Computational Neuroscience: Neural Dynamics

What is this course about?

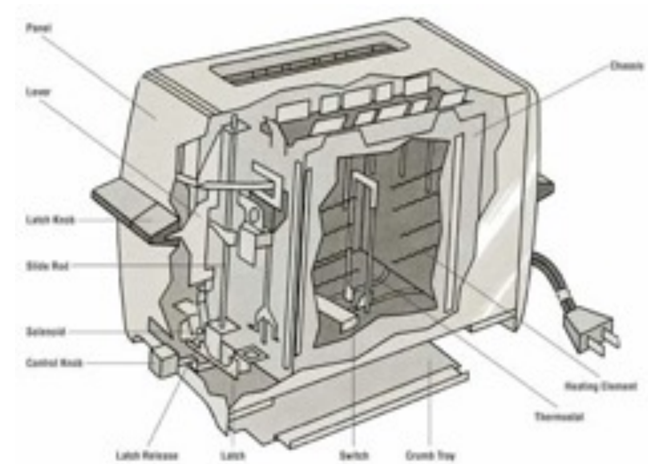
Embodied cognition vs. Information processing

Soccer playing contains a lot of cognition

- see and recognize the ball and the other players, estimate their velocities (perception, scene representation)
- select a visual target, track it, controlling gaze (attention)
- use working memory when players are out of view to predict where you need to look to update (working memory)
- plan and control own motion, initiate and control kick, update movement plans any time (planning)
- get better at playing (learning)
- know goal of the game/rules, how hard the ball is, how fast players are (background knowledge)

Cognition contains a lot of embodiment

- explore scene, recognize screws, while keeping track of spatial arrangement (scene representation, coordinate transforms)
- plan action, find tools, apply them to remembered locations, updated by current pose of toaster (working memory, scene representation)
- manipulating cover, taking it off, recognizing spring, re-attaching it (goal-directed action plan)
- mounting cover back on, generating the correct action sequence (sequence generation)
- get better at this (learning)
- know about cover, screws, hard to turn (background knowledge)



[image: HowStuffWorks]

[image: mystery fandom theater 3000]

Embodied cognition implies constraints

- active perception for a purpose through which perceptual objects are grounded: sensory autonomy
- cognitive processes continuously updated and continuously linkable to motor processes: stability
- invariance and abstraction must retain this linkage to the sensory and motor surfaces
- cognition is sensitive to behavioral history, environmental context: learning, adaptation
- (cognition arises from neural systems)
- build in “back-ground knowledge” (Searle)

The embodiment hypothesis

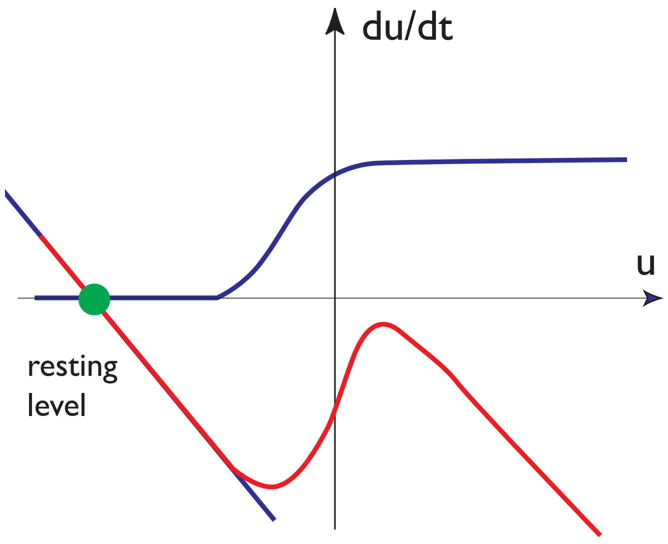
- there is no particular boundary
  - up to which, cognition is embodied
  - beyond which cognition loses the properties of embodiment
- => all cognition shares properties of embodied cognition

Neural dynamics hypothesis

- because embodied cognition unfolds in time, in interaction among processes, including often interaction (loop) between organisms and their environment
- => embodied cognition requires dynamics...

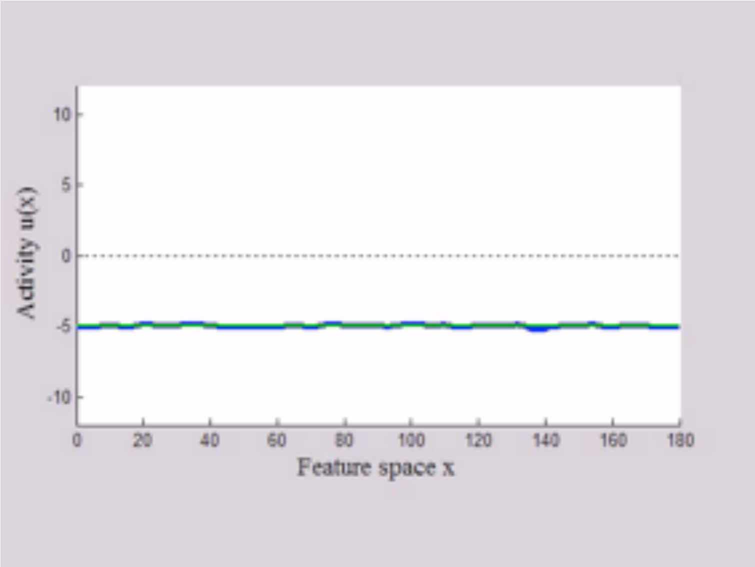
Neural dynamics hypothesis

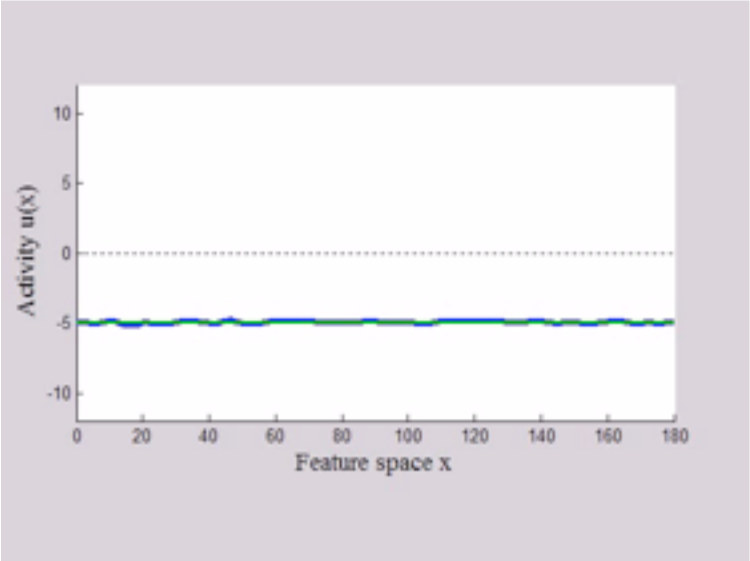
- neural dynamics is a powerful theoretical language with which embodied and situated cognitive systems can be designed and modeled



Dynamic Field Theory

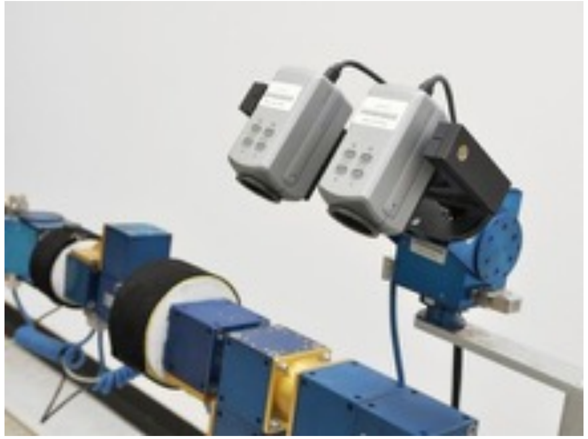
- the most conceptually consistent branch of this language
- which focusses purely on the functional significance of neuronal activity
- abstracting from the functionally insignificant discrete spatial and temporal structure of neuronal computation





Autonomous cognitive robots

- autonomy: actively generate behavior, initiating, selecting, terminating actions based on the system's own perceptual processes
- autonomous robots are model systems on which ideas of embodied (and general) cognition may be tested, evaluated, and heuristically expanded
- autonomous robots are also artificial embodied cognitive systems of interest in their own right.



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
  - Braitenberg vehicles
  - rate code
  - population code

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
  - compute fixed points and determine stability
  - perform "mental simulation" of differential equations
  - write and run numerical simulators

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