Kapitel 12*

Grundlagen - ME
Our daily life

Decision making:
- select enjoyable food
- distinguish fresh food from its smell
- weather (sunshine, cloudy, rain, snow)
- recognize face / gender / age / beauty
- read text
- understand spoken words / sentences
- recognize objects of many classes
- decide stock purchase
- use spam mail filter
- medical diagnosis
- activity recognition
- many other others ......
Pattern recognition

“The assignment of a physical object or event \([\text{pattern}]\) to one of several prespecified \textit{categoeries}\)” [\textit{pattern classification}]

– \textit{Duda & Hart}

“The science that concerns the description or classification (recognition) of measurements”

– \textit{Schalkoff}

Pattern Recognition is concerned with answering the question

“\textit{What is this?}”

What to do?

– \textit{Morse}
Pattern recognition

“A pattern is the opposite of a chaos; it is an entity vaguely defined, that could be given a name” (Watanabe)

- enjoyable food (yes, no)
- fresh food (yes, no)
- weather (sunshine, cloudy, rain, snow)
- face (identity, gender, age, beauty)
- text (words)
- spoken text (words)
- object classes
- stock purchase (yes, no)
- spam mail (yes, no)
- medical diagnosis (healthy, illness X/Y/Z)
- activity (walking, running, eating, meeting, ……)
- many\textsuperscript{n} others ……
Pattern recognition

How to classify these athletes?

- gymnastics
- basketball
Pattern recognition

- Weight
  - Basketball
  - Gymnastics

- Height
Pattern recognition

Feature vector $\mathbf{x}$:
- $n$ observations (properties)
- a point in feature space $\mathbb{R}^n$

Task: design a **classifier** (decision rule)

$$R^n \to \{ \text{class}_1, \text{class}_2, \ldots, \text{class}_c \}$$

(vector space $\to$ classification space)

that decides about the category (class) based on an observation feature vector
Pattern recognition

weight

decision boundary

height

basketball

gymnastics
Pattern recognition

Make an optimal decision (classification) in feature space $\mathbb{R}^n$

(5,11,2,1,0,1,...,8)

Magic of dealing with vector spaces!
Pattern recognition systems: Architecture

- Physical environment
  - Data acquisition/sensing
    - Pre-processing
    - Feature extraction
      - Features
      - Classification
      - Post-processing
    - Decision
  - Model
    - Model learning/estimation
- Training data
  - Pre-processing
  - Feature extraction/selection
  - Features
Pattern recognition systems: Preprocessing (segmentation)
Pattern recognition systems: Postprocessing

Context information extremely useful for correcting potential classification errors:

- postal code
- street name
- legal vs. courtesy amount

\[
\text{check against dictionary}
\]
Features

Repräsentation von Mustern im Merkmalsraum $F$

- Intuitive Merkmale

  Unterscheidung Äpfel/Orangen (links): Verhältnis von Grün- und Rot-Komponente ($F = \Re$); gilt allerdings nicht für Situation rechts

- Komplexe Merkmale

  Kieselalge (diatom), > 15000 Typen (Klassen), Anwendung in Biologie, Klimaforschung, Gerichtsmedizin. Merkmale: Konturform + Textur

  - String: Text, Objektkontur (zyklische Strings)
  - Graph: Schriftzeichen, komplexe Strukturen
Features

Classification is all about modeling variability

- camera position
- illumination
- within-class variations (shape variations, …….)
Features: Illumination invariance
Features: Viewpoint invariance
Features: Shape invariance

Within-class variations (why are they chairs?)
World of pattern recognition

kNN, ANN, SVM, Bayes, decision trees, rule-based, HMM, MCS
Multiple classifier combination

**Doctor:** I think you have illness X. But *I am not sure.* It may also be illness Y or Z.

**Patient:** …..
Multiple classifier combination

Pattern classification is a difficult task

- There is no best classifier for all test cases
- Different classifiers typically show different behaviors
  → Multiple Classifier Systems (MCS):
    Take over the common strengths and ignore the weakness of the involved classifiers

*Consult more experts if you are uncertain in your decision*
World of pattern recognition

supervised

kNN
ANN
linear classifier
SVM
decision trees
HMM
Bayes
MCS

unsupervised

clustering

rule-based

Kapitel 12* “Grundlagen - ME” – p. 21
Supervised vs. unsupervised pattern recognition

- **Supervised classification** (known categories)
- **Unsupervised clustering** (creation of new categories)
Supervised vs. unsupervised pattern recognition

Training samples are labeled (cat, dog)
Supervised vs. unsupervised pattern recognition

Training samples are unlabeled
Clustering

Group data into clusters such that there is
- high intra-class similarity (→ compact clusters)
- low inter-class similarity (→ good separability)
World of pattern recognition

supervised

kNN
linear classifier
SVM
HMM
MCS

ANN
decision trees
rule-based
Bayes

unsupervised

clustering

Bag of words
World of pattern recognition

supervised

kNN
ANN
linear classifier
SVM
decision trees
rule-based
HMM
Bayes
MCS

unsupervised

clustering

Bag of words

............

rule-based

HMM
Mobile computing

1) Mainframe
   1 Computer
   Many users

2) PCs
   1 Computer
   1 User

3) PDA, Smart Phone
   Smart Card
   1 User
   Many computers

Source: Mark Weiser (adapted)
Pattern recognition on mobile platforms

- **320x240**: $10
- **640x480**
- **1280x960**
- **3500x2200**: $1000

**Examples**:

- **Barcode reading**
- **Speech understanding (Siri)**
Pattern recognition on mobile platforms

Traffic Light Detection on a Mobile Phone


3rd Prize at Nokia Ubimedia MindTrek Awards 2009
Applications

- large-scale image search
- biometrics
- action classification
- written text recognition
- speech recognition
- industrial quality control
- medical screening
- intelligent driving assistance
- spam mail filtering
- remote sensing (satellite images, SAR)
- biomedical image analysis
- plagiarism detection (be careful with your assignments!)
- many others ……
License plate reading system

Modules: 1) acquisition, 2) enhancement, 3) segmentation, 4) character recognition (should work in real time)
Intelligent driving assistance systems

- pro.pilot Traffic Jam Assist
- pro.pilot Traffic Sign Recognition
- pro.pilot Park Mate
- pro.pilot Night Vision (FIR)
- pro.pilot Night Vision (NIR)
- System Concept HMI
- pro.pilot Adaptive Cruise Control
- pro.pilot Sensitive Guidance
- pro.pilot Lane Departure Warning
- pro.pilot Safe Exit Assist
- pro.pilot Blind Spot Detection / Lane Change Assist

© Siemens VDO Automotive
Intelligent driving assistance systems


The optimal deployment of vehicle airbags for maximum protection requires information about the occupant's size and position. The aim of this system is to detect the occupancy of passenger seat and classify it into one of the following classes: 1) empty seat; 2) rearward facing infant seat; 3) forward facing child seat; 4) adult.
Statistical pattern recognition

Make an optimal decision (classification) in feature space $\mathbb{R}^n$

(5, 11, 2, 1, 0, 1, ..., 8)

Magic of dealing with vector spaces!
Structural pattern recognition

How to compare graphs/strings?
- We need distance function between graphs/strings

Representation by parts and their relationships:
- Graph algorithms
- Tree algorithms (simpler graphs)
- String algorithms (linear graphs)
Syntactic pattern recognition

- Classes are represented by grammars
- Classification is done by means of parsing

\[ G = (N, T, P, S) \]
\[ N = \{S, A\} \]
\[ T = \{a, b, c, d\} \]
\[ P = \{S \rightarrow cA, \ A \rightarrow aAb, \ A \rightarrow d\} \]
\[ L(G) = \{ca^n db^n \mid n \geq 0\} \]

Ableitung:

\[ S \rightarrow cA \rightarrow cd \]
\[ \rightarrow caAb \rightarrow cadb \]
\[ \rightarrow caaAbb \rightarrow caadbb \]
\[ \rightarrow \ldots \text{etc.} \]
Pattern recognition systems: Design cycle

1. **Start**
2. **Collect data**
3. **Choose features**
4. **Choose model**
5. **Train classifier**
6. **Evaluate classifier**
7. **End**

Prior knowledge (e.g., invariances)
Pattern recognition systems: Design cycle

- Datengewinnung: repräsentative Stichprobe zum Trainieren/Testen; zeit- und kostenintensiv. Zweistufiges Vorgehen:
  ✓ Machbarkeitsstudie: kleine Menge von typischen Mustern
  ✓ Realisierung: stark erweiterte Menge von Mustern

Es gibt keine besseren Daten als mehr Daten!

- Merkmalsselektion: Wahl von charakteristischen Merkmalen stellt einen kritischen Schritt dar und hängt von der jeweiligen Problemstellung ab
- Methodenselektion: Wahl des Klassifikationsverfahrens
- Training: Bestimmung von Modellparametern
- Performance Evaluation: Steuerung des Entwicklungszyklus
Generalization

Single feature histograms; decision based on threshold

Length or lightness alone does not suffice!
Generalization

Using two features:

Linear decision boundary separates reasonably well – but incurs errors!

Can achieve zero classification error!

Is this good?
Generalization

Compromise

Quadratic boundary – balance complexity and error
Why is pattern recognition difficult?

- Localization / segmentation
- Invariances (normalization not always easy)
- View point
- Occlusion
- Context
- Temporal structure
- Missing features
- Noisy data
- Semantic gap
Challenges: Segmentation

Face detection on hard datasets
competition 2011
http://vast.uccs.edu/FDHD
Challenges: Segmentation

Medical imaging:
- 3D liver tumor segmentation challenge (MICCAI2008)
- prostate segmentation challenge (MICCAI2009)
- 4D cardiac left ventricular segmentation challenge (MICCAI2011)
Challenges: Segmentation

Camera-based text reading:
Challenges: Variations

- **Pose, lighting, expression**
- **Occlusion**
- **Aging**
- **Sketch vs. photo**
Challenges: Variations

Intra-class Variation:

Inter-class similarity:

identical twins
Challenges: Viewpoint

boy + girl ?
Challenges: Semantic gap

Pattern recognition problems that are trivial for us may be quite challenging for automated systems.
World of pattern recognition

supervised
kNN
ANN
decision trees
linear classifier
SVM
rule-based
HMM
Bayes
MCS

unsupervised
clustering
Bag of words
............
Broad world of pattern recognition

Pattern recognition > pattern classification

21st International Conference on Pattern Recognition
November 11-15, 2012
Tsukuba International Congress Center
Tsukuba Science City, JAPAN
Broad world of pattern recognition

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“The real power of human thinking is based on recognizing patterns. The better computers get at pattern recognition, the more humanlike they will become.”

Ray Kurzweil, NY Times, Nov 24, 2003

Pattern recognition is mature and ubiquitous. We are not even aware of many built-in PR solutions.