Neural Networks
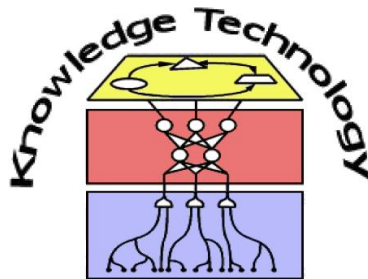
Overview and Introduction

Prof. Dr. Stefan Wermter, Dr. Weber
Knowledge Technology Research Group

http://www.informatik.uni-hamburg.de/WTM/

Neural Computing: The brain as the most exciting inspiration for computing

"Man is still the most extraordinary computer of all." [John F. Kennedy 1963]

… but only because of neural computing in the brains in humans

Motivation for this module

- To provide an insight into building neural architectures for intelligent systems

- To give examples of intelligent system architectures in cognitive robotics, natural language processing,….

- To provide introduction and deepening in neural networks

- To provide background and basis for possible undergraduate or postgraduate projects, MSc and PhD studies

- Research-informed teaching mode on neural networks

Module delivered in English

- Module in Int. MSc. Intelligent Adaptive Systems

- International education gets more and more important for research, industry, business...

- ...from international schools to colleges and universities

- We want to help students to prepare for a career in industry or academia with an international English language element

- Most relevant computer science literature in English

- Slides will be in English and we deliver this module in English

Logistics

- **Lecture**
  Thursday 10:15, D-220

- **Seminar** presentations
  - Suggested as a block
    on Aug 8-9.8, 11-12.8

- Examinations: verbal in English or German,
  tentative 22.7, 5.8, 15.9, 16.9 (Wermter, Weber)

- You can take this
  - as a single module (**Vertiefung *Master Informatik*, Core lecture *Master Intelligent Adaptive Systems*)** ...
  - or as part of the **Integriertes Anwendungsfach Neuroinformatik**

Your Choice!
Will be discussed
after this lecture

Integrated Subject "Neuroinformatics"

- http://www.informatik.uni-hamburg.de/WTM/teaching/IAFNeuroInformatics.shtml

Neuroinformatik I				
Lecture	Allgemeine Psychologie	Jonas, Kao	WS, Tue 14-17,	Audimax 2
Lecture	Bio-inspired Artificial Intelligence	Wermter	WS, Thu 10-12	D-220
Integrated Seminar	Bio-inspired Artificial Intelligence	Magg, Wermter	WS, As a block	D-220
Neuroinformatik II				
Lecture	Biopsychologie	Bruns	**WS**, Wed 10-12 Mon 14-16 (2nd w.)	Audimax 1, Erzwiss H
Lecture	Neural Networks	Wermter	SS, Thu 10-12	D-220
Integrated Seminar	Neural Networks	Weber, Wermter	SS, As a block	D-220

- The Examination for Neuroinformatics II will include all courses.

IAF "Neuroinformatics" 2: Biopsychology

■ ***Should have been heard last semester!***

- Will be offered again next winter semester
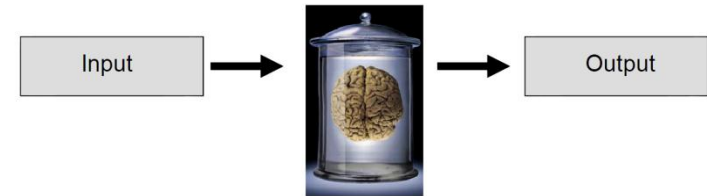
■ Topics:

- Neurons, action potential, synapses, anatomy
- Qualitative and quantitative methods
- Visual and auditory systems
- Vestibular, gustatory and olfactory systems
- Somatosensory and sensorimotor systems
- Plasticity and lateralisation
- Sleep, emotions, and stress
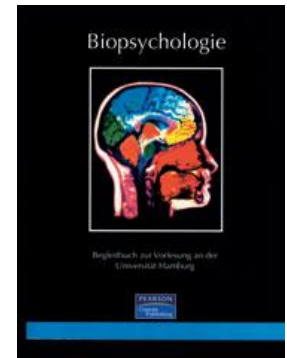
Remarks about slides

- These slides/notes are meant to facilitate access

- They are "pointers" to the learning

- Slides are not meant to replace text books or journals

A bit about us…

- Joined the University of Hamburg in 2010

- Head of Knowledge Technology Group

- Main research interest in Neural and Hybrid (Neural Symbolic) Knowledge Technology

- Previously at

  - University of Sunderland, UK

  - ICSI / University of California, Berkeley, USA

  - University of Hamburg

  - University of Massachusetts, USA

The challenge: building neurocognitive agents ...

Agents need to reason, communicate, learn and develop many complex tasks…

How to do it? Rule-Based Systems?

- Use rules to represent knowledge in an **IF…THEN…** form or more complex formalisms

- Use an "inference engine" to **chain the rules** together in different ways

- Allows the ability to **explain decision** by tracing which rules are used and when

- Strict symbolic logic rules alone may be brittle… extensions for learning and robustness possible?

Fuzzy Logic

- Based on human reasoning which is imprecise

- Uses a "membership function" to describe how strongly something belongs to a group

- Membership functions can be learned adaptively using for instance neural techniques

- Leads to interesting hybrid neural symbolic architectures

Fuzzy Sets

- The notion of membership in fuzzy sets becomes a matter of degree (real number in the closed interval [0,1])

- Membership of an element in fuzzy set is measured by a *function that attempts to describe vagueness*
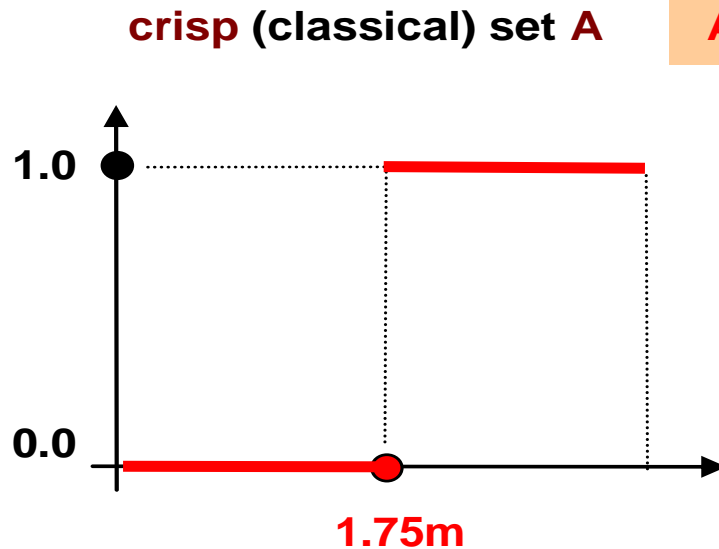
crisp (classical) set A   **A = set of TALL people**   **fuzzy set A**
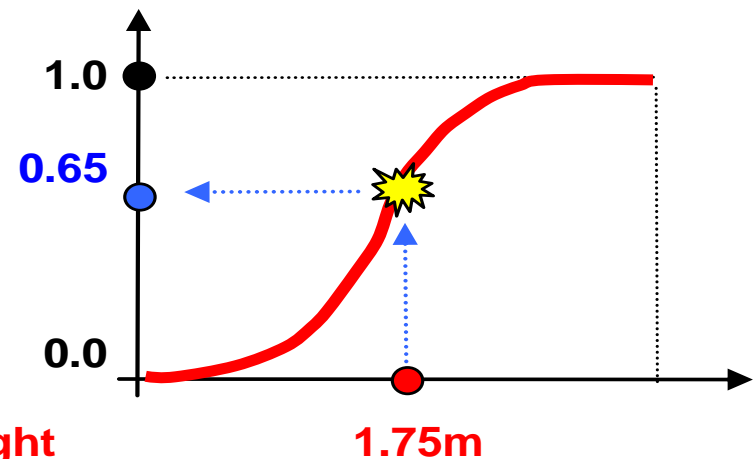
Statistical Methods

- Allow for the incorporation of prior knowledge into decision making models

- Provide an answer to a problem in terms of probability of an outcome

- Robust and consistent

- Assumptions to be made about distribution functions etc (not always this information is available)

Knowledge Representation in Bayesian Networks

Diagnostic: From symptoms to causes. Reasoning occurs in opposite direction to network arcs

Predictive: Reasoning from new causes to new effects, follows the directions of the networks arcs

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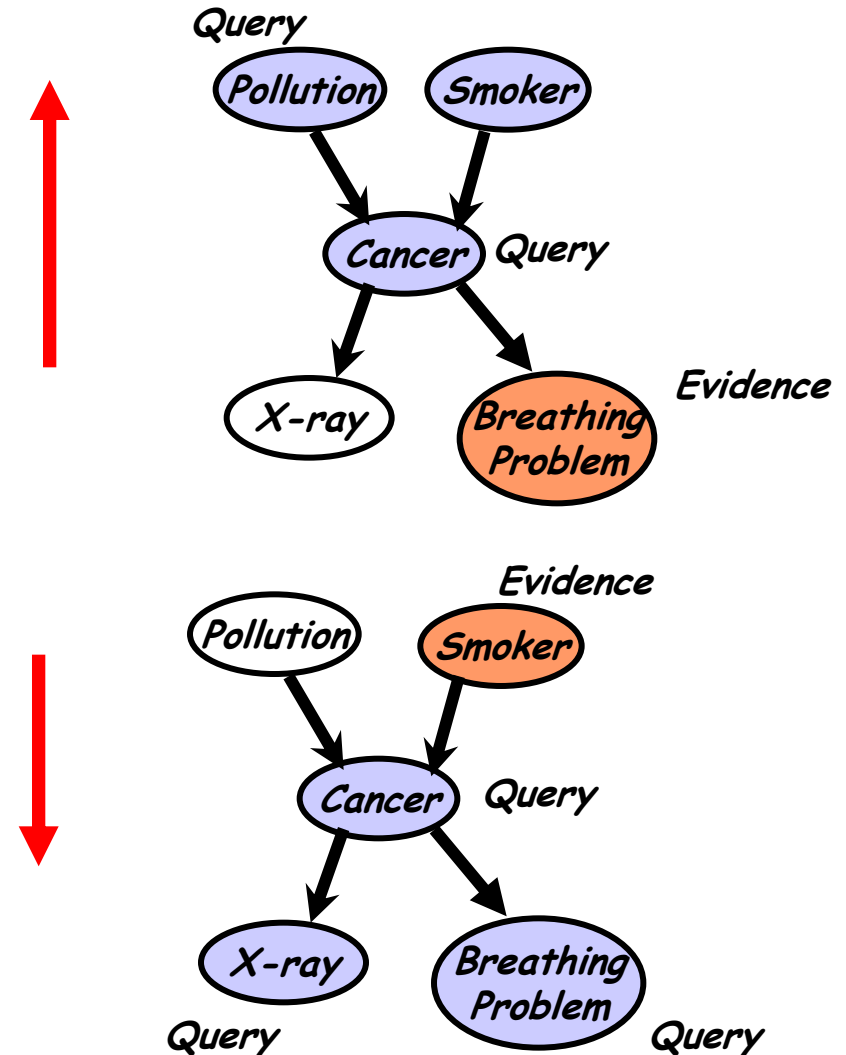
Focus in this Module: Neural Networks

- Use a simple mathematical model of a brain cell

- Many neurons connected together in a layered structure - a network

- Weights between neurons adjusted to learn mappings of inputs to outputs

- Powerful pattern recognition and generalisation technique
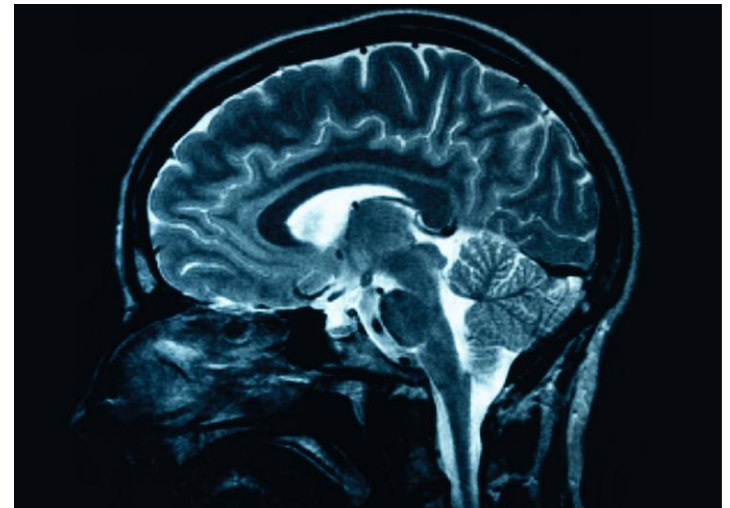
Integration into Hybrid Systems

- The neurocognitive view

    - Neural networks in the brain compute all intelligent behaviour

    - Neural networks are therefore key start to understand intelligent processing

    - Higher cognitive tasks, like reasoning and language are characterised by some form of symbolic processing

- The knowledge engineering view

    - Integration of these techniques

    - Often more powerful than any single technique

    - Often part of a larger, integrated system

Motivating questions… or how to make a coffee

- How is it possible to bridge the large gap between neural network processing in the brain and intelligent performance of humans?

- How is it possible to build more effective systems which integrate neural techniques into intelligent systems?

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Approach: Hybrid Processing for Learning Cognitive Agents

- Symbolic knowledge and planning
- Fast encoding and manipulation
- Interpretable knowledge and rules

- Reactive behavior
- Neural connectionist learning
- Robustness

- Embodied bioinspired computation
- Neuroscience and plasticity
- Spatiotemporal integration
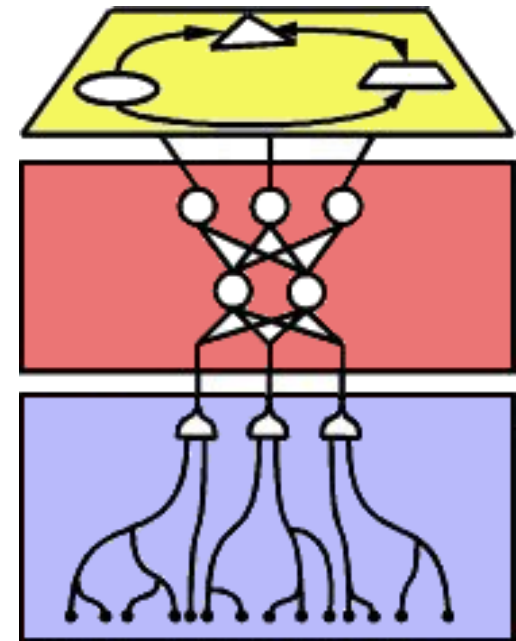
One of our Neurocognitive Platforms in Knowledge Technology

Voice synthesis

Emotions

Embedded CPU with Wi-Fi

LiPo battery

25 Degrees of Freedom

Digital camera

Voice recognition

Swapable head

Prehensive hands

Run Linux OS

23 inches
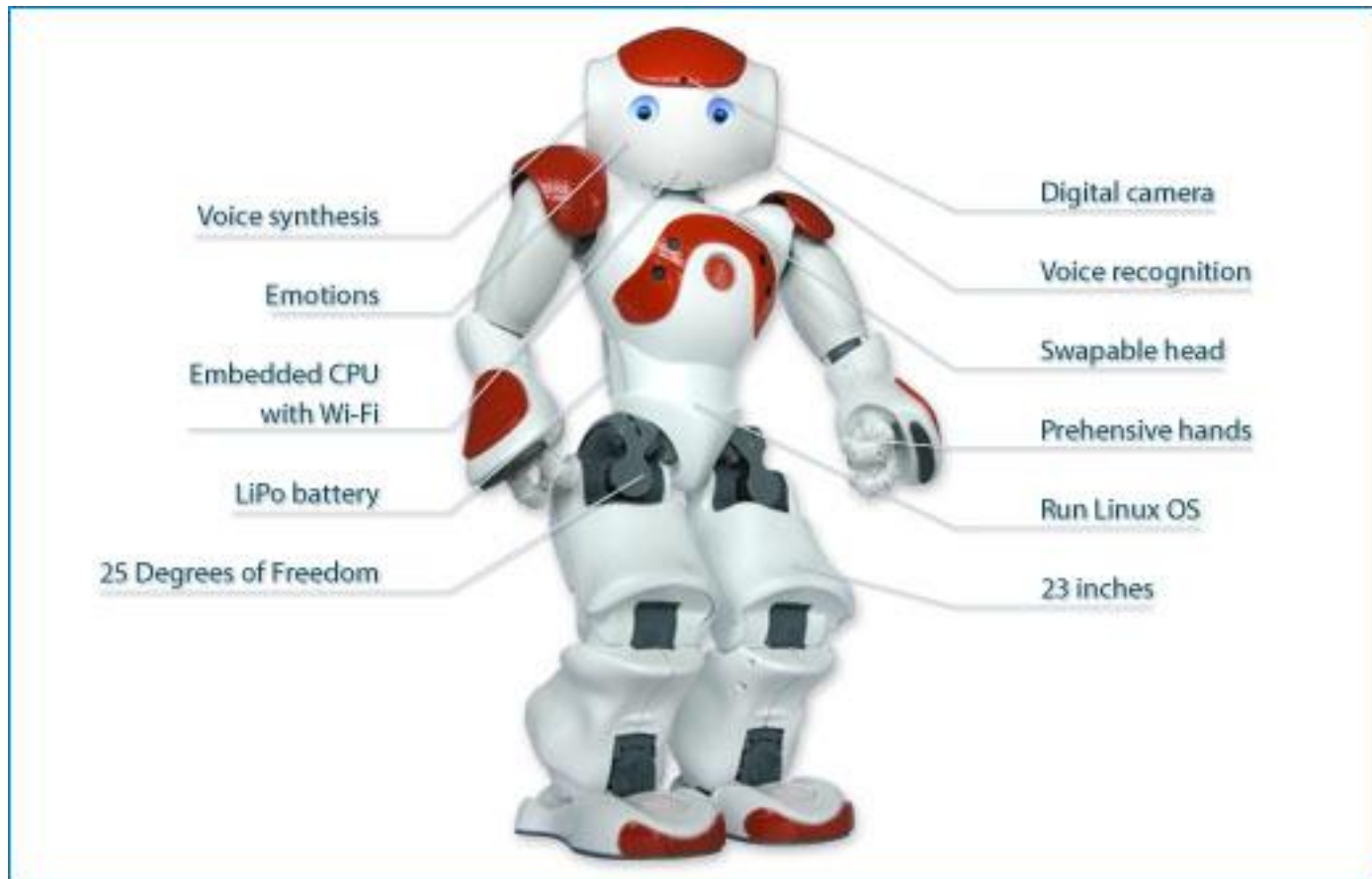
Some initial robotic answers…
or how to make a coffee

- How is it possible to bridge the large gap between neural network processing in the brain and intelligent performance of humans?

- How is it possible to build more effective systems which integrate neural techniques into intelligent systems?

Research methodology
for better neural models

- Collect neurocognitive data

  ↓

- Identify architectures and develop computational models

  ↓

- Train and evaluate the robot/agent to perform actions e.g. based on visual perception and language input

  ↓

- Feed back results to end users or patients (with psychologists etc.)

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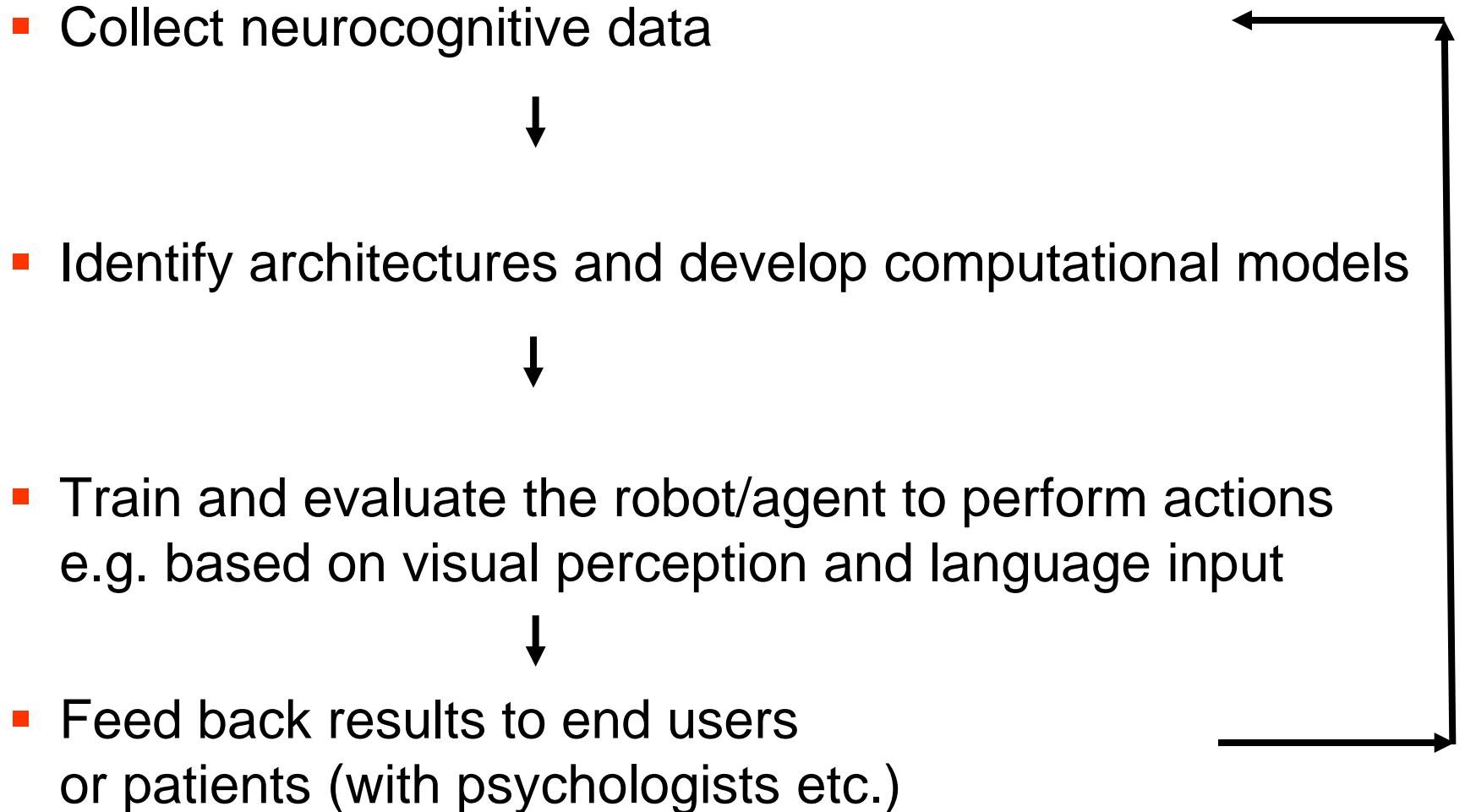
Introduction and topics of the module

- Overview of hybrid knowledge representation

- Neural networks introduction

- Learning in multilayer and recurrent networks

- Localist, distributed learning and shape recognition

- Neural network architectures

- Hybrid architectures

- Neuroscience-inspired architectures

- MLP, SOM, SRN, ESN, CNN Architectures

- Bioinspired robotic architectures

- …

General literature background

- Haykin S. Neural networks and learning machines. Prentice Hall, 2008.

- Rojas R. Introduction to Neural Networks. Berlin: Springer, 1996. (free online)

- Marsland, S. Machine Learning: An Algorithmic Perspective. Chapman & Hall. 2009.

- Wermter S., Sun R. 2000 Hybrid Neural Systems. Springer Verlag, Heidelberg, 2000.

- Wermter S., Riloff E., G. Scheler (Ed). Connectionist, Statistical and Symbolic Approaches to Learning for Natural Language Processing Springer Verlag, Berlin, 1996.
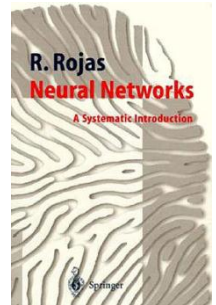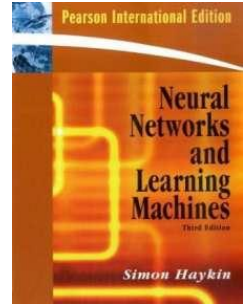
MIN-CommSy page
and apply for membership ...

... to get the slides and recent announcements.

Summary

- Traditional approaches and knowledge representation approaches have mainly focused on symbolic representations

- Objective is to examine the foundations, representations and applications of neural systems

- Newer hybrid symbolic/neural/statistical approaches can be more nature-inspired

- Drawing inspiration from biological systems, neural systems or cognitive performance

Link and topics for the Seminar
(Dr. Cornelius Weber)

- Neuroscience-inspired architectures

- Spiking neural networks

- Midbrain / Cortical architectures

- Mirror neuron theory

- Neuroscience-inspired robotics

- Hybrid representations in natural language processing

- Hybrid representations in robotics

- Multimodal integration

- Integration of symbolic, neural and statistical approaches

- Neural networks and language processing