Christian-Albrechts-Universität zu Kiel

Lecture
„Intelligent Systems“

Chapter 1: Organisation

Prof. Dr.-Ing. habil. Sven Tomforde / Intelligent Systems

Winter term 2020/2021

Before we start …

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Language:

- UniVIS says: The course is held in English.
  → Which language do youu prefer?

Curriculum:

- Which semester are you in?
- Which programme are you studying (Bachelor / Master)?
- Everybody is studying Computer Science?
- For Master-students: Which Bachelor do you hold?
  From which university?
- Do you have any previous knowledge or experiences in the field “intelligent systems” / “machine learning” or “artificial intelligence”?

Contents

- Motivation
- Intelligent Systems group
- Organisational issues
- Train of thoughts for the lecture
- Further readings

Goals

- Understand the schedule and organisation of the lecture
- Get details on lecturers and contact information
- Know which topics and goals are followed by the lecture

Agenda

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- Motivation
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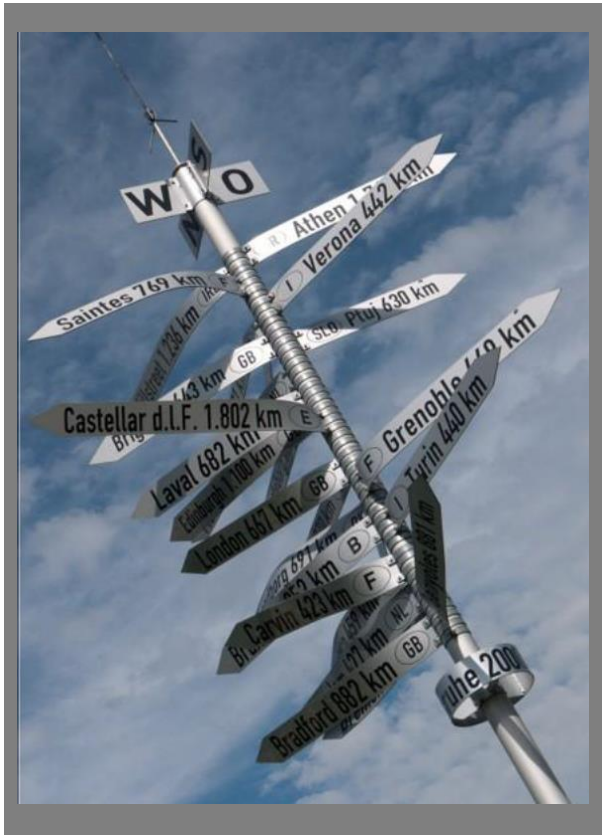

World Wide Web
- Spatially distributed computers/information/services
- Data exchange/access/manipulation

Traffic Control
- Spatially distributed intersections
- Signalisation and coordination

Electric Grid
- Spatially distributed prosumers
- Stability of the shared network

Distributed systems consisting of various autonomous subsystems are everywhere!

Challenges for intelligent systems

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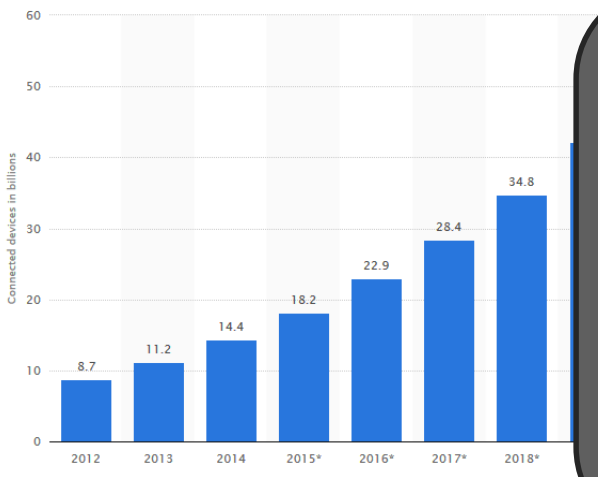
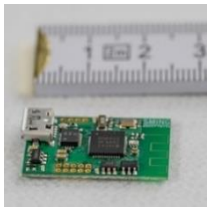
Massively increasing number of interconnected devices



Interconnection:
- Openness
- Unknown cooperation partners
- Mutual influences

Dynamics:
- User demands
- Environmental changes



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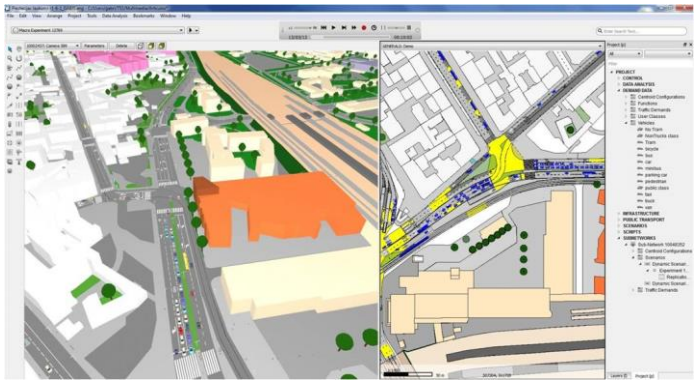
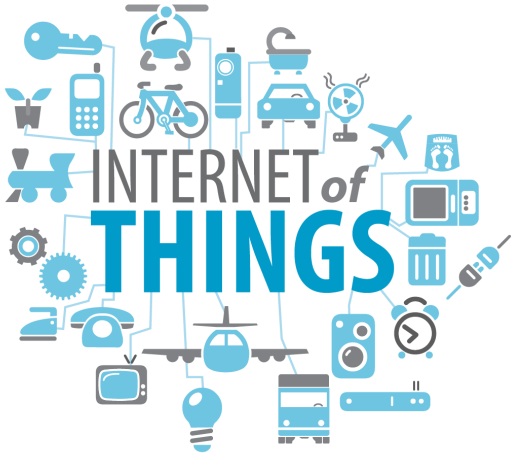
Traffic control



Energy / smart grid

Internet of things



Surveillance networks

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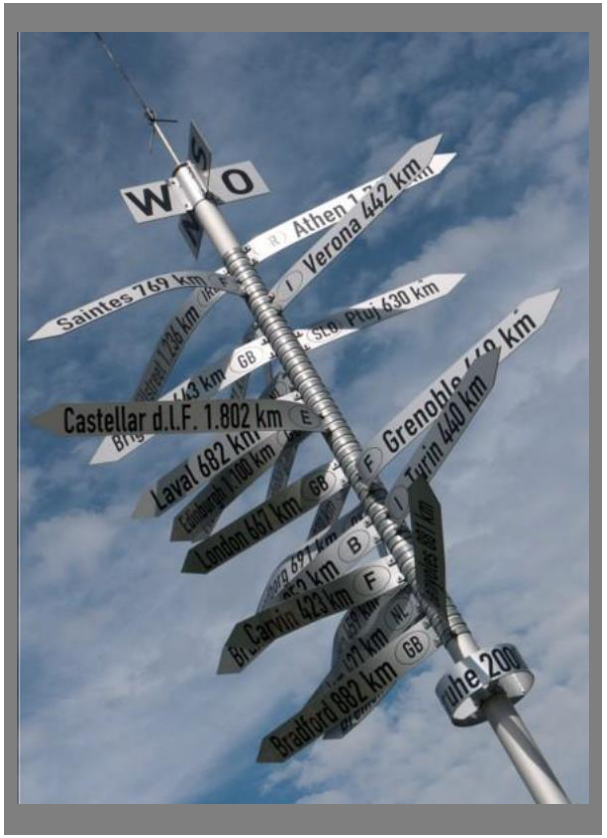

“ What is an
Intelligent System ? “

A computer system that:

- achieves a certain performance even …
  - in time-variant environments
  - in emergent situations
- which is self-adapting and
- improves its own behaviour over time.

What is an “intelligent system“?

- An ”intelligent computer system“ is able to improve its own performance.
- Alternatively: It is at least able to maintain an acceptable goal achievement if unexpected events or other disturbances and uncertainties occur.
- This typically requires that the system is able to autonomously assess its own performance (utility, goal achievement).
- Basis for such a continuous assessment is an ongoing observation, analysis and evaluation of sensor signals at runtime – especially in terms of state analysis, prediction of behaviour, and detection of anomalies.
  → Autonomous behaviour based on learning!

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Intelligent Systems group

- Prof. Dr.-Ing. Sven Tomforde
- Claudia Seewald, MA (secretary)
- Simon Reichhuber, M.Sc. (research assistant)
- Dipl-Inf. Ingo Thomsen (research assistant)
- Torge Storm (lab engineer)

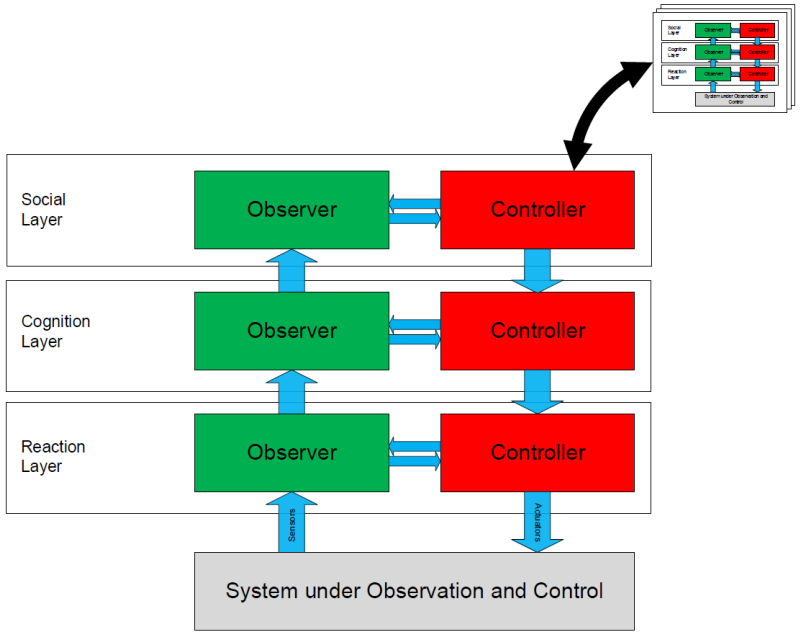
- Ghassan Al-Falouji (external PhD student, OTH Regensburg)
- Michael Meyer (external PhD student, Astyx GmbH)
- Martin Goller (external PhD student, freelancer)
- Ferdinand von Tüllenburg (external PhD student, Salzburg Research)

Research statement

- Goal: development and establishment of intelligent systems and their integration into current teaching (lectures, seminars and internships).
- Focus of the research group:
  - Design and implementation of intelligent, distributed systems that can automatically adapt to changing conditions through learning ability and self-organisation.
  - Means: Development and testing of novel methods in the field of autonomous learning, i.e. independent, opportunistic learning at runtime without (or with only minor, highly efficient) user interaction.
  - The conceptual work is complemented by application-oriented projects in order to demonstrate the practicability of the developed methods.

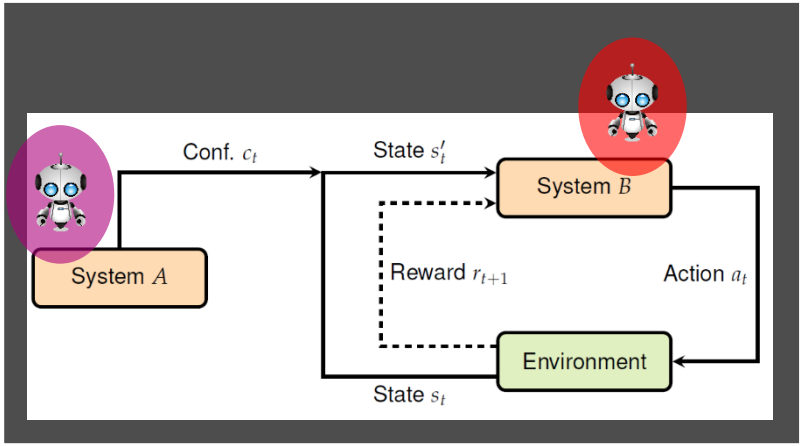
Part 1: Design of intelligent systems

- Architectures of intelligent systems
- Transfer of design decisions to the systems themselves and into the runtime
- Integration of machine learning techniques, security/safety methods, and self-organisation schemes
- Interwoven system structures and self-integration processes of autonomous (sub-)systems



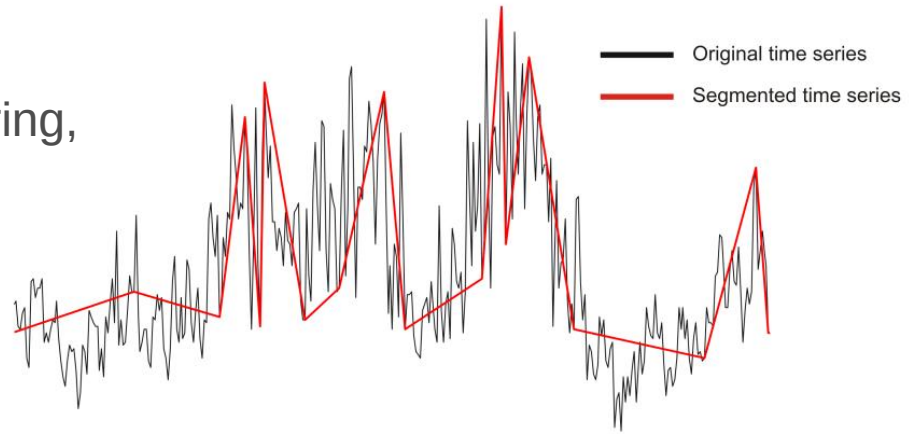
Part 2: Autonomous learning

- Methods for learning at runtime without / with only limited external intervention (of the user)
  - Reinforcement learning (learning from feedback, comparison of observed and expected conditions) based on utility functions
  - Anomaly detection
  - Transfer learning
  - Active learning (actively querying an oracle for knowledge)
  - Collaborative learning



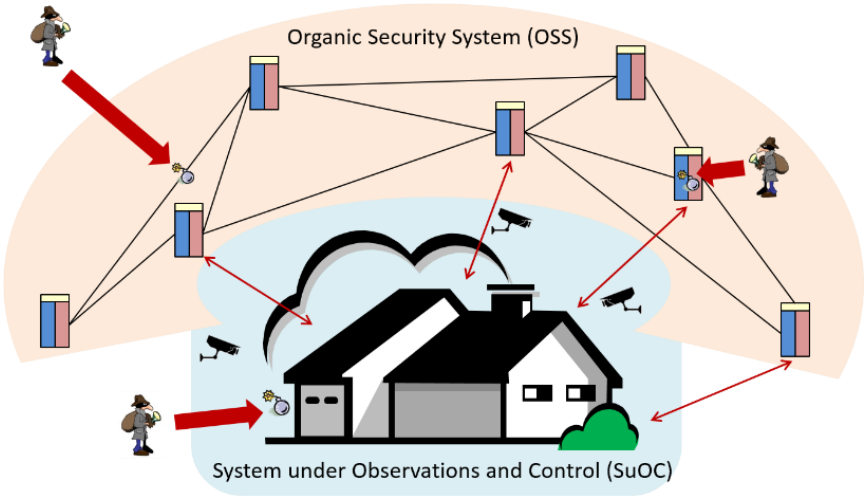
Part 3: Data analysis

- Modelling (representation) and similarity measurement
- Time series segmentation and event detection
- Time series with technical origin (e.g., sensor signals)
- Real-time constraints
- Forecasting, classification, clustering, anomaly detection, …



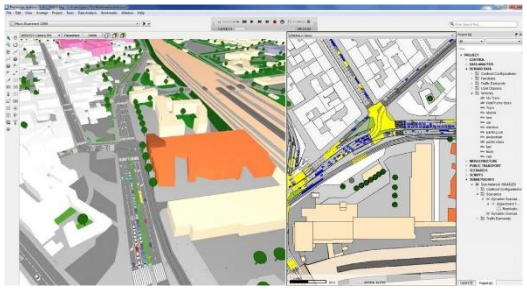
Part 4: Trust and security

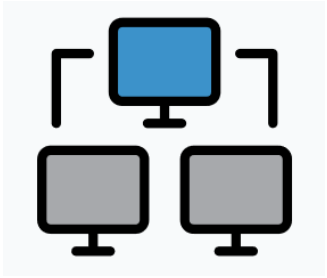
- Techniques for detecting attacks and assessing conspicuous conditions
- Methods for establishing computational trust among autonomous subsystems
- Trust-based system organisation
- Methods for detecting mutual influences
- Security-oriented communication protocols and self-organisation schemes

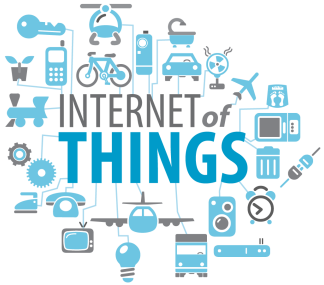


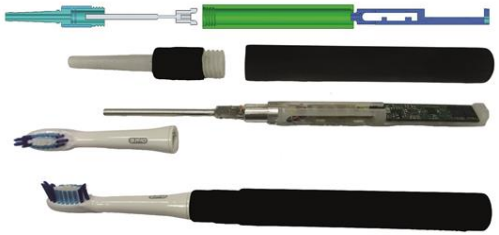
Part 5: Applications

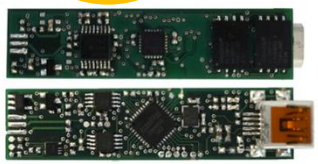
- Traffic control and management
- Data communication networks
- Smart Grid
- Internet of things
- Surveillance networks
- Intelligent devices











Courses of the group in the current term:

- Intelligent Systems (4+2, in English)
- Computational Intelligence (4+2, in German)
- Master project “Intelligent Systems” (team project with Turtle Bots 3)
- Bachelor Seminar “Self-Organised Systems”
- Master Seminar “Deep Learning” (together with Koch/Nowotka)

Courses planned for the next term:

- Autonomous Learning (2+2+2, in English)
- Master project “Intelligent Systems” (team project with Turtle Bots 3)
- Bachelor Seminar “Self-Organised Systems”

Theses

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You are invited to apply for a topics for:

- Bachelor thesis
- Master thesis
- Project work
- …

Our concept is:

- Topics are defined in cooperation with students, including their preferences
- Participate in current research projects
- Participate in scientific publication process if wanted

We also have open positions for HiWis – just ask!

Agenda

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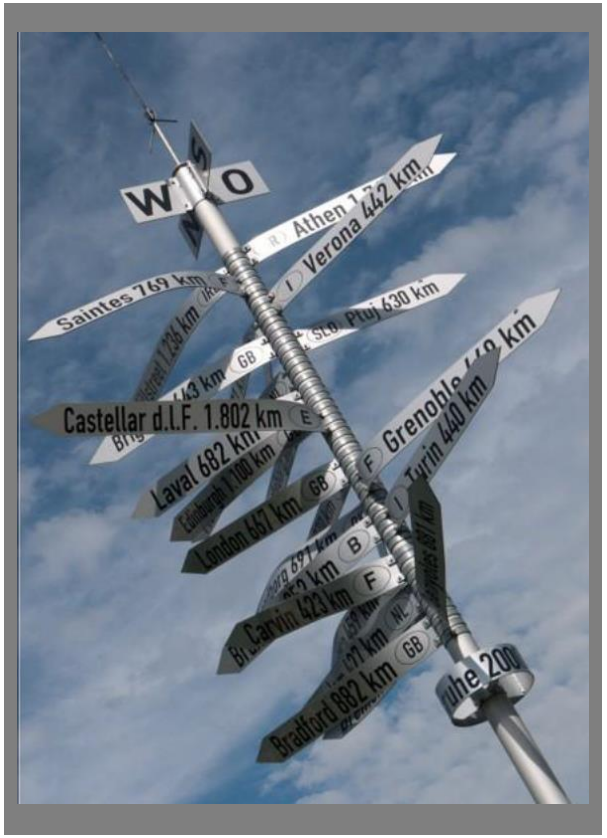

- Teaching method:
  - 4 units lecture
  - 2 units exercises

- Persons:
  - Lecturer:
    Prof. Dr.-Ing. Sven Tomforde
    st@informatik.uni-kiel.de
  - Exercises:
    Dipl.-Inf. Ingo Thomsen
    int@informatik.uni-kiel.de
    Simon Reichhuber, M.Sc.
    sir@informatik.uni-kiel.de

Appointments:

- Lecture:
  - Mondays, 14:15 to 15:45
  - Wednesdays, 12:30 to 14:00
- Exercises:
  - Wednesdays, 10:15 to 11:45

Please also register at studidb (exam)

Materials

- Slides and work sheets in OpenOlat
- Password is “AGINS20”
- Please sign up there (changes in schedule, etc)

Concept of the module

- You will get an overview of many different models and methods of intelligent systems.
- The aim is an introduction with "sufficient" mathematics.
- Focus on linking ideas with formalisation. Means: No continuous, stringent, mathematical notation.
- Course provides tools, methods and best practises for many use cases in further study and practice.
- You will receive the basics and the tools to improve this on your own.
- Course is designed as a lecture with interactive elements (demos, videos, interactions - YOU).

Each chapter follows the same structure:

- Goals and contents of the chapter
- Introduction and motivation
- Contents
- Summary
- Further literature and references (literature references for specific elements from the unit)

Further information about the chapters:

- Slides that invite interaction are marked with a different background colour (orange).
- Used images are either borrowed from e.g. Wikimedia Commons (for licensing reasons) or self-drawn. In the first case, the source is mentioned (hopefully).
- This is version 1 of the slides; empirical observations suggest that the probability of correctness is ≈1, but < 1. Please report errors by e-mail. A corrected version will then be made available to everyone.
- Some of the slide sets are based on the version by Prof. Sick (Uni Kassel), Prof. Müller-Schloer (Leibniz Uni Hannover), and Dr. Rudolph (Uni Augsburg / AUDI)

Interaction slides

1. Binary questions:
   - Who grew up in Kiel?
   - Who grew up in maximum distance of ~20 km from Kiel?
   - Who grew up in Schleswig-Holstein?

2. Questions with short answers:
   - Where do you come from?

3. Interactions in groups / pairs:
   - What did you do in your summer vacation (if you want to tell us)?

4. Open plenary discussions
   - Which is the best programming language / IDE? Why?

Whenever you see the orange boxes, you‘re asked to become active!

Exercises

- Goal:
  - Repeat and intensify content of the lecture
  - Also used for exam preparation
- Follows the lecture
- Check schedule, we may switch / adapt to conditions

- Content:
  - Worksheets
  - Programming tasks
  - Comparison of concepts based on reading articles
  - One major assignment resulting in a “competition” among groups

Assignments

- There will be a three-part task during the semester
- This is to be worked on as a team of 3 students
- It is about the application and experimenting with algorithms and approaches covered in the lecture so far
  - Preprocessing, representation, and visualisation of time series data
  - Feature generation, selection, and transformation of the data
  - Classification/clustering/forecast of the problem
- In addition, there will be three quizzes in OpenOLAT

Important: Successful participation in the assignments is a requirement for taking part in the exam!

This success is already a non-graded part of the exam!

Requirements for participation

- An inherent motivation to work on intelligent systems and machine learning! ;-)
- Successful participation in the assignments (as a team)

Contents

- All topics discussed in lecture and corresponding exercises / lab

Type

- Either oral exam (duration: 25 minutes) or written exam (duration: 90 minutes)
- Date will be announced as soon as possible

Depending on the particular topic, suitable open source or freely available software tools are used to provide support.

Examples include:

- Wolfram Alpha (http://www.wolframalpha.com)
- Jupyter-Notebooks with iPyhton (http://jupyter.org/)
- Netlogo (https://ccl.northwestern.edu/netlogo/)

A reference to the corresponding tools or the corresponding URL can be found in the slides / task sheets.

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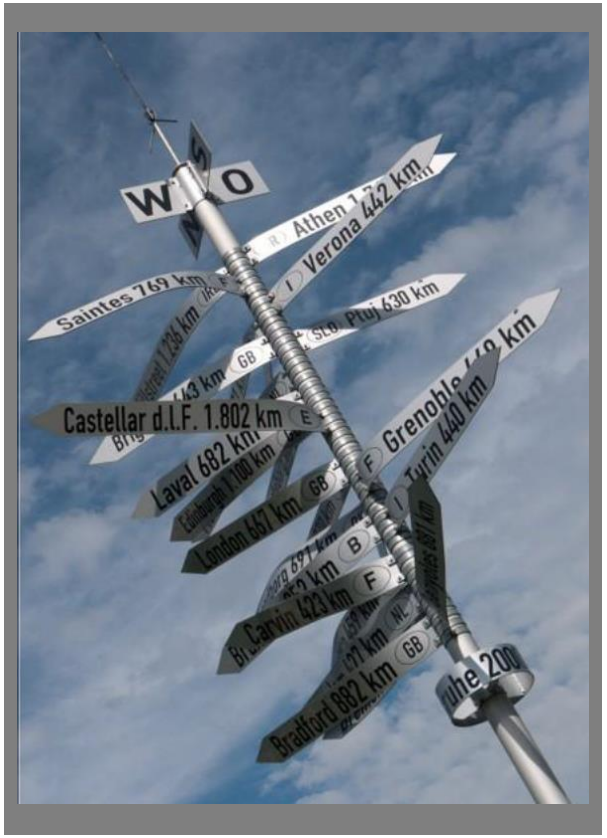

The “storyline” of the lecture

- Motivation
  - Complexity in technical systems
  - Current trends and problems
- General idea of intelligent systems
  - Learning from nature
  - Mastering complexity by means of self-organised order
- How to design intelligent systems?
  - Architectural concept of an individual system
  - Organisation of several autonomous subsystems
- Gathering data
  - Sensor-based systems
  - Time series of measurements as basis for intelligent decisions

The “storyline” of the lecture (ctd.)

- Data “handling” of time series
  - Pre-processing
  - Feature extraction
  - Feature selection
  - Feature transformation
  - Segmentation
  - Similarity between time series
- Learning
  - Clustering
  - Classification
  - Anomaly detection
  - Evaluation

The “storyline” of the lecture (ctd.)

- System analysis
  - Complexity is mastered by self-organised order = emergence
  - Self-organisation means autonomy, goal-oriented behaviour and runtime adaptation
  - Overall goal is to achieve robustness
  - Quantification of these system properties
- Engineering of intelligent systems
  - Based on initial design concepts
  - Basic techniques and methods for controlling intelligent systems
  - Modelling conditions in intelligent systems
  - Learning from feedback
  - Acting in shared environments: mutual influences
  - Collaboration

You may have heard of…

- Multi-agent systems
- Proactive Computing
- Autonomic Computing
- Control theory
- Autonomous learning
- Complex adaptive systems
- Collective systems
- Self-adaptive and self-organised systems
- …

Preliminary outline of the lecture:

- Chapter 1: Organisation
- Chapter 2: Introduction
- Chapter 3: Design of Intelligent Systems
- Chapter 4: Pre-processing
- Chapter 5: Representation / features
- Chapter 6: Similarities of time series data
- Chapter 7: Segmentation
- Chapter 8: Clustering
- Chapter 9: Classification
- Chapter 10: Anomalies

Preliminary outline of the lecture (ctd.):

- Chapter 11: Evaluation
- Chapter 12: Self-organised order
- Chapter 13: Quantification of system properties
- Chapter 14: Model learning
- Chapter 15: Learning from feedback
- Chapter 16: Mutual influences
- Chapter 17: Optimisation
- Chapter 18: Collaboration

… but, well, that is the *current* plan….

Outline

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Lecture (L)		Exercise (E)	
Monday, 02.11.2020	14:15 – 15:45	L 1	f.a.
Wednesday, 04.11.2020	10:15 – 11:45	E 1	f.a.
Wednesday, 04.11.2020	12:15 – 13:45	L 1	Orga
Monday, 09.11.2020	14:15 – 15:45	L 3	Intro
Wednesday, 11.11.2020	10:15 – 11:45	E 2	Intro + Orga
Wednesday, 11.11.2020	12:15 – 13:45	L 4	Design
Monday, 16.11.2020	14:15 – 15:45	L 5	Preprocessing
Wednesday, 18.11.2020	10:15 – 11:45	E 3	
Wednesday, 18.11.2020	12:15 – 13:45	L 6	Preprocessing
Monday, 23.11.2020	14:15 – 15:45	L 7	Assign #1a
Wednesday, 25.11.2020	10:15 – 11:45	E 4	Assign #1b
Wednesday, 25.11.2020	12:15 – 13:45	L 8	Representation
Monday, 30.11.2020	14:15 – 15:45	L 9	Representation
Wednesday, 02.12.2020	10:15 – 11:45	E 5	Preprocessing
Wednesday, 02.12.2020	12:15 – 13:45	L 10	Representation
Monday, 07.12.2020	14:15 – 15:45	L 11	Similarity
Wednesday, 09.12.2020	10:15 – 11:45	E 6	Representation
Wednesday, 09.12.2020	12:15 – 13:45	L 12	Segmentation+Clustering
Monday, 14.12.2020	14:15 – 15:45	L 13	Assign # 2a
Wednesday, 16.12.2020	10:15 – 11:45	E 7	Assign # 2b
Wednesday, 16.12.2020	12:15 – 13:45	L 14	Clustering (Quiz) + TETA

Outline (2)

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Monday, 04.01.2021	14:15 – 15:45	L 15	Classification
Wednesday, 06.01.2021	10:15 – 11:45	E 8	Similarity/Segm.
Wednesday, 06.01.2021	12:15 – 13:45	L 16	Classification
Monday, 11.01.2021	14:15 – 15:45	L 17	Classification
Wednesday, 13.01.2021	10:15 – 11:45	E 9	Clustering
Wednesday, 13.01.2021	12:15 – 13:45	L 18	Anomaly
Monday, 18.01.2021	14:15 – 15:45	L 19	Anomaly
Wednesday, 20.01.2021	10:15 – 11:45	E 10	Classification
Wednesday, 20.01.2021	12:15 – 13:45	L 20	Anomaly
Monday, 25.01.2021	14:15 – 15:45	L 21	Quantification
Wednesday, 27.01.2021	10:15 – 11:45	E 11	Assign # 3b
Wednesday, 27.01.2021	12:15 – 13:45	L 22	Assign # 3a
Monday, 01.02.2021	14:15 – 15:45	L 23	Quantification
Wednesday, 03.02.2021	10:15 – 11:45	E 12	Quantification/Eval.
Wednesday, 03.02.2021	12:15 – 13:45	L 24	RL
Monday, 08.02.2021	14:15 – 15:45	L 25	RL
Wednesday, 10.02.2021	10:15 – 11:45	E 13	RL / Quant.
Wednesday, 10.02.2021	12:15 – 13:45	L 26	Exam preparation
Monday, 15.02.2021	Examination period: no L + E		
Wednesday, 17.02.2021			
Wednesday, 17.02.2021			
Monday, 22.02.2021	Examination period: no L + E		
Wednesday, 24.02.2021			
Wednesday, 24.02.2021			

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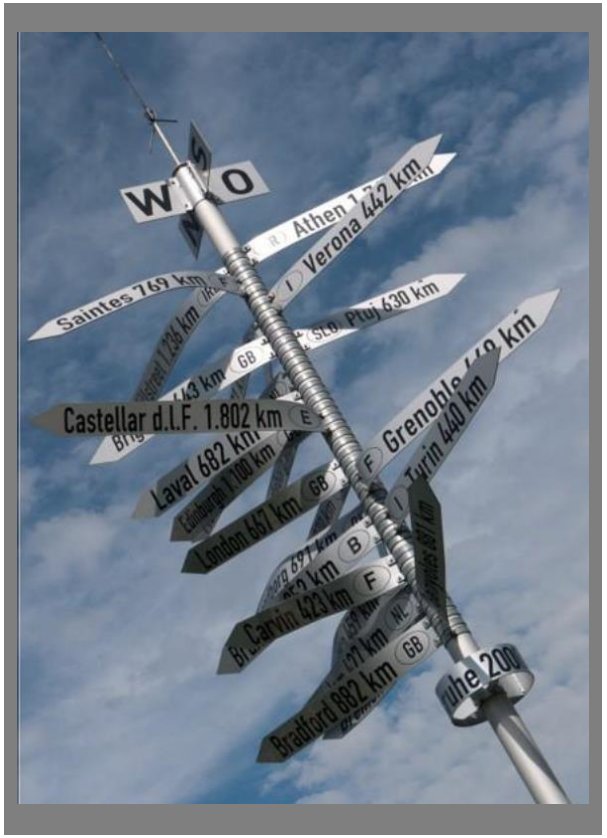
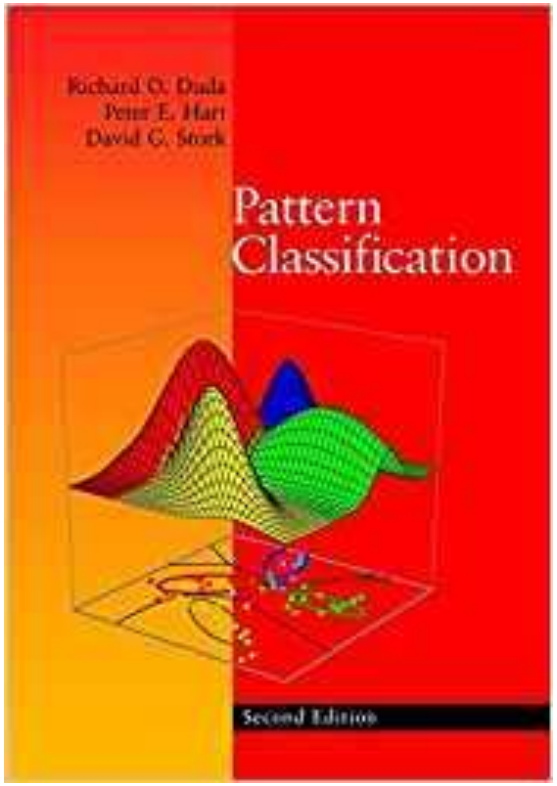


First part of the lecture is based on the book on "Pattern Classification"

- Duda, Richard O., Peter E. Hart, and David G. Stork: "Pattern classification", John Wiley & Sons, 2012, ISBN: 978-0471056690

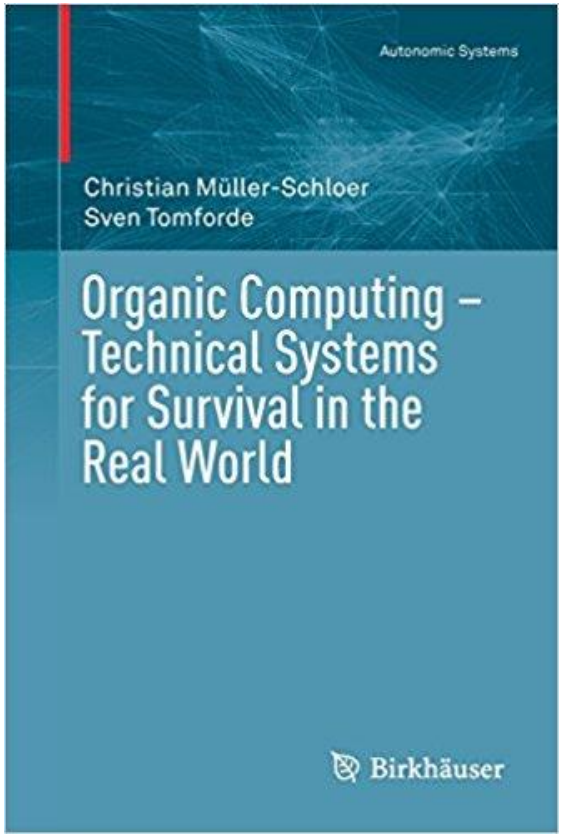


All mentioned books will be available in the computer science library of CAU.

Further readings (2)

Second part of the lecture is based on the current book on "Organic Computing"

- Christian Müller-Schloer and Sven Tomforde: Organic Computing – Technical Systems for Survival in the Real World, Birkhäuser Verlag, Basel, 2018, ISBN 978-3319684765



- Questions…?