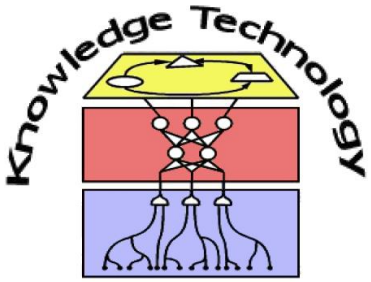
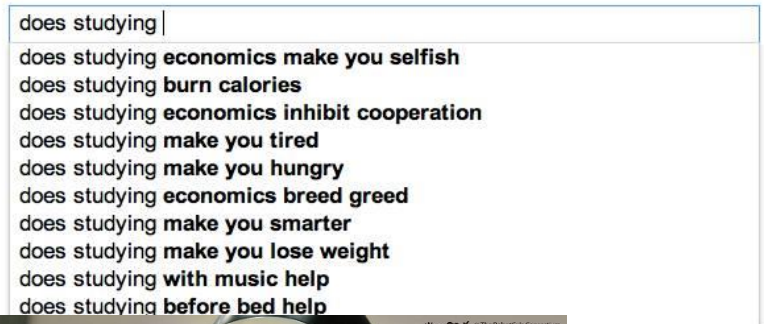
Neural Networks

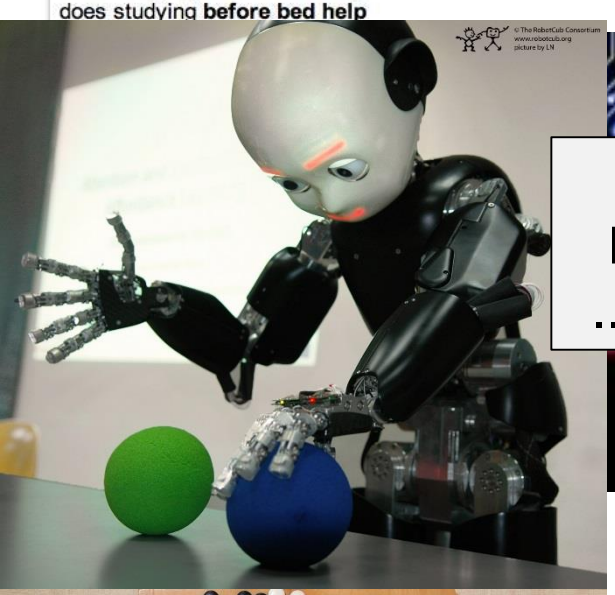
Lecture 1: Overview and Introduction

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

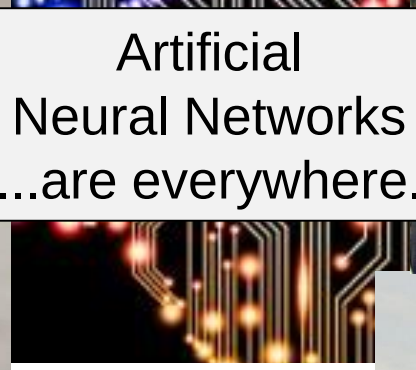


http://www.informatik.uni-hamburg.de/WTM/





Artificial
Neural Networks
...are everywhere.



…inspired by our own brain and mind

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

"The new century of the brain."
[Yuste, Church]

"Best examples for intelligent systems can be found in the brain."
[Wermter]

"Nobody phrases it this way, but I think that artificial intelligence is almost a *humanities* discipline.

It's really an attempt to understand human *intelligence* and human *cognition*."

[Sebastian Thrun]

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
  - As 2-4 blocks around Jul/Aug
- Examinations: verbal in English or German, July / September (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”

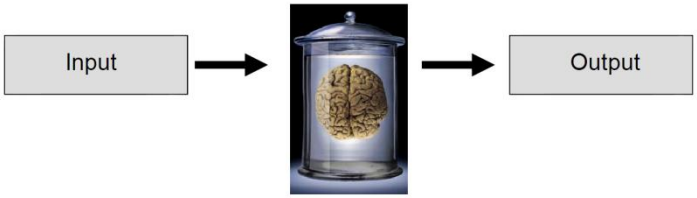
- https://www.inf.uni-hamburg.de/en/inst/ab/wtm/teaching/teaching-iaf-neuroinformatics.html

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	Wermter, Alpay	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

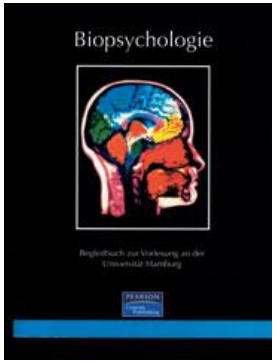
- The Examination for Neuroinformatics II will include all courses.

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



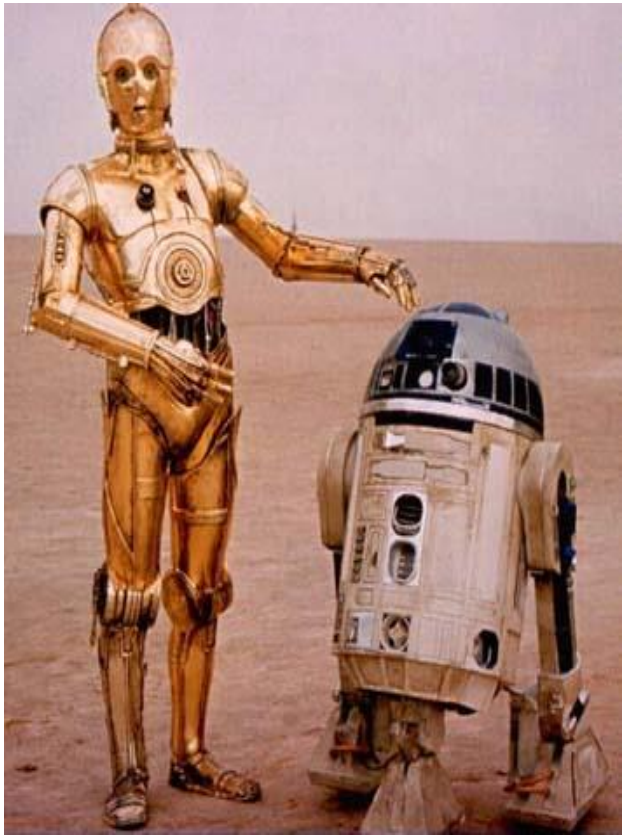
Remarks about slides

- 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…

- Knowledge Technology Group
  - www.knowledge-technology.info
- Prof Wermter started the team at the University of Hamburg in 2010
- 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 / Dortmund
  - 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?

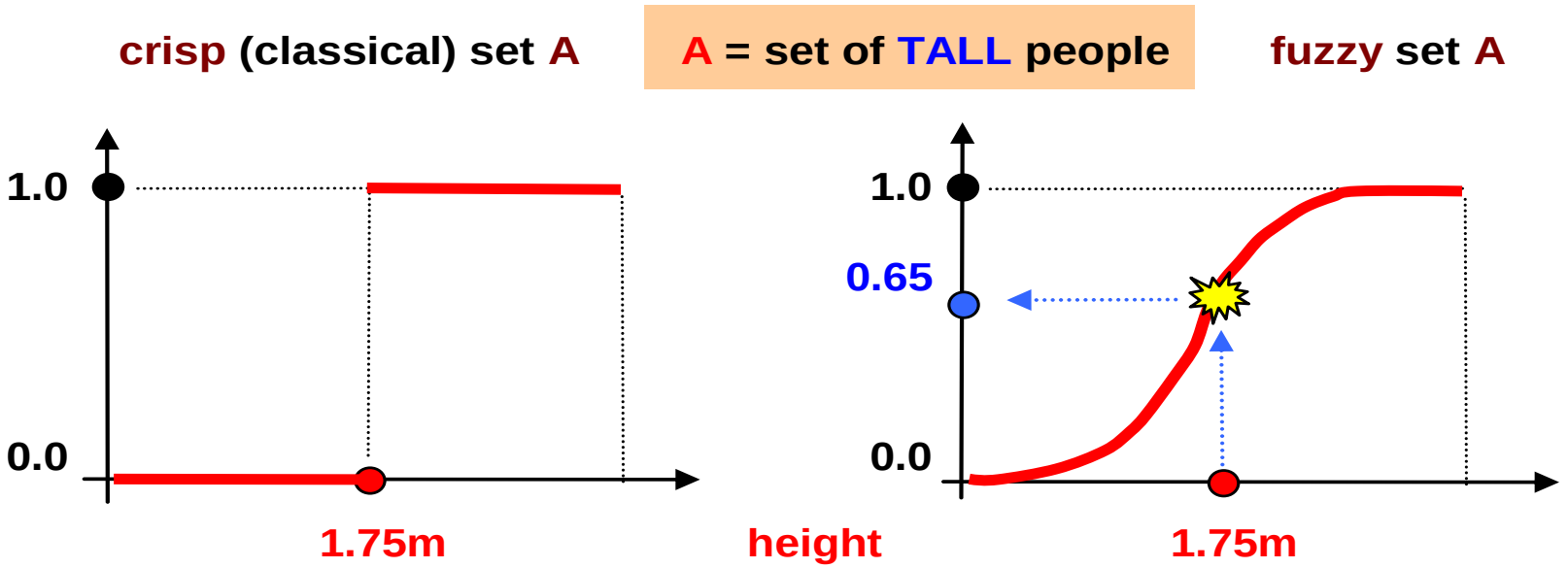
- Use rules to represent knowledge in an IF…THEN… form or more complex formalisms
- Use an “inference engine” to chain the rules together in different ways
- Allows the ability to explain decision by tracing which rules are used and when
- Strict symbolic logic rules alone may be brittle… extensions for learning and robustness possible?

Making strict symbolic reasoning more flexible: Fuzzy Logic

- Based on human reasoning which is imprecise, incomplete
- 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 powerful 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*

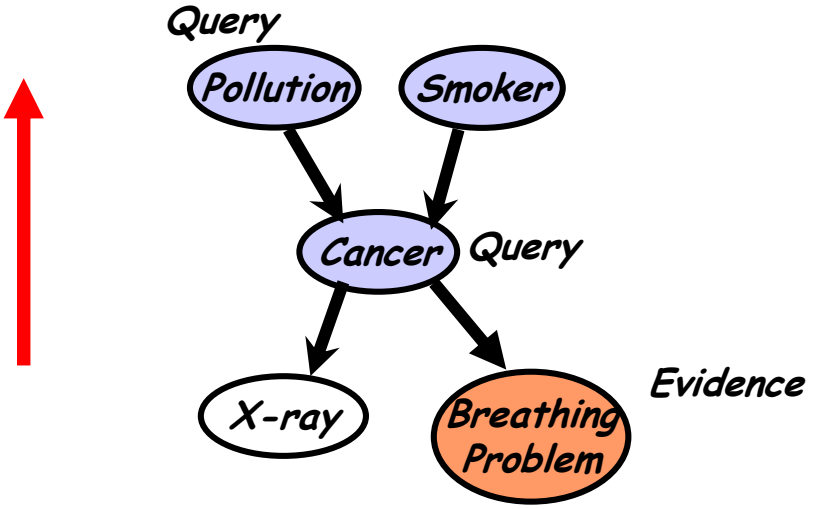


Statistical Methods

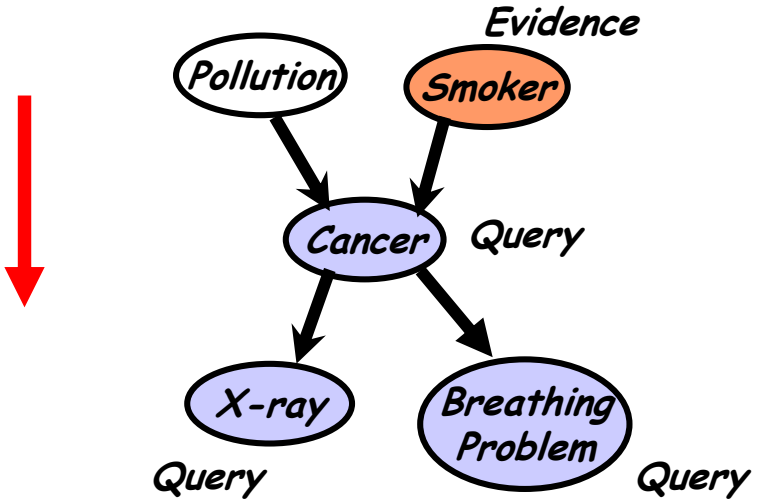
- Allow for the incorporation of prior knowledge into decision making models
- Provide an answer to a problem in terms of probability of an outcome
- Robust and consistent
- Assumptions to be made about distribution functions etc (not always this information is available)

Hybrid Knowledge Representation e.g. in Bayesian Networks

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

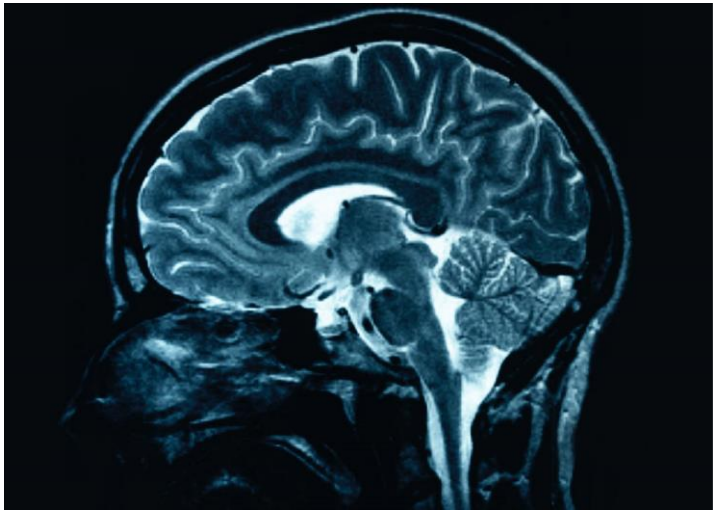


Predictive: Reasoning from new causes to new effects, follows the directions of the networks arcs



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 techniques



A favourite Example for these approaches:

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 in Hybrid Neural Systems

- The neurocognitive view
  - Neural networks in the brain compute all intelligent behaviour
  - Neural networks are therefore key to model neurally or cognitively observed behaviour

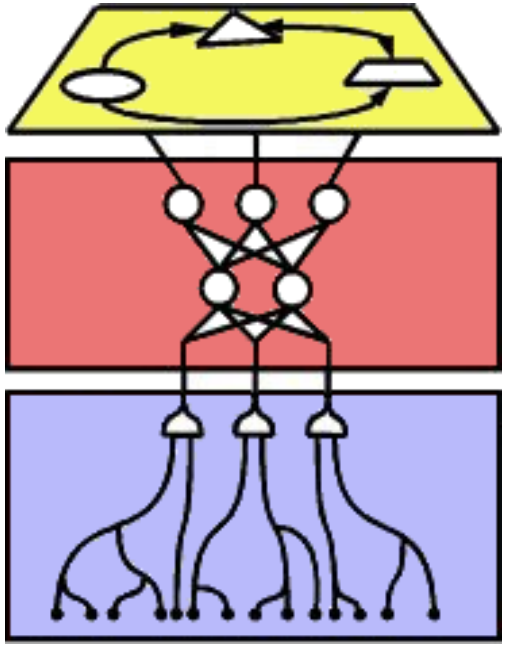
- The knowledge technology view
  - Intelligent systems need both symbolic architecture processing and graded robust learning with neural networks
  - Integration of these techniques since often more powerful than any single technique
  - Neural networks are often part of a larger, integrated intelligent system (e.g. NICO, iCub, Alexa, Siri…)

Approach in our team: Neural Processing for Learning Cognitive Agents

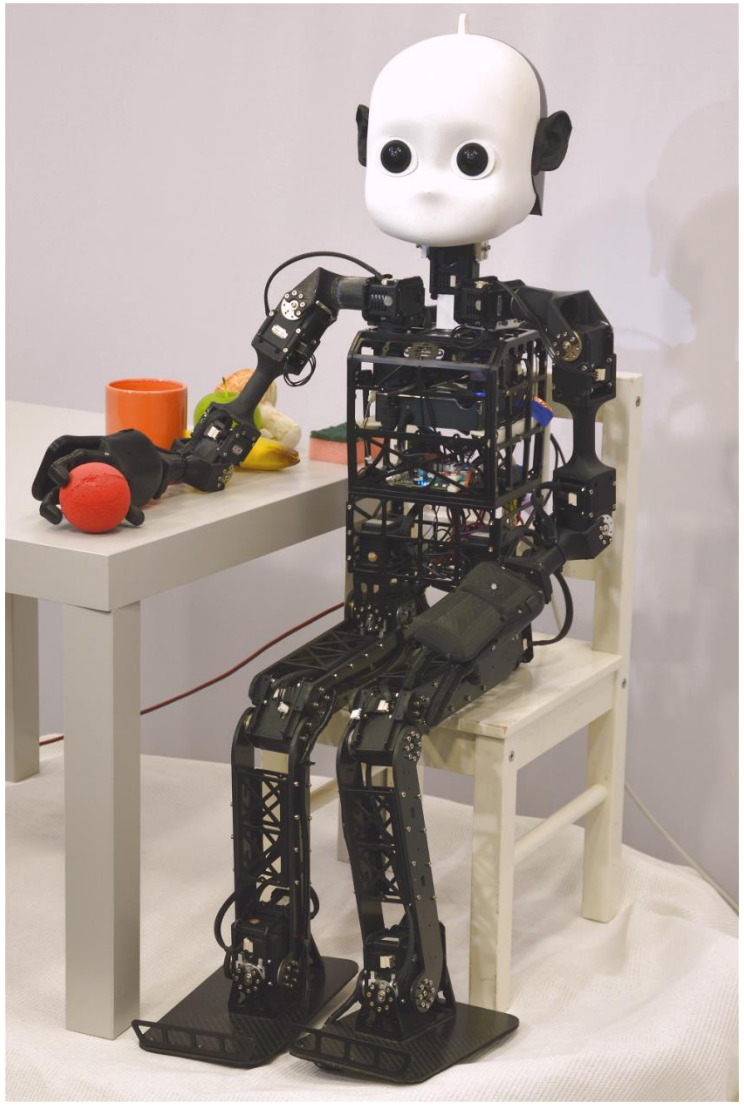
- Symbolic knowledge and planning
- Fast encoding and manipulation
- Interpretable knowledge and rules

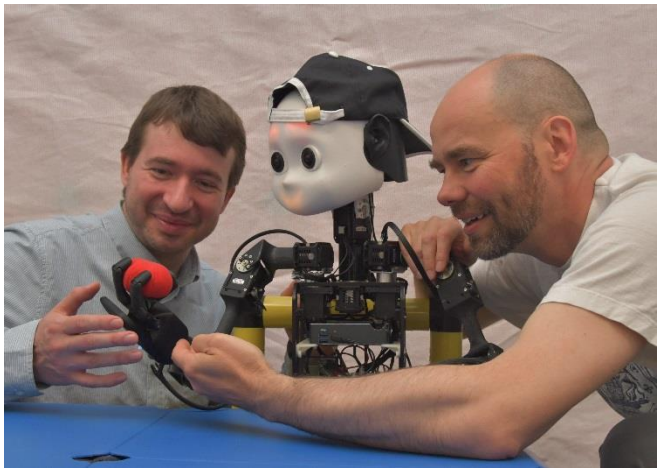
- Reactive behavior
- Neural connectionist learning
- Robustness

- Embodied bioinspired computation
- Neuroscience and plasticity
- Spatiotemporal integration

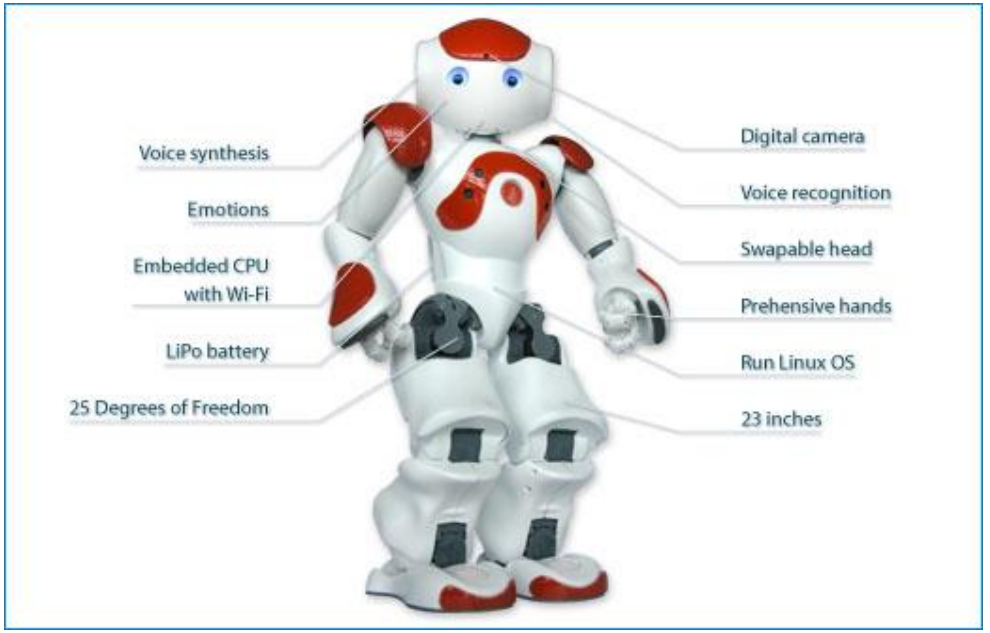


Some of our Neurocognitive Platforms in Knowledge Technology for the Real World





left: NICO
bottom: NAO



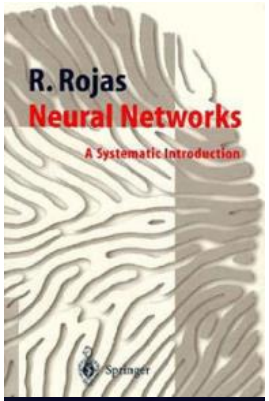
On national TV

Introduction and topics of the module

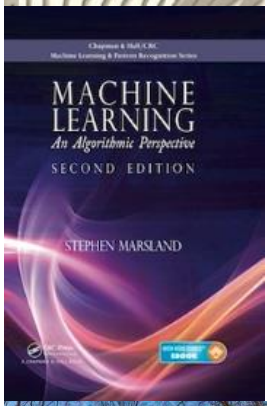
- Overview of hybrid knowledge representation
- Neural networks introduction
- Learning in multilayer and recurrent networks
- Localist, distributed learning and shape recognition
- Neural network architectures
- Neuroscience-inspired architectures
- MLP, SOM, RNN, ESN, CNN Architectures
- Deep Learning
- Bioinspired robotic architectures
- …

General literature background

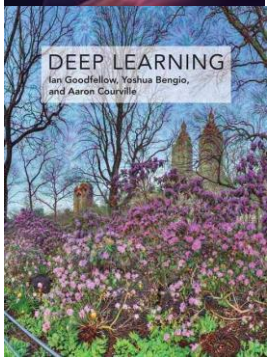
- Rojas R. *Introduction to Neural Networks.* Berlin: Springer, 1996. (free online)
  page.mi.fu-berlin.de/rojas/neural



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

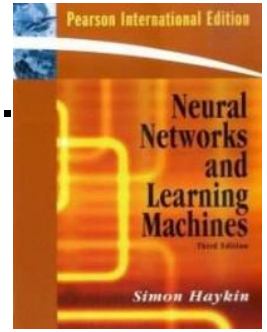


- Goodfellow I., Bengio Y., Courville A.*:*
  Deep Learning.
  MIT Press, 2016. (free online)
  www.deeplearningbook.org

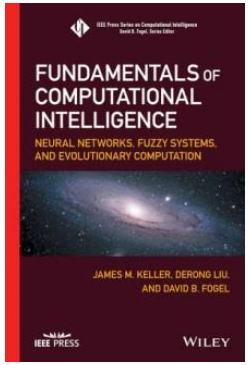


Further Reading (Foundations)

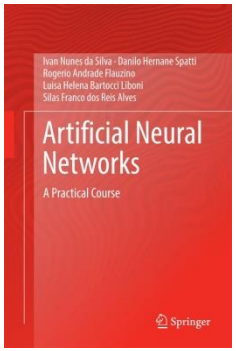
- Haykin S. *Neural Networks and Learning Machines*. Prentice Hall, 2008.



- Keller, J.M. et al.: *Fundamentals of Computational Intelligence: Neural Networks, Fuzzy Systems, and Evolutionary Computation.* (Chapt. 2,3,4,5) Wiley-IEEE Press, 2016. [1]



- Da Silva I. N., et al.
  Artificial Neural Networks – A Practical Course.
  Springer International Publishing, Switzerland, 2017



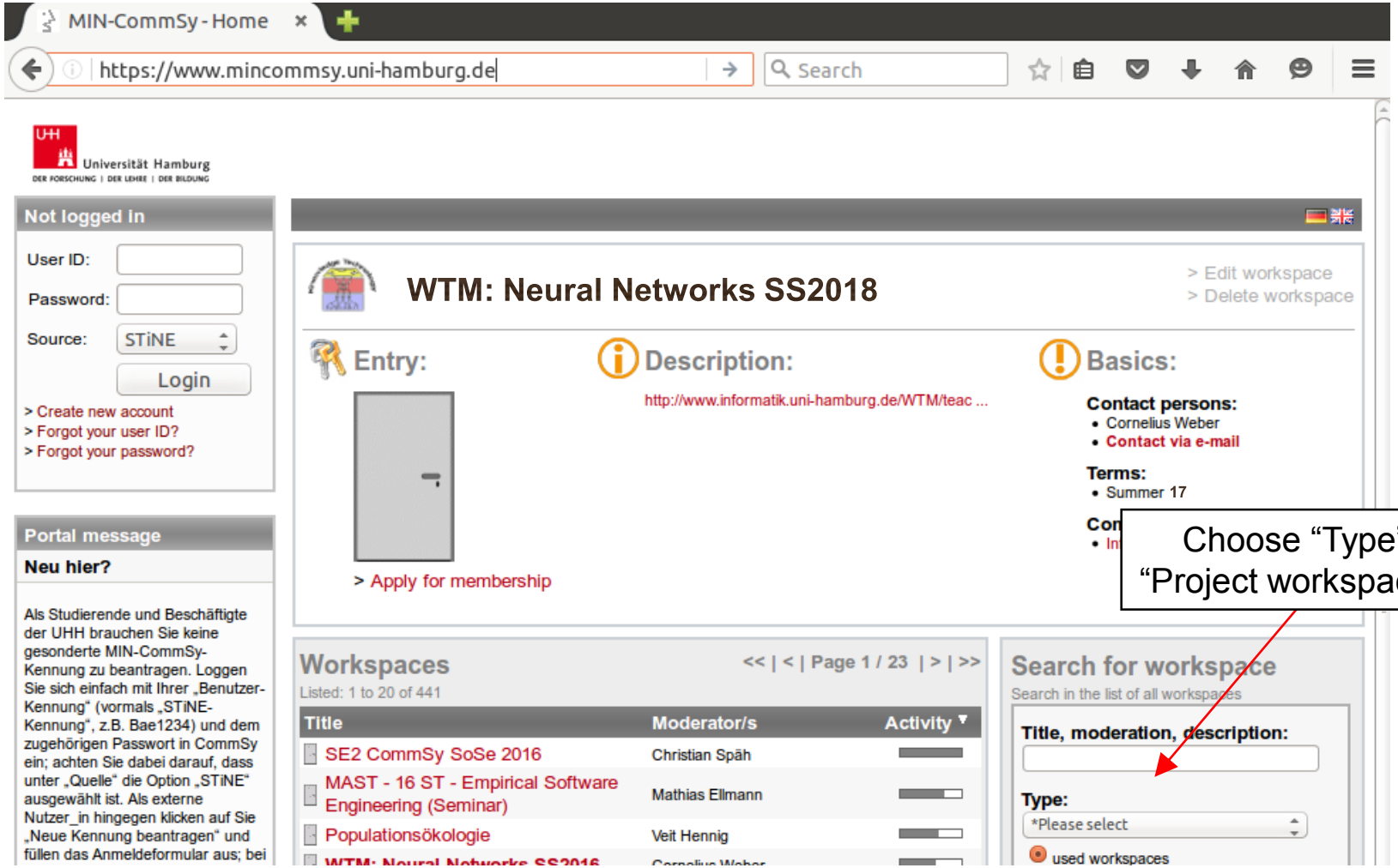
[1]: kataloge.uni-hamburg.de/DB=1/XMLPRS=N/PPN?PPN=868258822

Further Reading (Seminar/Research)

- Wermter S., Sun R. *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.

MINCommSy: Apply for membership (I)



https://www.mincommsy.uni-hamburg.de/room/10623387

MINCommSy: Apply for membership (II)

Changing Language:
Name-Icon > Account >
> Zusatzfunktionen > Sprache

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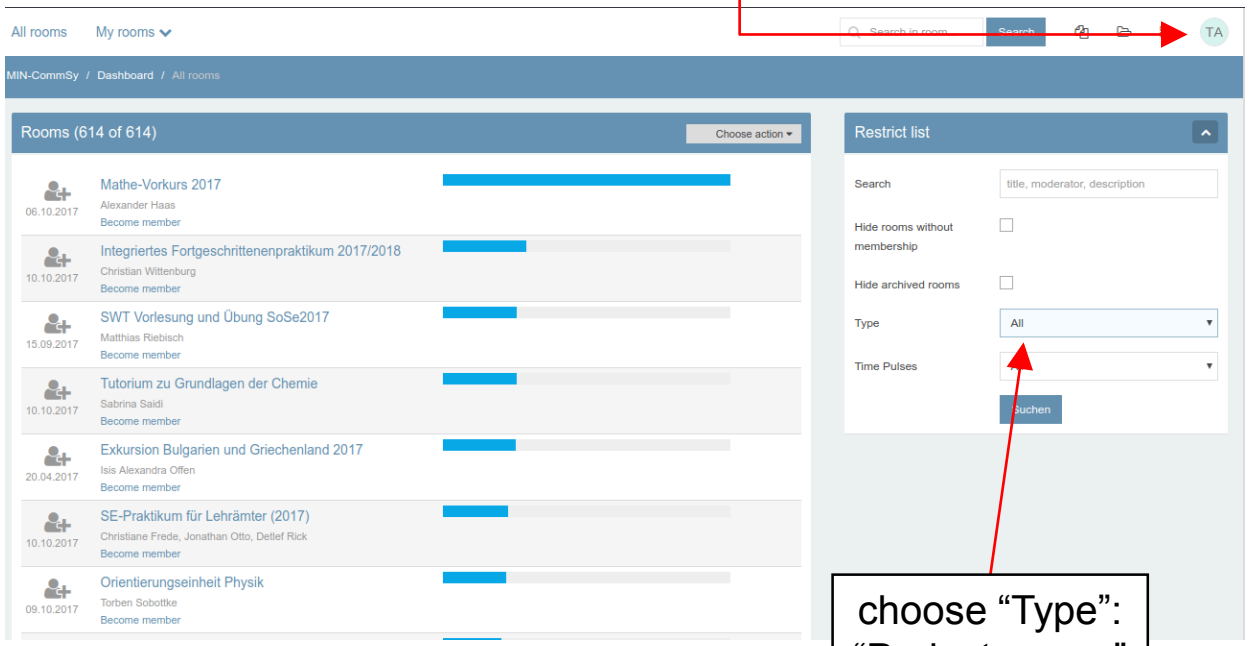
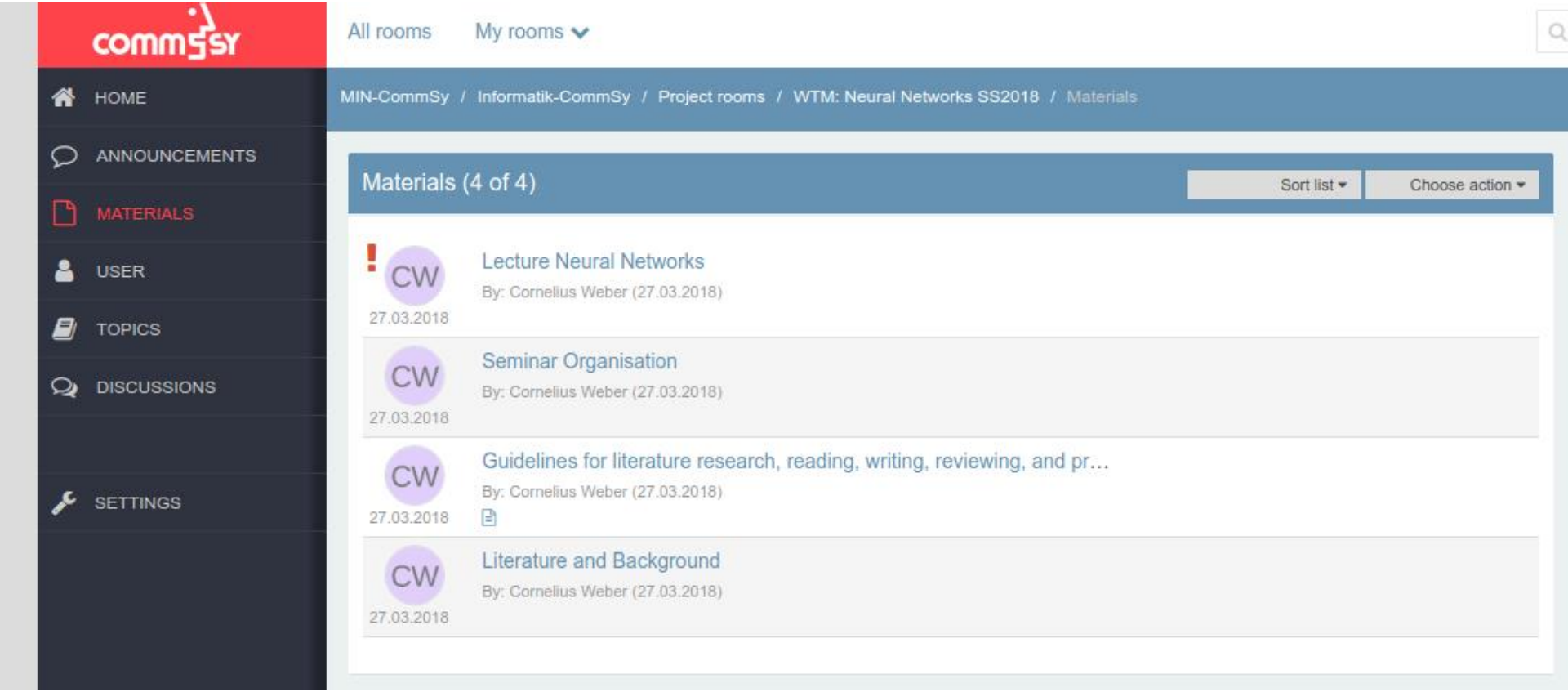


choose “Type”:
“Project rooms”

Slides, announcements, background material.



...make sure to change your default email to one where we can contact you (seminar)!
We'll upload additional (optional) material for those interested (videos, papers, blogs)

Summary

- Previously 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
- Neuroscience-inspired robotics
- Spiking neural networks
- Midbrain / Cortical architectures
- Multimodal integration
- Mirror neuron theory
- Neural networks and language processing (NLP)
- Hybrid representations in robotics and NLP
- Integration of symbolic, neural and statistical approaches