Computational Neuroscience: Neural Dynamics
Learning goals/syllabus

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Theoretical research program

- theory of behavior and thinking…
  emergence from the sensory-motor domain

- process accounts based on neural principles

- naturalistic tasks that connect to elementary
  behaviors and elementary forms of cognition

Experimental research program

- look for behavioral signatures of the postulated neural principles

  - e.g. metric effects, role of time, context, online updating

- study links between different domains

Robotic research program

- autonomous robots: actively generate behavior, initiating, selecting, terminating actions based on the system's own perceptual processes

- use autonomous robots as heuristic devices to demonstrate process accounts
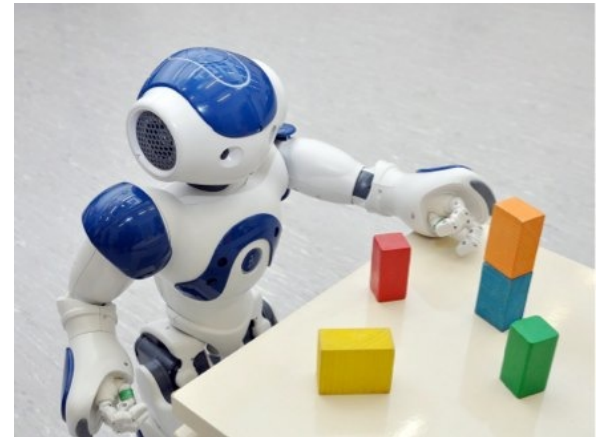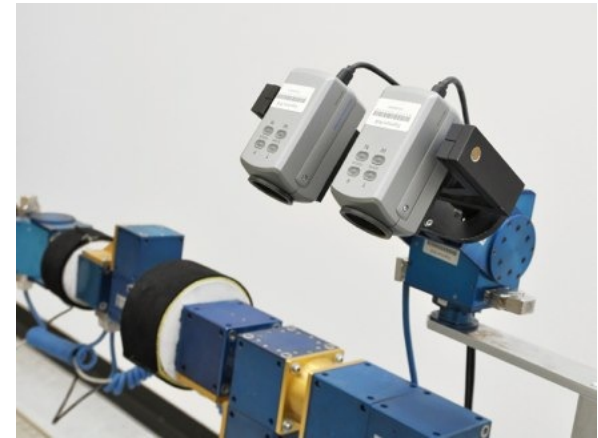
What contents do you learn?

- elements of embodied cognition
  - detection decisions
  - selection decisions
  - working memory for metric information
  - memory trace

What contents do you learn?

■ theoretical concepts

- behavioral dynamics

- neural dynamics

- dynamic neural fields

- Dynamic Field Theory

What contents do you learn?

■ neural foundations

   ■ rate code, neural maps

   ■ population code

   ■ neurophysics

What contents do you learn?

- mathematic concepts

    - dynamical systems

    - stability, attractors, instabilities

    - numerical solution of differential equations

What contents do you learn?

- theory-experiment relationships
  - accounting for neural and behavioral data
  - accounting for behavior in process models

What contents do you learn?

- robotic and simulated behavior
  - as a heuristic tool
  - to demonstrate function from neural dynamics
  - to uncover overlooked problems

What skills do you learn?

- academic skills
  - read and understand scientific texts
  - write technical texts, using mathematical concepts and illustrations

What skills do you learn?

- **mathematical skills**
  - conceptual understanding of dynamical systems
  - capacity to read differential equations and illustrate them
  - perform "mental simulation" of differential equations
  - use numerical simulation to test ideas about an equation

What skills do you learn?

- interdisciplinary skills
  - handle concepts from a different discipline
  - handle things that you don't understand
  - sharpen sense of what you understand and what not

Syllabus

■ **1) Dynamical systems tutorial**

■ a very brief conceptual survey over the basis concepts of dynamical systems, including attractors and instabilities

■ **2) Braitenberg vehicles**

■ a simple demonstration of synthetic psychology/ neuroscience: how behavior emerges from simple embodied situated nervous systems

Syllabus

3) Neurophysics

a very brief survey over basic concepts of the nervous systems: neurons, spiking, networks, learning, neural networks, the brain

4) Neural dynamics

the core dynamical systems properties of recurrent neural networks: single neuron with self-excitation and two competing neurons

Syllabus

5) Dynamic neural fields

- the key instabilities in dynamic neural fields

- detection

- selection

- memory

- the memory trace

Syllabus

6) Higher dimensional fields

- joint representations
- visual search
- binding
- coordinate transforms
- grounding
- mental maps

Syllabus

- 7) sequences
  - condition of satisfaction
  - action initiation/termination
- 8) intentional systems
  - architectures
- 9) relation to other neural theories of cognition