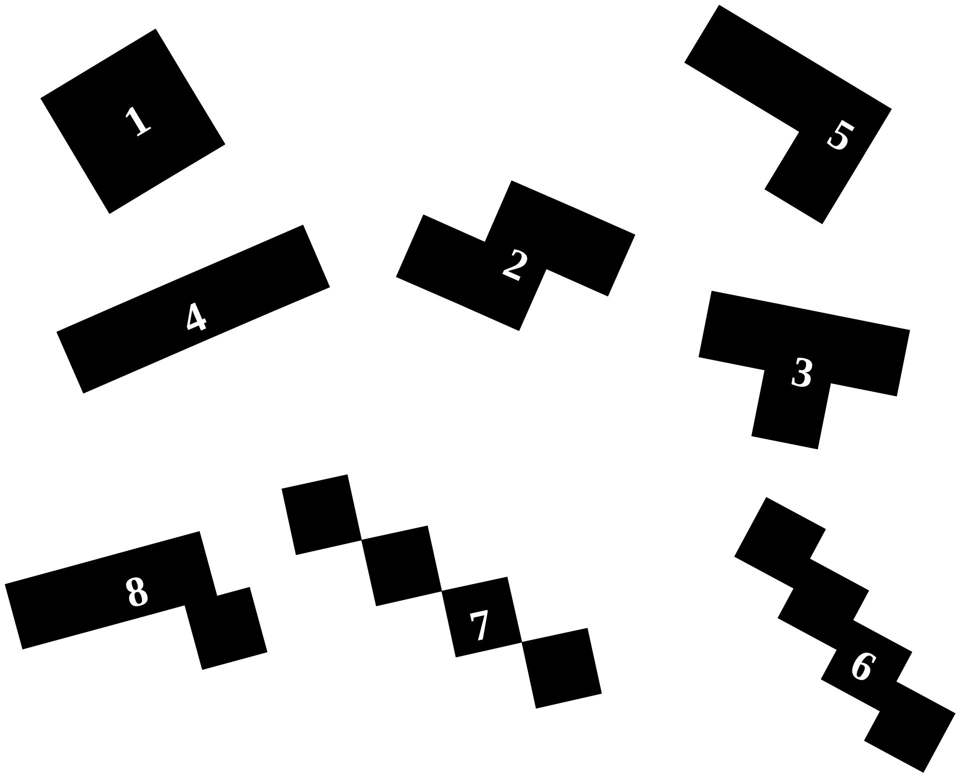
• It is not desired to imitate man, but to find mathematically and technically realizable methods (planes do not imitate birds wing beat)
• Since the human approach is mostly unexplained (except for simple preprocessing) it mainly helps to motivate and orientate solutions (*proof of existence* for a solution) rather than offering methodics.

Simple recognition exercise: classification of objects



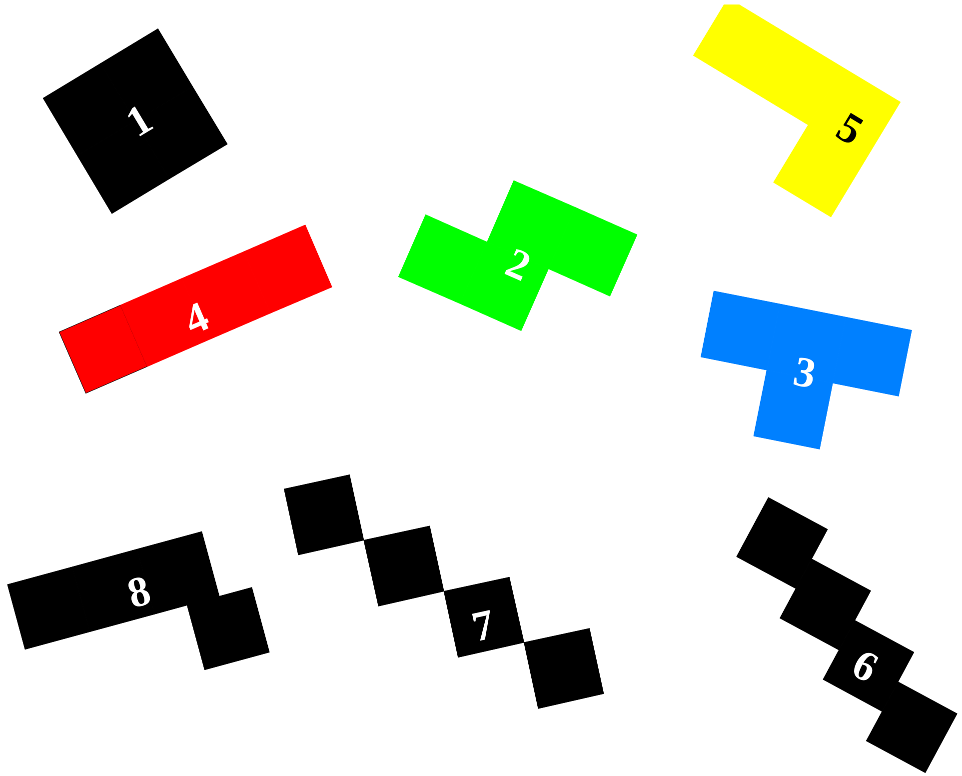
Classification of objects
characterization with two features

object	area	perimeter
1	4	8
2	4	10
3	4	10
4	4	10
5	4	10
6	4	13
7	4	16
8	4	11

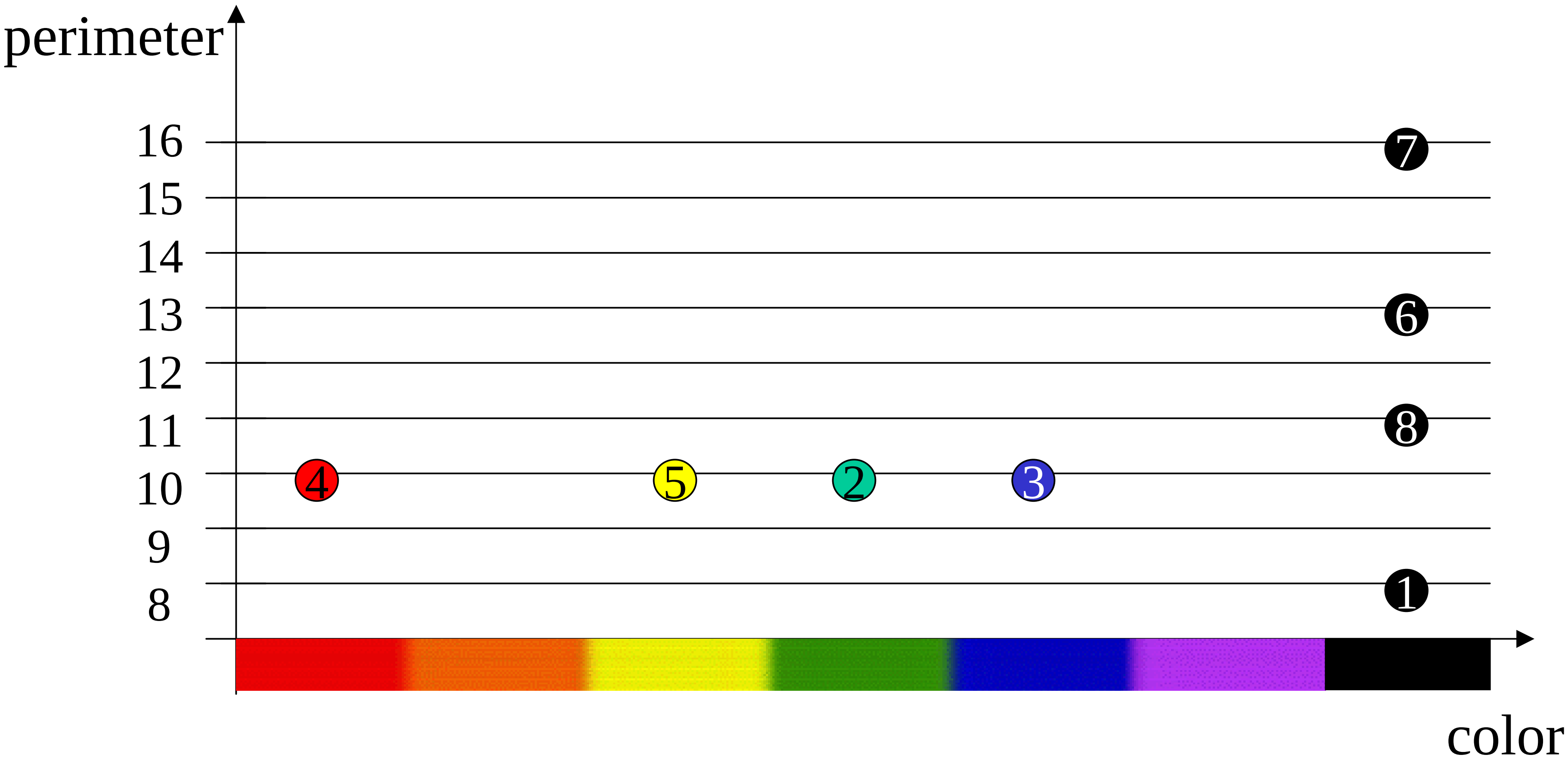


Classification of objects characterization with <u>three</u> features

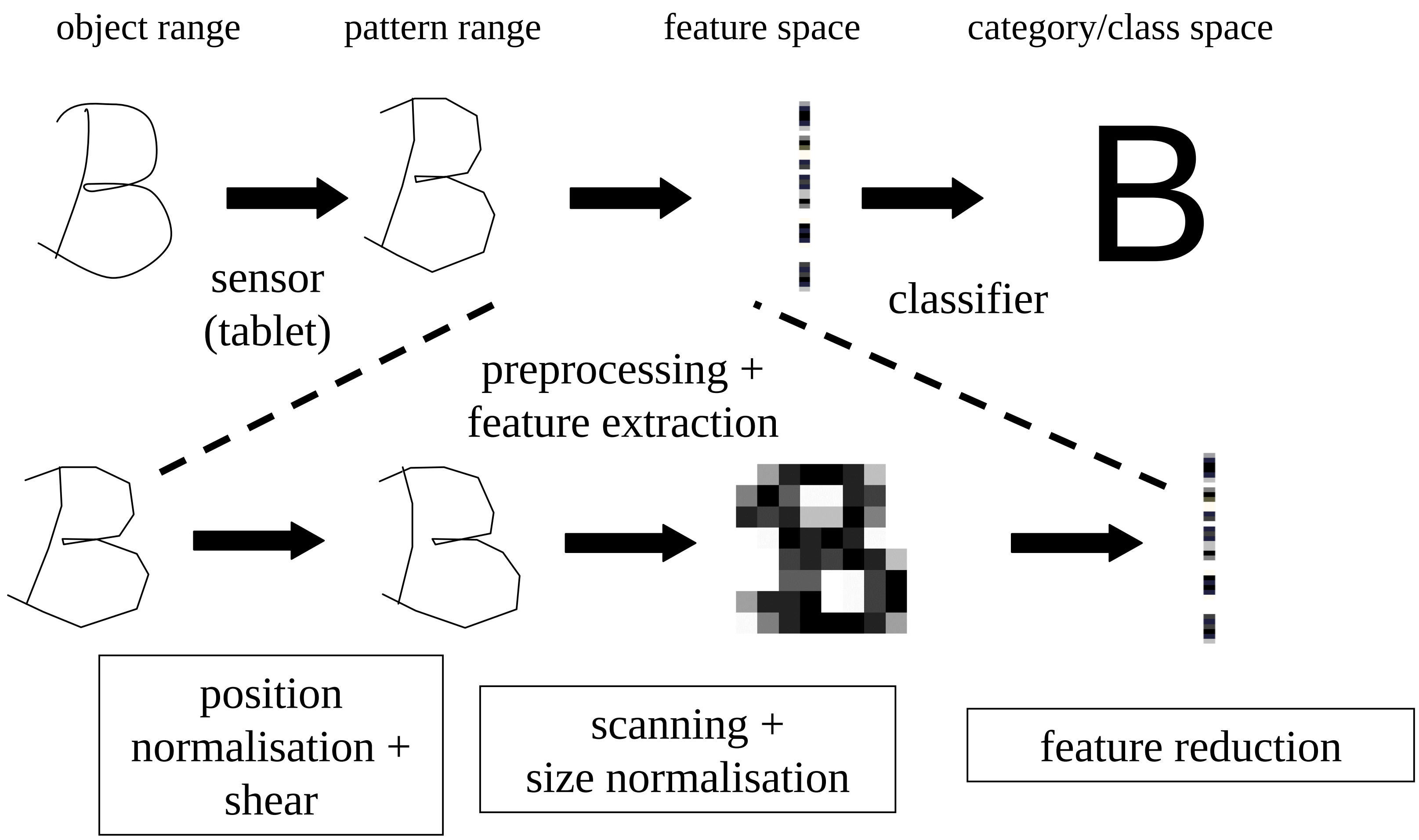
object	area	perimeter	colour
1	4	8	black
2	4	10	green
3	4	10	blue
4	4	10	red
5	4	10	yellow
6	4	13	black
7	4	16	black
8	4	11	black



Two-dimensional feature space



Demonstration: Handwriting Recognition



FIELDS OF APPLICATION FOR DIGITAL PICTURE PROCESSING AND PATTERN RECOGNITION

1. Visual Quality Control and Production Monitoring, Robotics, Machine Vision
   - inspection of material, analysis of surface and grinding surface pattern, ultrasonic scan analysis, early damage detection (turbine sounds, fractured drills), assembly check, infrared analysis, workpiece identification, navigation
2. Picture Data Transmission with Compressed Data (Image Coding)
   - videoconferencing, visual telephone, Internet-applications

3. Character Recognition and Automatic Document Evaluation and Processing
    - address and document reader, image and text retrieval, symbolic interpretation of maps and drawings, symbolic object storage, recognition of handwriting and signature authentication
4. Speech and Music Recognition
    - speech recognition, automatic information systems, voice recognition (for entrance/access control)
    - automatic note generation from music records (folk music/records by natives)
5. Computer-Aided Diagnosis
    - ECG (elektrocardiogram of the hearts blood streams => detection of potential myocardial damage, also performance and metabolism disorder)
    - EEG (elektroencephalogram of the brains activity streams => detection of potential cerebric dysfunction)

- tomographic images (MR,CT), ultrasound images, radiographs, microscopic analysis (cellpicture classification, chromosomes, tissue transection, haemogram), ECG, EEG

Medical study in the US:

(source: H. Niemann)

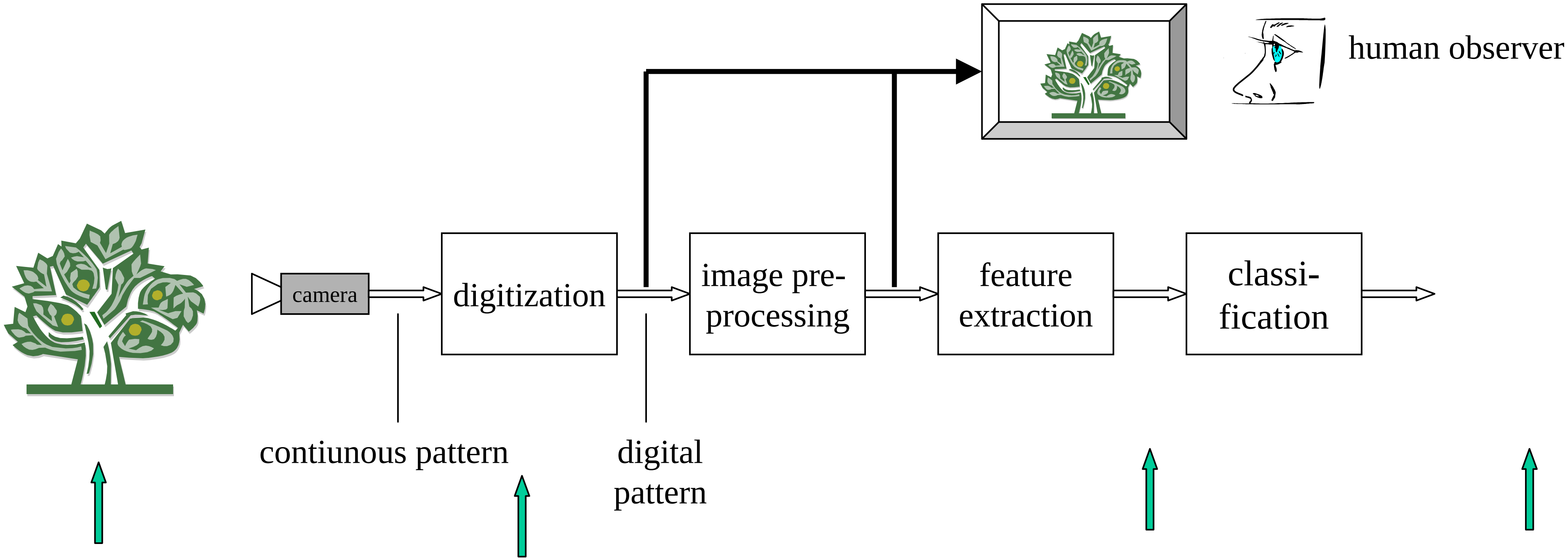
The amount of medical data to be evaluated is extremely high. Every year, 650 mio. radiographs are taken in the US and an estimated 30 % of anomalies remain undetected.

Cell diagnosis: 20,000-40,000 employees, and estimately 40 % of all orders are not evaluated in a satisfying way.

On the other hand, for haemogram analysis already exist very good machines. Though, in the field of radiograph analysis a lot of research still has to be done!

6. Satellite and Aerial Photographs (Multispectral Sensors)
   - remote sensing (evaluation of airplane and satellite pictures), photogrammetry, environment monitoring, meteorology and oceanography (cloud pictures, wave analysis), vegetation monitoring (pest control, harvest, tree crop), exploration and geology, geography (urban planning, autom. map generation)
7. Biology
   - monitoring cell growth (with and w/o tracer), analysis of microorganisms e.g. in sludge (biologic sensor)
8. Crime Investigation
   - fingerprint identification, face recognition
9. Improve Resolution of Normal and Electron Microscopes

General Schema for Image Processing and Pattern Recognition



object range $\in \mathbb{R}^\infty$ | pattern range $\in \mathbb{R}^P$ | feature space $\in \mathbb{R}^N$ | one-dim. category $\in \mathbb{Z}_K$

$\infty \ggg P \ggg N \ggg K$ e.g. $\infty \ggg 512^2 \ggg 200 \ggg 20$

In general there is no complete solution for a pattern recognition problem.
Tiered, modular approaches are chosen due to the complexity of the tasks.

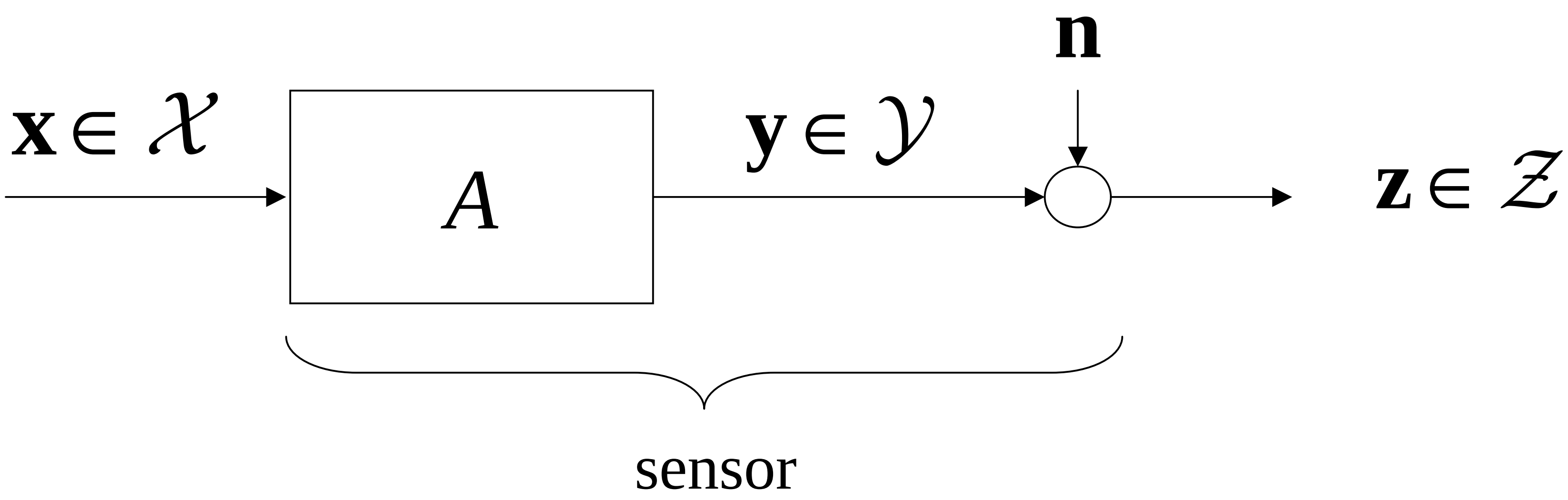
Object space:

f(x) vector function depending on a vectorial independent variable **x**
e.g. color and intensity function of
2-3 coordinates, or: absolute value and orientation of a electromagnetic field function of position and time

Pattern space:

f**(x)** mostly scalar function
e.g. gray picture function of position and time
using cameras i.a. projection of a 3D-scene to the cameralevel (centric- oder simplified: parallel projection)
or: recording speech or music over time

How to describe mathematically the effect of the sensor?



$\mathcal{X}$: object space

$\mathcal{Z}$: pattern space

The mathematic transformation A describes the sensors properties:

$$\mathbf{z} = A(\mathbf{x}) + \mathbf{n} \qquad \text{(I)}$$

Often additional knowledge in the form of constraints e.g. only positive intensities, limites time and space or discrete values, contribute. These constraints often can be specified as a fixed point condition:

$$\mathbf{x} = C(\mathbf{x}) \qquad \text{(II)}$$

Which cases are to distinct when recording pictures (sensor):

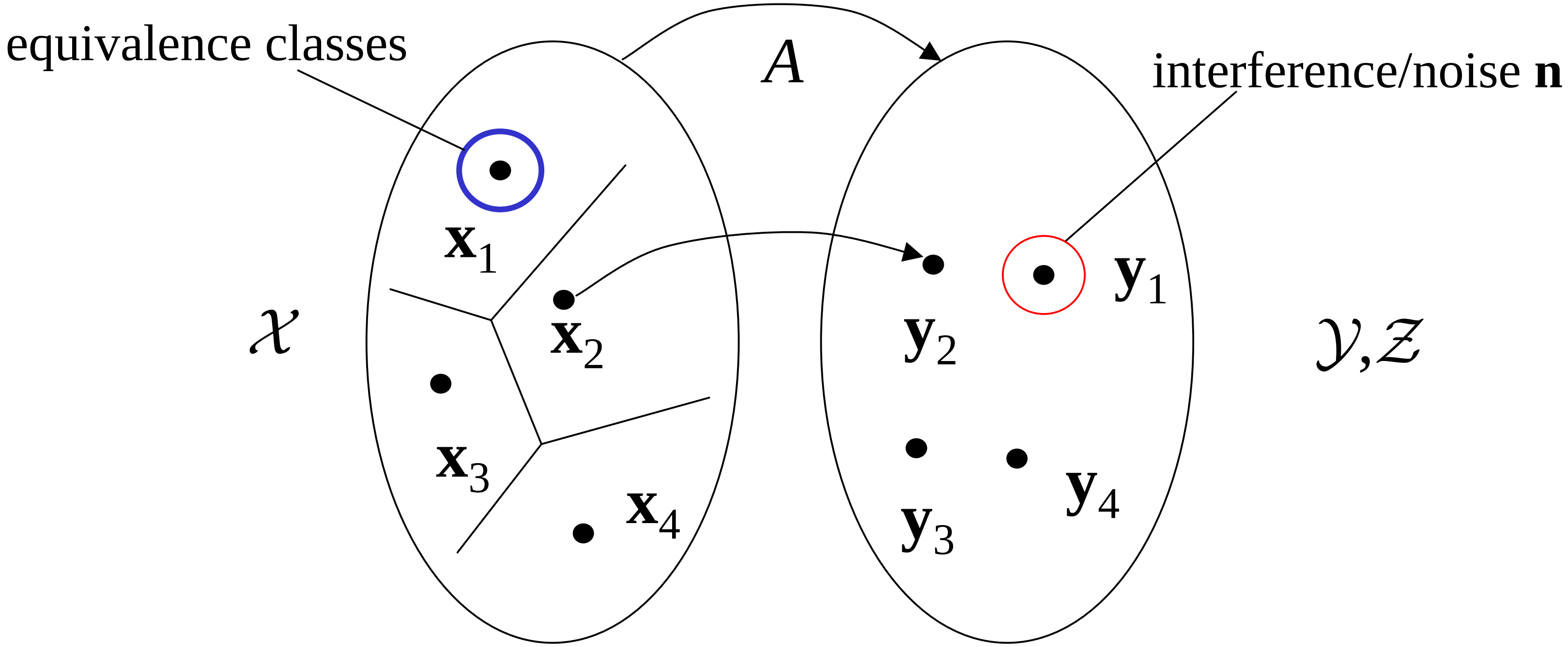
- *A* bijective
  i.e. equivalence- or category classes form closed and complete sets, e.g. geometric transformations with properties of mathematic groups have an effect on the objects
- Incomplete and faulty data
  - Incomplete observations due to transformation A to subspaces (tomographic projections, occlusions and partial views), hence: mathematically ill-posed inverse problems
  - noisy observations ($\mathbf{n} \neq \mathbf{0}$)

How does the field of pattern recognition integrate in the general theory of estimation for pictures or general signals?

The theory of estimation distincts between:

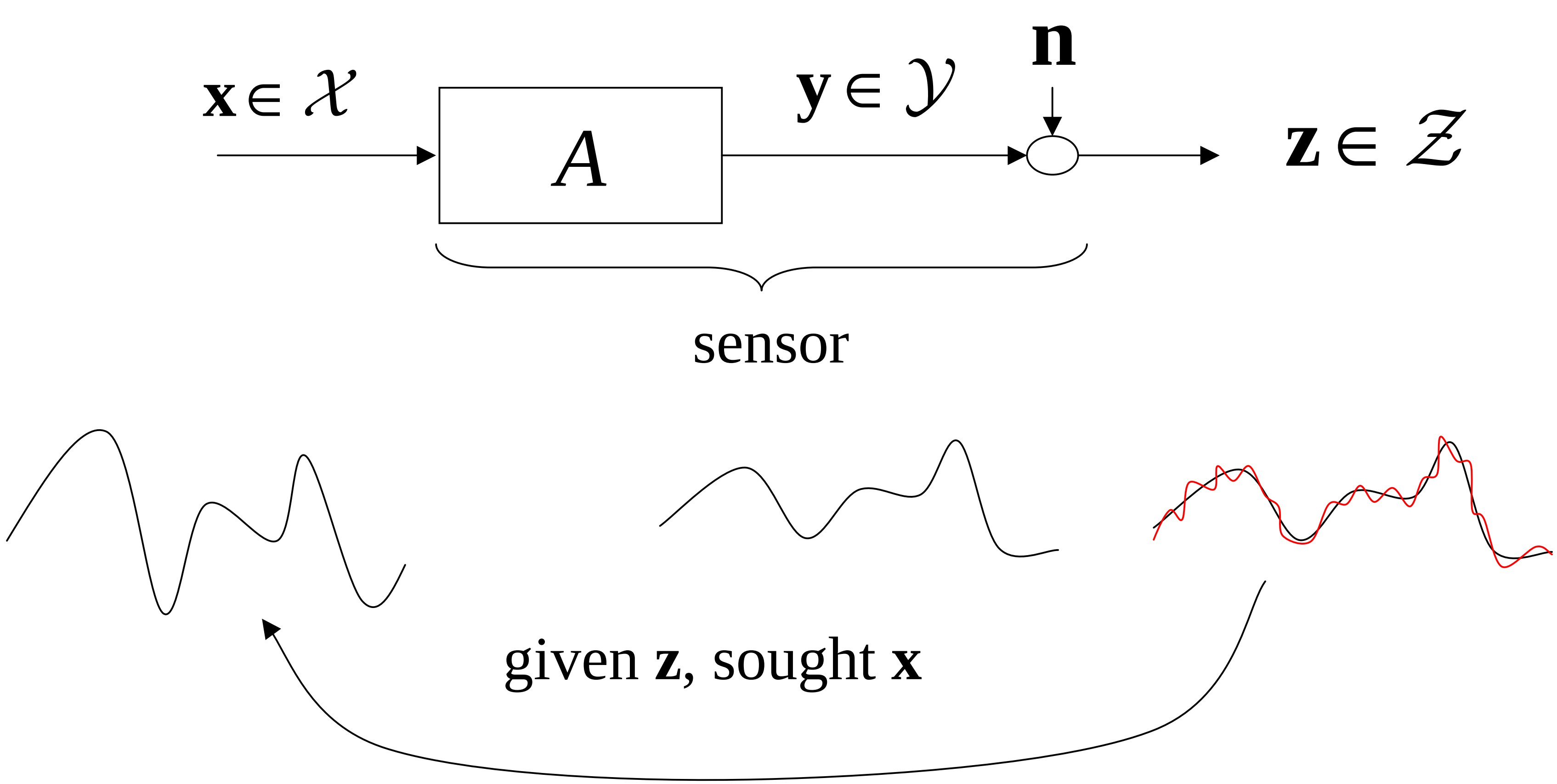
- Estimation
- Detection
- Pattern Recognition

Characterization of the three tasks in signal vector spaces:

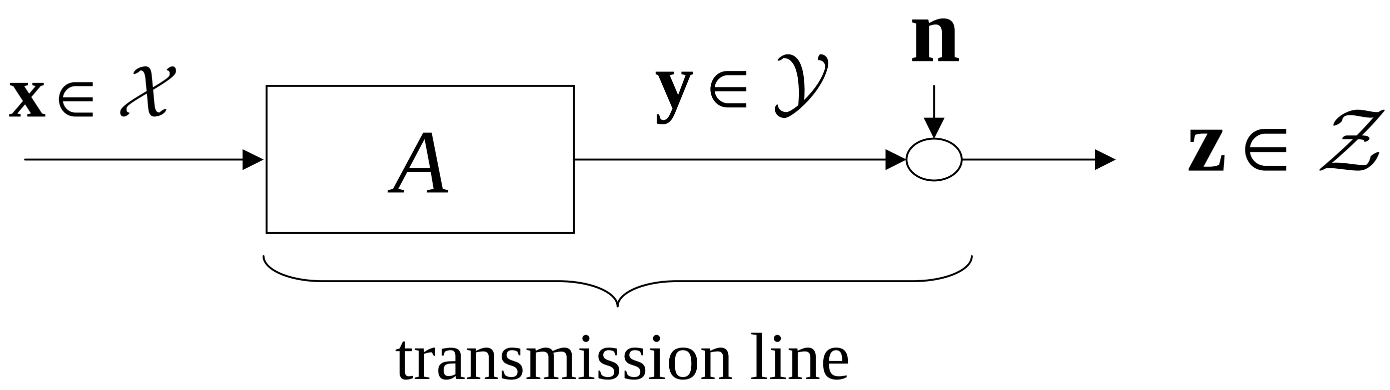


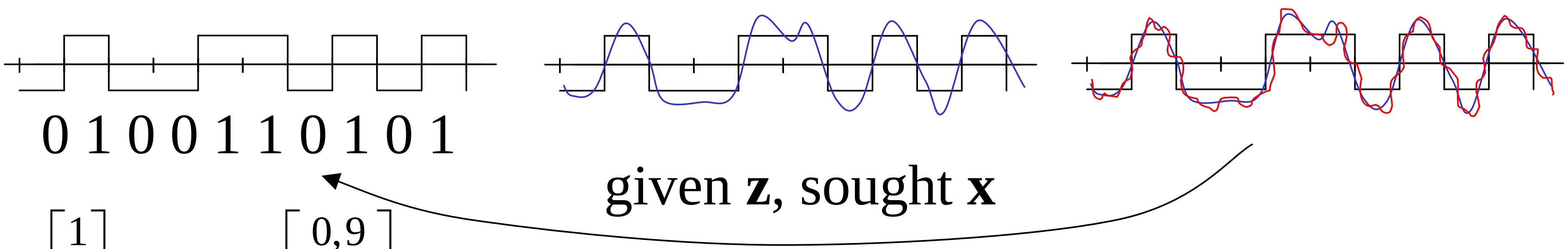
1. fully occupied objectsignal space: ***signal estimation*** $\mathbf{x} \in \mathcal{X}$
2. There is only one subset of all possible signals: ***detection*** $\mathbf{x} \in \{\mathbf{x}_i\} \subset \mathcal{X}$
3. There is a limited amount of signal classes (equivalence or category classes): ***Pattern Recognition*** $\mathbf{x} \in \mathcal{E}_i\{\mathbf{x}_i\} \subset \mathcal{X}$

Example for signal estimation: tasks for measurement technology



Example for signal detection: digital signal transmission





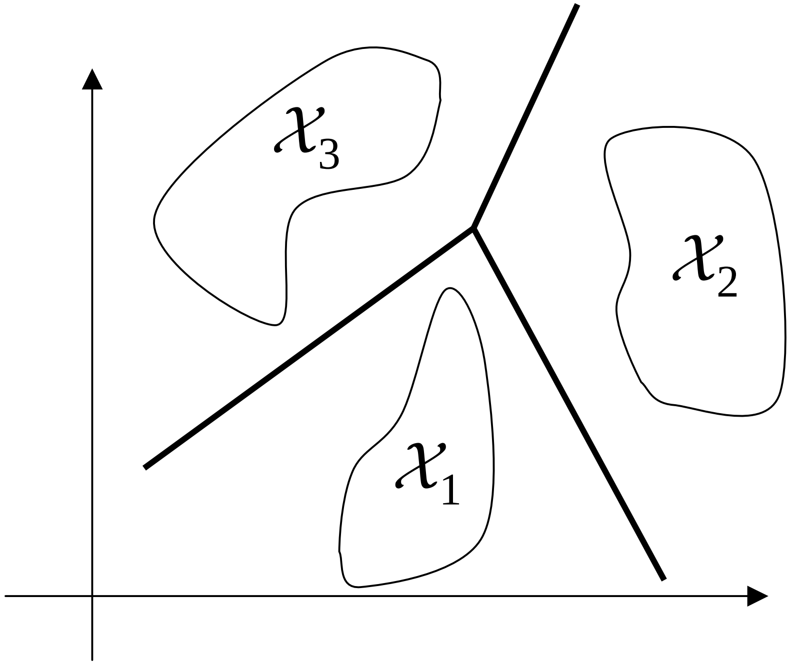
$$\mathbf{x} = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{bmatrix} \xrightarrow{A} \mathbf{y} = \begin{bmatrix} 0{,}9 \\ 0{,}1 \\ -0{,}1 \\ 1{,}1 \\ 1{,}2 \end{bmatrix}$$

x is on a hypercube!

Importance of feature extraction

1. Extraction of features, that are highly relevant for classification to equivalence classes or unambiguously distinguishable
2. Reduction of the dimension of pattern space i.a. due to expenses/cost, while keeping distinction properties (adequate distance between the classes of the feature space)

Last step: Classification, i.e. distinction of feature space in categories



- The set „Unknown“ can form a class (classification with rejection)
- The categroy is often represented by a random sample (training patterns)
- It should have a certain compactness in the sense of a metric (Cluster)