Christian-Albrechts-Universität zu Kiel

Intelligent Systems

Chapter 1: Organisation

Winter Term 2019 / 2020

Prof. Dr.-Ing. habil. Sven Tomforde
Institute of Computer Science / Intelligent Systems group

Before we start…

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Language:

- Which language?

Curriculum:

- Which semester?
- Which programme (Bachelor / Master)?
- Everybody studying computer science?
- For Masters: Which Bachelor do you hold? From which university?
- Any prior knowledge or experiences in intelligent systems / Organic or Autonomic Computing / machine learning?

About this Chapter

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Content

- 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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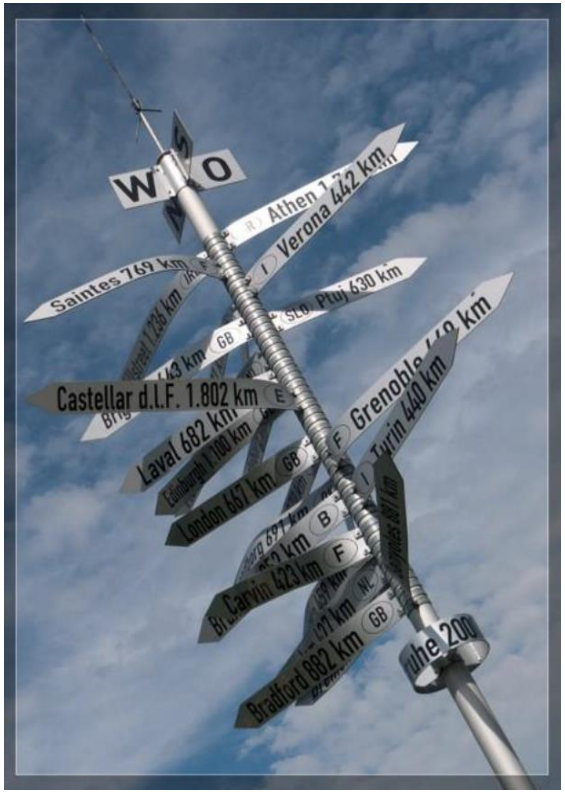

Motivation

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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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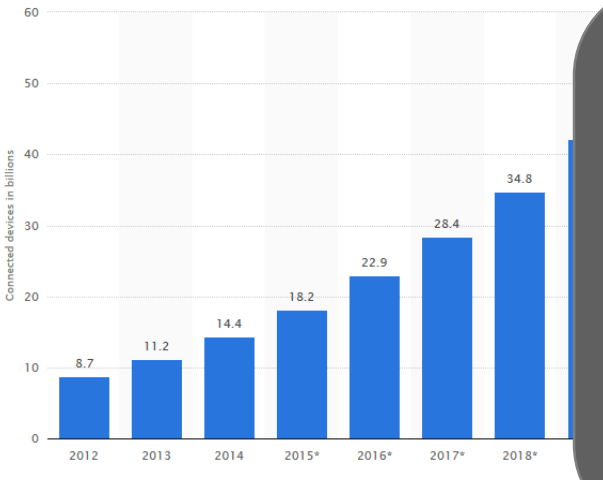
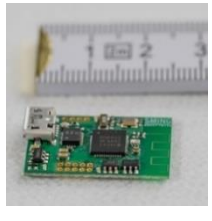


Source: statista.com

Interconnection:
- Openness
- Unknown cooperation partners
- Mutual influences

Dynamics:
- User demands
- Environmental changes



Examples of application scenarios

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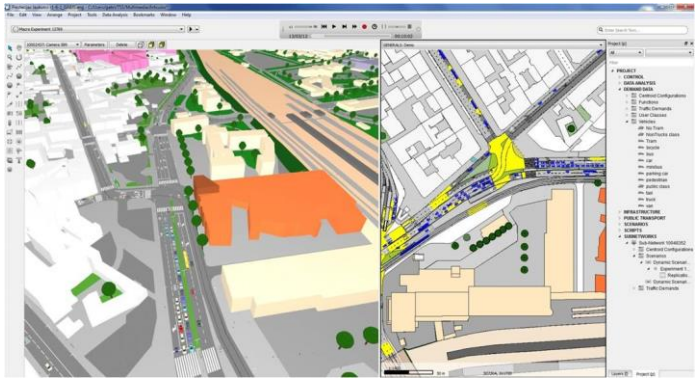
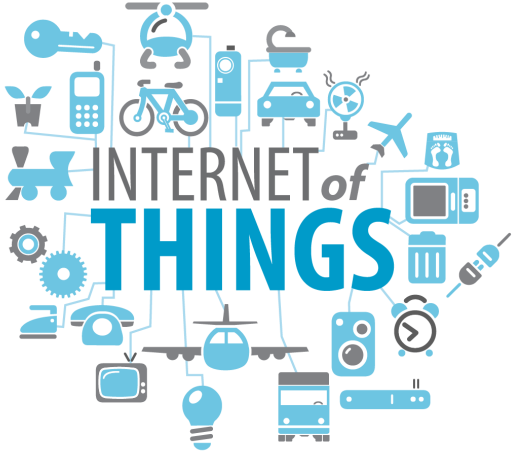
Traffic control



Energy / smart grid

Internet of things



Surveillance networks

Agenda

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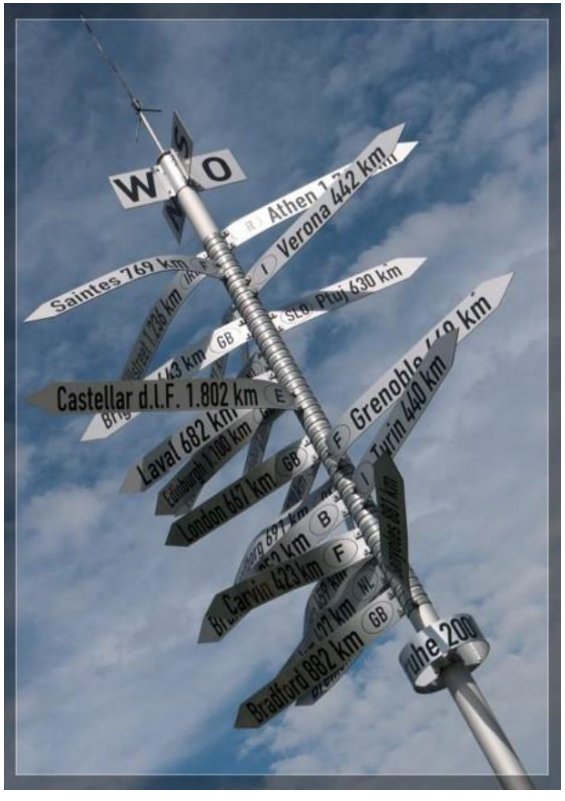

“ What is an Intelligent System ? “

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.

Intelligent Systems (2)

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!

Team

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Intelligent Systems group

- Prof. Dr.-Ing. Sven Tomforde
- NN (secretary)
- Simon Reichhuber, M.Sc. (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

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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.

Research (2)

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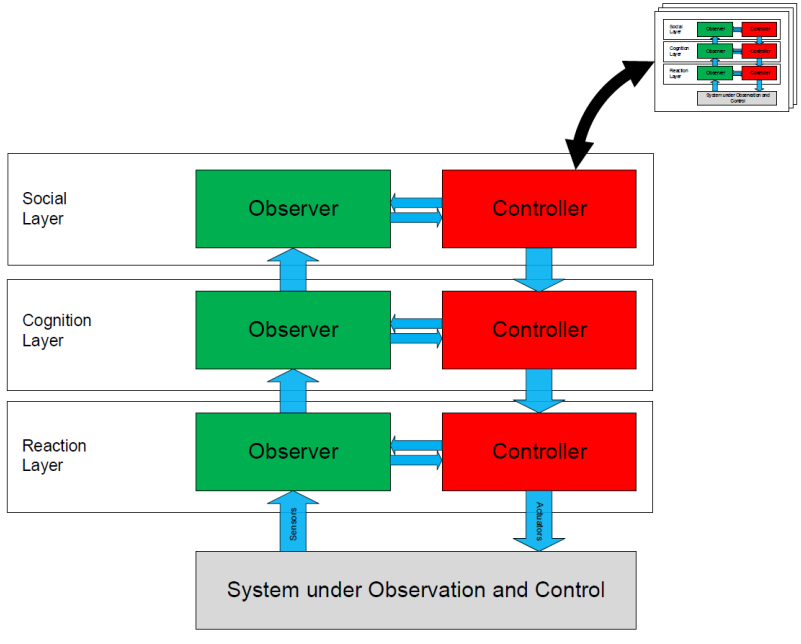
Part 1: Design of intelligent systems

- 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



Research (3)

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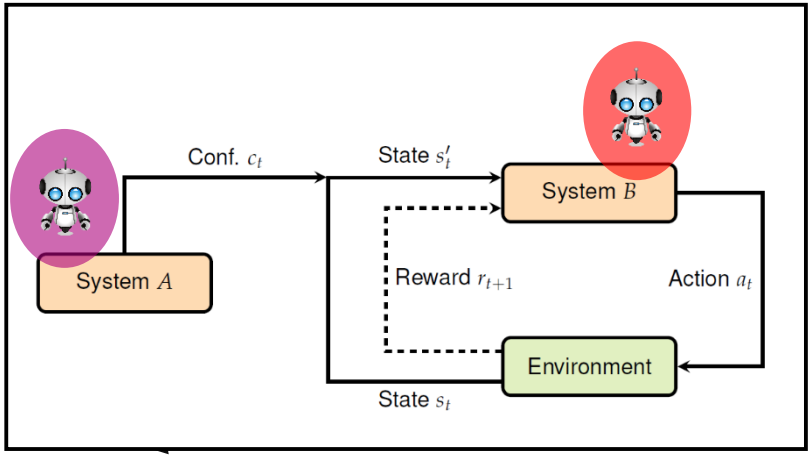
Part 2: Autonomous learning

- 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



Research (4)

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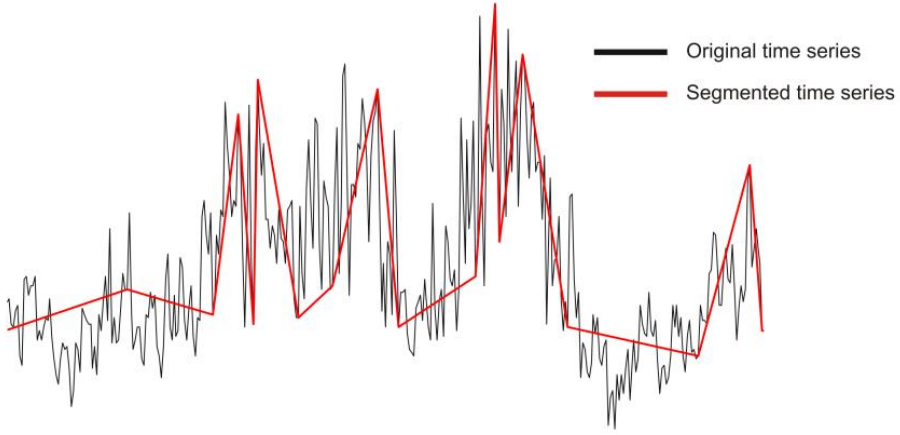
Part 3: Data analysis

- 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, …



Research (5)

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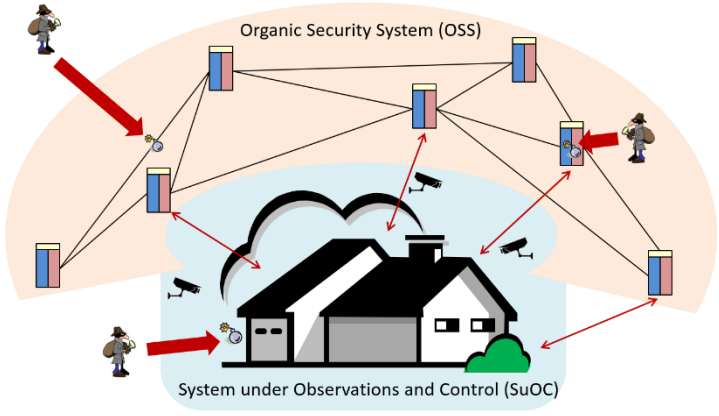
Part 4: Trust and security

- 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



Research (6)

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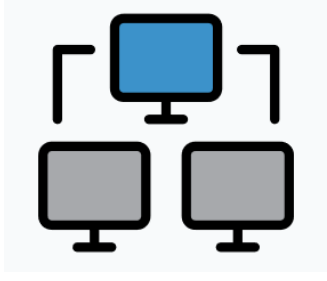
Part 5: Applications

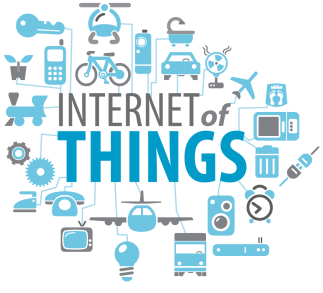
- Traffic control and management

- Data communication networks



- Smart Grid

- Internet of things



- Surveillance networks

- Intelligent devices

Teaching

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Courses of the group in the current term:

- Intelligent Systems (4+2, in English)
- Computational Intelligence (4+2, in German)
- 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)
- tba

Thesis

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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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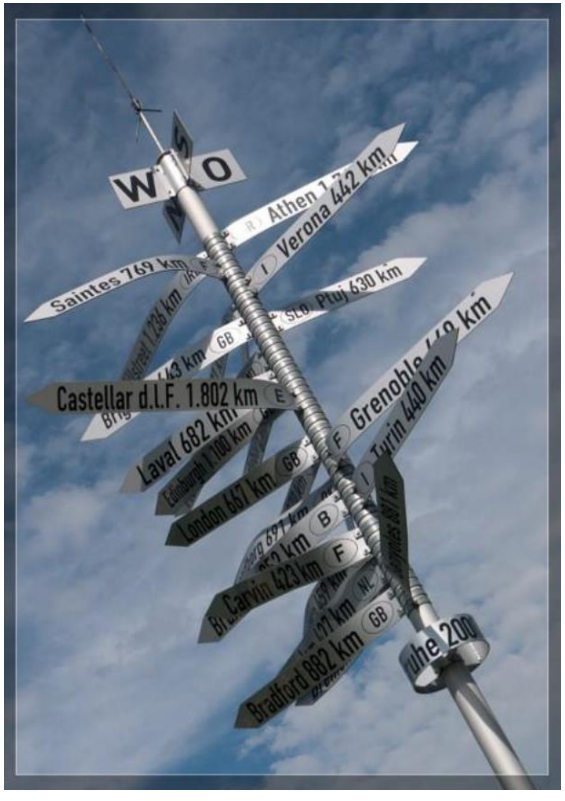

Course “Intelligent Systems“

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

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

Schedule

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Appointments:

- Lecture:
  - Wednesdays, 10:15 to 11:45
  - Thursdays, 12:15 to 13:45
- Exercises:
  - Tuesdays, 14:15 to 15:45

Materials

- Slides and work sheets in OpenOlat
- Password is “INS-2019”, deadline is October 31st
- Please sign up there (changes in schedule, etc)

Concept of the module

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- 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).

Chapters

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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)

Chapters (ctd.)

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Further information about the chapters:

- Slides that invite interaction are marked with a different background colour.
- Used images are either drawn from e.g. Wikimedia Commons (for licensing reasons) or self-drawn. In the first case, the source is mentioned.
- 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

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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

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

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.

Exam

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Requirements for participation

- None
- Besides an inherent motivation to work on intelligent systems and machine learning!

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

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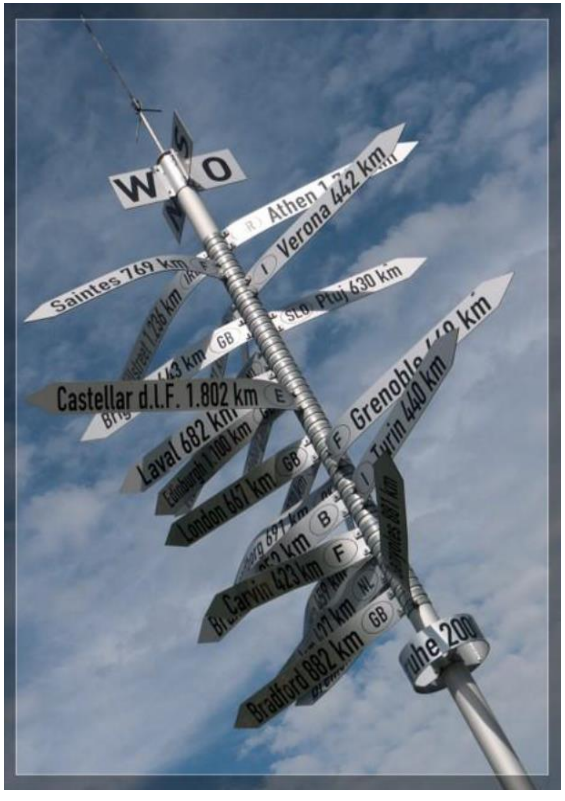

Train of thoughts

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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

Train of thoughts (2)

The “storyline” of the lecture (ctd.)

- Data “handling”
  - Pre-processing
  - Feature extraction
  - Feature selection
  - Feature transformation
- Learning
  - Clustering
  - Classification
  - Evaluation

Train of thoughts (3)

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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
  - Optimisation
  - Collaboration

Related domains

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
- …

Organisation

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Preliminary outline of the lecture:

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

Organisation (2)

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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….

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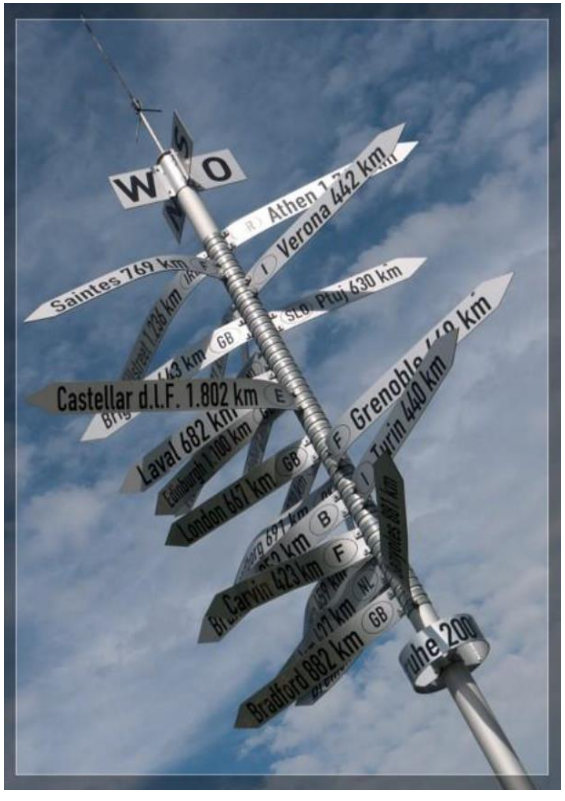
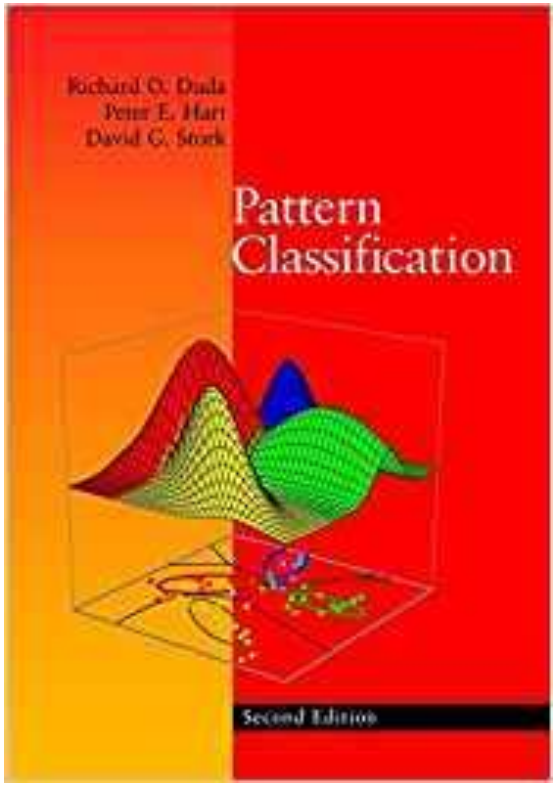


Further readings

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)

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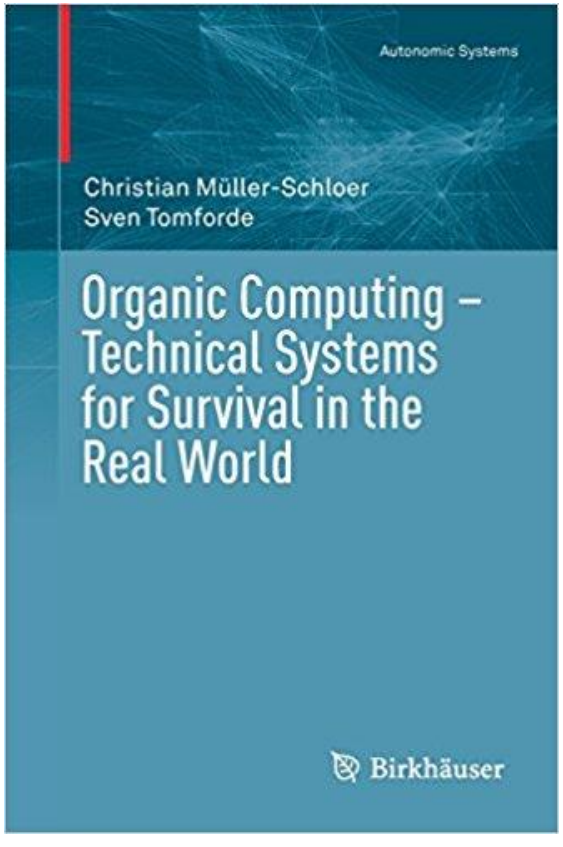
Second part of the lecture is based on the current book on "Organic Computing"

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



Further readings (3)

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Further sources:

- Christian Müller-Schloer, Hartmut Schmeck, Theo Ungerer (eds.): Organic Computing – A Paradigm Shift for Complex Systems, Birkhäuser Verlag, Basel, 2011, ISBN 978-3034801294
- Rolf Würtz (ed.): Organic Computing (Understanding Complex Systems), Springer Verlag Berlin, 2008, ISBN 978-3540776567
- Thomas Mitchell: Machine Learning, The McGraw-Hill Companies, 1997, ISBN 978-0071154673
- Philippe Lalanda, Julie McCann, Ada Diaconescu: Autonomic Computing – Principles, Design and Implementation, 2013, Springer Verlag, ISBN 978-1447150060
- Ethem Alpaydin: Introduction to Machine Learning (Adaptive Computation and Machine Learning). The Mit Press, 3rd revised edition, 2014. ISBN: 978-0262028189.

End

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- Questions….?