

# Cognitive Science

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## *What the is Cognitive Science?*

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- No definite answer
- Try of a approximate definition
- study of mind/intelligence
- multidisciplinary field
  - **collaborates with psychology, linguistics, neuroscience, AI , philosophy, computer science etc.**
  - ...

## *Cognitive Abilities*

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### higher C.A.

- Problem solving
- Perception
- Art/Poems/Fiction
- natural language
  - **metaphors**
  - **Speech acts**
  - **Anaphora resolution**
  - **presupposition**
- Games (Chess)
- Planning/Learning (Example Hypothesis)
  - **Deductive/Inductive reasoning**
- Memory

### lower C.A.

- motor actions
- sensory
- emotions
- intuition

## *Grounding Problem*

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- How is it possible that a representation of a scene, a situation, an event, an object etc. in the mind can refer to the outer world?
- Designing of new AI Is related to this problem
- philosophical & technical problems

## *Cognitive Science*

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- tries to model, understand and explain these cognitive abilities

# Methods of Cognitive Science

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## *Interdisciplinary field various of methods*

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### Examples from other disciplines

- computer science
  - complexity classes
  - Travelling Salesman Problem
  - Most interesting Problems are of complexity class NP or Higher
    - nevertheless it is possible to build applications for this tasks

### Methods in the used in the Bachelors program

- Linguistics (phrase structure grammar, formal semantics ...)
- Mathematics (needed for many disciplines)
- Logic (important for A.I., Philosophy)
- Statistics
- Experimental Design
- Programming languages
- Philosophical methods

# What the hell is neurobiopsychology?

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## *How does the Brain construct our perceptual world*

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- is the answer as complex as our cortex or is there a simple principle
- CNS
  - **10<sup>10</sup> Neurons, each interacting with 10<sup>4</sup> simultaneous**
  - **Specialist in our brain**
    - **selective & invariant response**

## *Hypothesis: the world is complex our brain is simple*

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### Many experiments

- Where do we look?
  - **Human eye movement**
  - **Konvergenz der Fragestellung (Understanding Language)**
- Properties of cortex correlate with the statistical properties of natural stimuli.

### **A physiological learning rule + natural stimuli explain complex cells.**

- functional approach/general principle
- Looking at natural stimuli and behaviour we learn a lot about cognition.
- Maybe the brain can be understood to a substantial part on the basis of a few principles.

# Homo Sapiens – the emotional animal?

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## What philosophy is concerned with

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- |                        |              |
|------------------------|--------------|
| - What can I know?     | Metaphysics  |
| - What ought I to do?  | Ethics       |
| - What may I hope for? | Religion     |
| - What is man?         | Anthropology |

## What is man?

- |                              |                   |
|------------------------------|-------------------|
| - an animal rationale?       | Descartes         |
| - a free being?              | Mirandola, Kant   |
| - a zoon politikon?          | Aristoteles       |
| - an animal symbolicum?      | Cassirer          |
| - a creative being?          | Mirandola         |
| - a being with deficiencies? | Gottfried, Gehlen |
| - an image of god?           |                   |

## More general concept

- genus proximus
  - animal
  - zoon
  - being

vs

## special features

- differentia specifica
  - rationale
  - politikon
  - free, creative

## Emotional being

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### Without Emotion

- we would not care, nothing would matter
- no basis for rational judgements/decisions
- not able for social & cultural life

# Cognitive robotics

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## ***Design of social robots***

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- Robots that can interact with people naturally

### **Reasons**

- To work in human environments
- companionship/entertainment
- to study human cognition/social behaviour

## ***Aspects of social robots***

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### **Social Interaction**

- embodiment (having a body)
- sharing an environment with the user
- *situated/social cognition/* contextual understanding & action

### **Social Intelligence**

- *Understand human behaviour*
- emotions/ empathy/ communication
- act in an understandable way

### **Autonomy**

- Illusion of life, intentionally, personality (including unexpected behaviour)

### **Understanding “self”**

### **Social learning**

- from interaction (tutoring)
- Imitation

## ***Design Issues***

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### **Social environment**

### **Real-time performance**

### **Appropriate social expectations**

### **self motivated interaction**

### **Readable social cues**

### **Interpret human social cues**

### **believable behaviour**

## ***Advantages***

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- Enjoyable Interaction
- No special Training needed to use the robot
- The user can teach the robot

## **Cognitive robotic studies**

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### **History**

- Eliza Program
- Revival
  - **Castle mate**
  - **XDR3, Primo Puel**
- Therapeutic role of Eliza-like User Interfaces
  - **user centred/ no threatening personality**
  - **availability**
  - **Can sometimes be more efficient than a human therapist**

### **Actual robot studies**

- Kismet
  - **Interaction with the user at infant level**
- Infanoid
- AMD

# Comprehension - as a Paradigm for Cognition

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## *Favourite Cognitive Scientists*

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- Douglas Hofstadter
- Noam Chomsky
- Marvin Minsky
- Alan Turing
- Alan Newell & Herbert Simon
- Walter Kintsch

## *What is Meant by Comprehending and/or Understanding the World?*

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- Comprehension (or understanding) is the formation of a mental representation of some stimulus (e.g. Text, picture) on the basis of prior knowledge and experiences of the comprehender
- Such mental representations are used to guide current and future behaviours

## *Research Methods of Cognitive Science (theoretical and empirical)*

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- Discrete models vs. analogue representations

### **Experiments**

- Sentence comprehension and perception
- KIWI-Model
- Interaction of inferred and perceived emotions
- The influence of viewing direction on spoken sentence comprehension

## **Summary**

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- Comprehension is the mental construction of a virtual reality about the situations described in a text
- Such mental representations are called situation models
- Empirical evidence by behavioural experiments and neural indicators (ERP, MRI)

# Lessons from neurodegenerative diseases for a molecular approach to cognition

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## *Mind Brain & neurodegenerative diseases*

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### Psychophysical problem

- Mind vs. Brain
- Dualistic solution vs. Dualistic interactionism

### Diseases & affected brain regions

- Parkinson      Substantia Nigra
- ALS              a-motor Neurons/Spinal cord
- Alzheimer      Hippocampus

## *Alzheimer*

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- Senile (amyloid) plaques
- Neurofibrillary tangles (NFTs)
- 95% are spontaneous, 5% is familial (genetically)

## *A molecular approach to cognition*

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- Neurodegeneration of specific brain regions can be tracked down to the function of single genes
- Functional knock out of specific brain regions causes a very specific phenotype
- Individual proteins may be capable of affecting specific cognitive abilities
- learning and memory are based on modifications of synaptic strength among neurons that are simultaneously active
- enhanced synaptic coincidence detection would lead to better learning and memory

### Genes for language

- Mutation in a single gene severely impairs language

# Aspects in artificial intelligence

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## Overview

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- AI in movies
- Everyday life
  - cars (Exp. Intelligent lightning systems etc.)
  - computer games
  - e-dictionary
  - Dialogue systems (Telephone)
- Current hot Topics
  - Chess (Deep Fritz won 4:2 against Kramnik)
  - autonomous agents/robots
  - Cognitive Substrate/Architectures
  - Semantic Web

## Historical remarks

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- Intelligent systems based on neural networks
- Turing Test
- cognitive processes and general principles of intelligent behaviour
- functional logic programming
- 90's Birth of Cognitive Science

## Future Tasks

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- Human-level intelligence
- creativity
- higher+lower cognitive abilities
- improved learning abilities
- autonomy
- simple user-computer interfaces

## AI in Osnabrueck

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### General

- modelling of higher cognitive abilities
- models for semantic information processing
- knowledge representation/ reasoning/ machine learning

### Groups

- Text technology
- Analogical Reasoning
- Machine learning

# Combinatorial Optimization

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## **Famous combinatorial problems**

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- Shortest path (routing planner)
- Travelling salesman problem (TSP, also see Methods of CS)
- Minimum spanning Trees
- Bridge Problem of Koenigsberg
- Four colour problem
- packing problems
- scheduling
  - **timetabling**
  - **shift scheduling**
  - **Sports league**
  - **Traffic scheduling**

## **General procedure**

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- Problems are easy to understand but hard to solve (complexity classes, number of solutions)
- abstraction of the model, formulation of side constraints (mathematics)
- Solve the problem (exact/appropriate algorithms, lower bound)
- Objects used
  - **graphs, sequences subsets**

### **Methods**

- Branch-and-Bound procedures
- Dynamic Programming
- Linear Programming
- Constraint Programming(AI)
  - **Four Colour Problem (Latin square)**
  - **reduce domains(infeasible values)**
    - **contains one value (value determined)**
    - **empty (no feasible solution)**
    - **more than one element (Trial&Error, Branching etc.)**
- Local Search: Simulated Annealing, taboo Search
- Genetic Algorithms
  - **merge to strings (parents) to get:**
    - **child (also a string)**
    - **mutation change a value (gene) randomly**
- Ant Algorithms

# Knowledge based systems

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## Research topics

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### Mobile robots

- ingredients from various fields (mechatronic/informatics/AI)
- Scientific/Technical Challenge
  - **autonomous**
  - **real-time close-up control**
- Application perspective
  - **improve everyday life/products**
  - **Rescue robotics**
    - **3d Mapping**
    - **6D Slam**
    - **HRI**

### 3D environment models

- a mobile robot needs to know the geometry around
- humans/animals stereo vision, ultrasound, electrical fields, ..
  - robots stereo cameras, mostly laser scanners
  - Registering 3D scans (fitting two different scans together)
    - **Variant of the ICP (Iterative closest point) algorithm**

### Semantic Mapping

- Find interpretations for a given 3D environment(model)
  - **objects, environmental structures**
- Understanding a scene
  - **recognition/classification**
  - **constraint propagation**
  - **controlled hallucinations**
  - **functional perceptions**
- Mobile robots allow the symbol grounding problem to be explored practically

### Seamless simulation

- used for testing algorithms and software for robots
- allow to run exactly the same code like real robots owing to device level simulation

## Projects

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### Lisa

- safe manipulation in a working biotechnology lab

### MACS

- functional perception into robots control

### Kurt

- Kurt's Grand Challenge: Autonomous Driving in the Botanical Garden

# Language & Cognition

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## Why should Cognitive Science deal with natural language

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- CogSci is about information processing
- NL is the most natural and most convenient way that humans have for
  - **communicating information and**
  - **storing information.**
  - **Every human being can speak a language**

## Where is language?

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- Central systems vs. modular systems

### Language Comprehension

- sometimes sentences cannot be understood without additional knowledge (discourse, context)
- sometimes domain knowledge can replace grammar

### Grammar as a module of cognition

- Garden path effect
- Modular syntactic processes
- anaphora resolution
- also if grammar is a module of cognition it interacts with other modules

## Experiments

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### Eye-tracking studies

- "Click on..." Task
  - **subjects decide about reference as soon they have enough information**
    - **(Deutsch: gender, colour...)**
- Konvergenz der Fragestellung (see also neurobiopsychology)
  - **Esp. Market day**
- General conclusions
  - **people use whatever information is available as soon as it is useful in interpreting utterances**
  - **this strikes against modularity**
  - **it argues for a model of language in which information is represented in a uniform, order-independent fashion**

## Natural Language Processing

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- The interaction of grammatical knowledge and world knowledge in discourse understanding is still not fully understood
- Grammatical knowledge of some kind is clearly required, but also knowledge from experience