
人工智能
The ShanghAI Lectures
上海授课

# The ShanghAI Lectures
## An experiment in global teaching

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Today from CNR-ISSIA, Genoa and Bari, Italy and
University of Oxford, UK

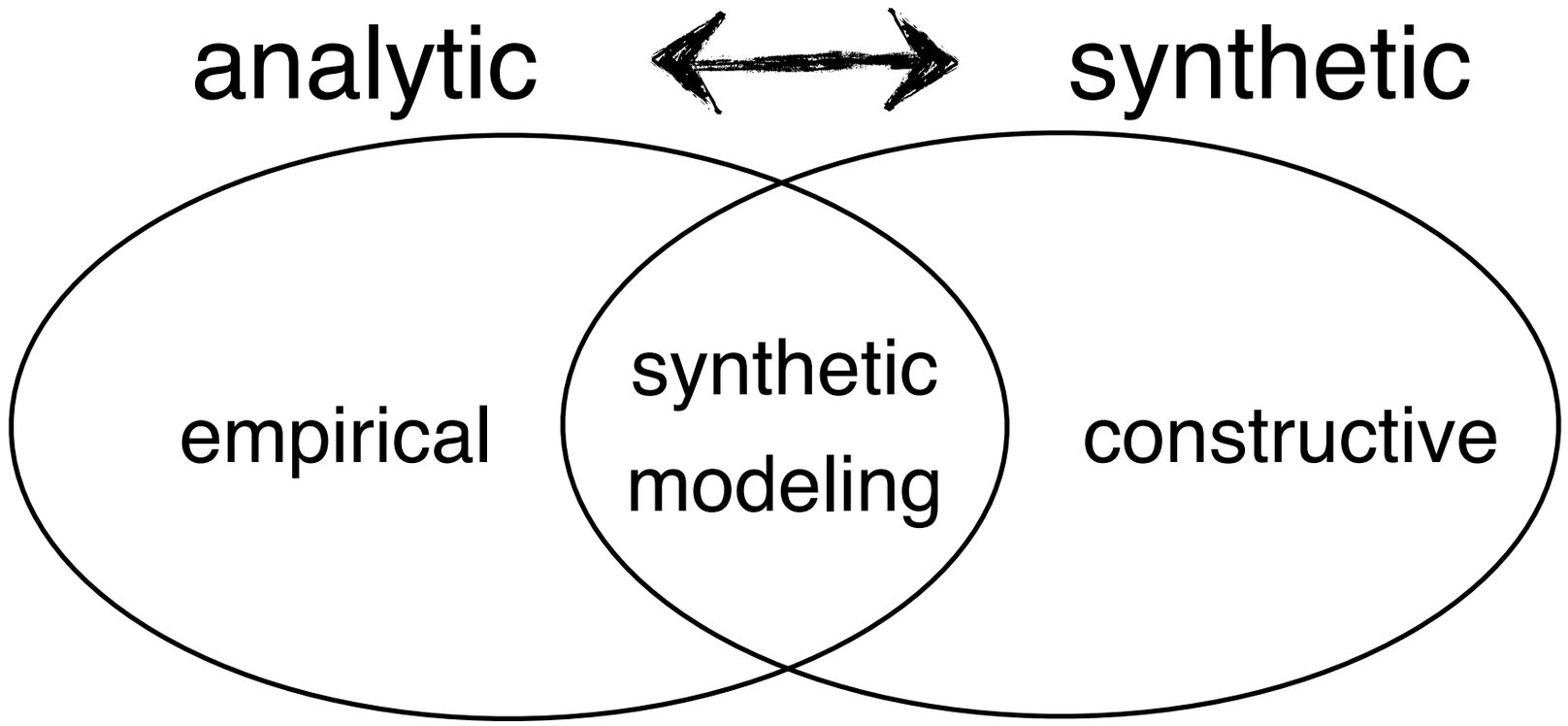
欢迎您参与
**“来自上海的人工智能系列讲座”**

# Lecture 3

## Design principles for intelligent systems

## 30 October 2014

# How to study intelligence?




psychology
biology
neuroscience

artificial intelligence
engineering
cognitive science

# The synthetic methodology

Slogan:

**“Understanding by building”**

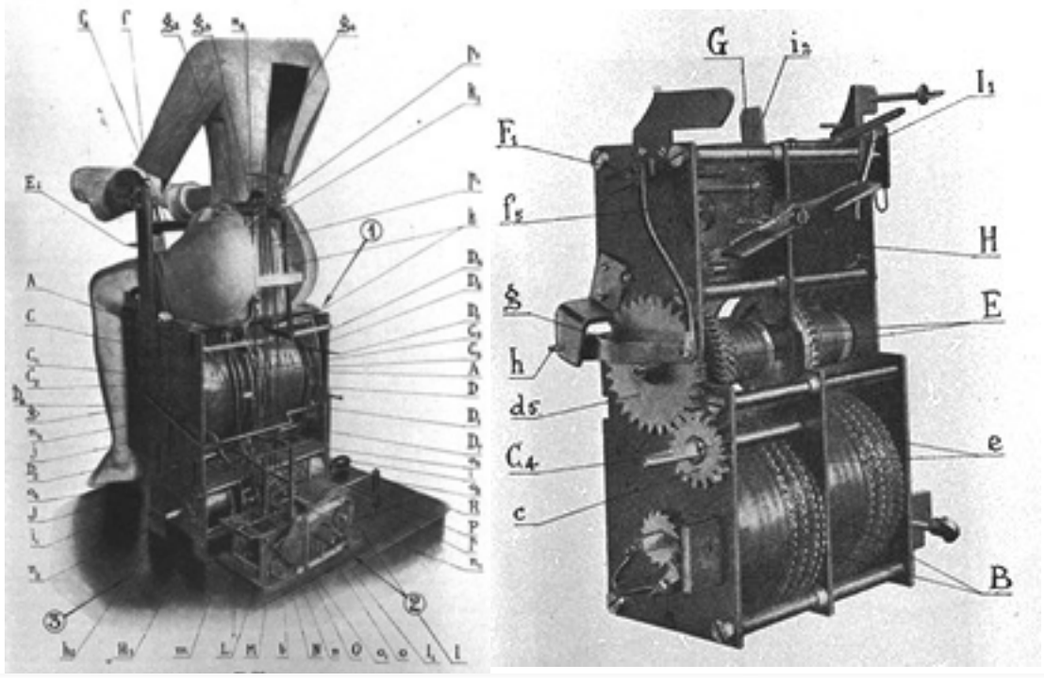
**modeling behavior of interest**

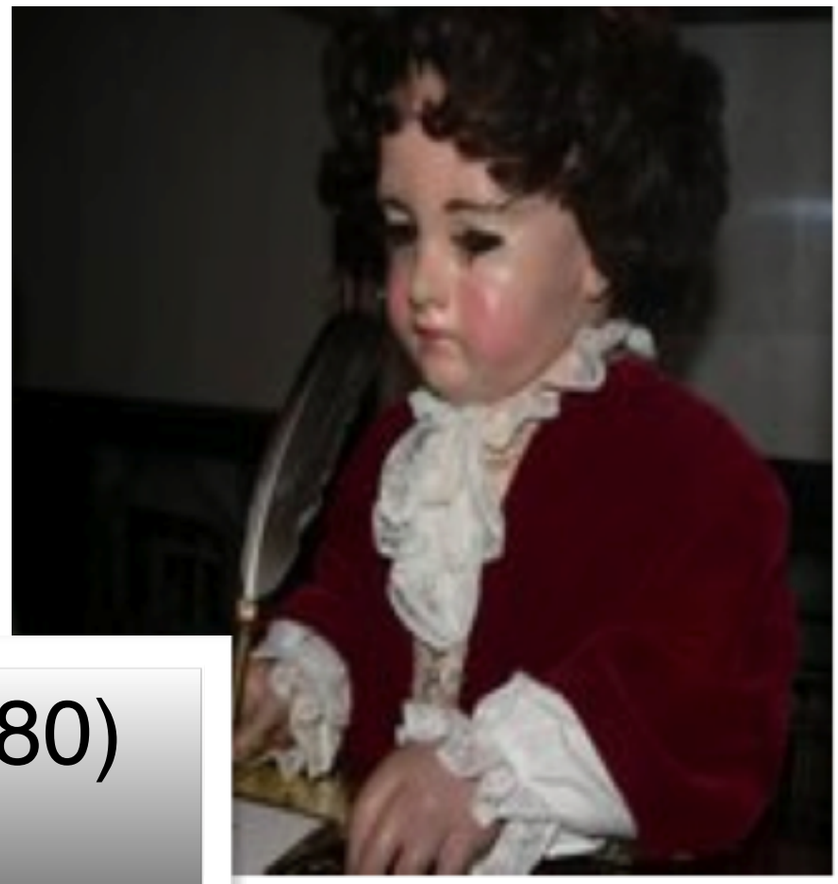
**abstraction of principles**



**robots as tools for scientific investigation**

# Old attempts



Jaquet-Droz Brothers (1720-1780)

# Old attempts

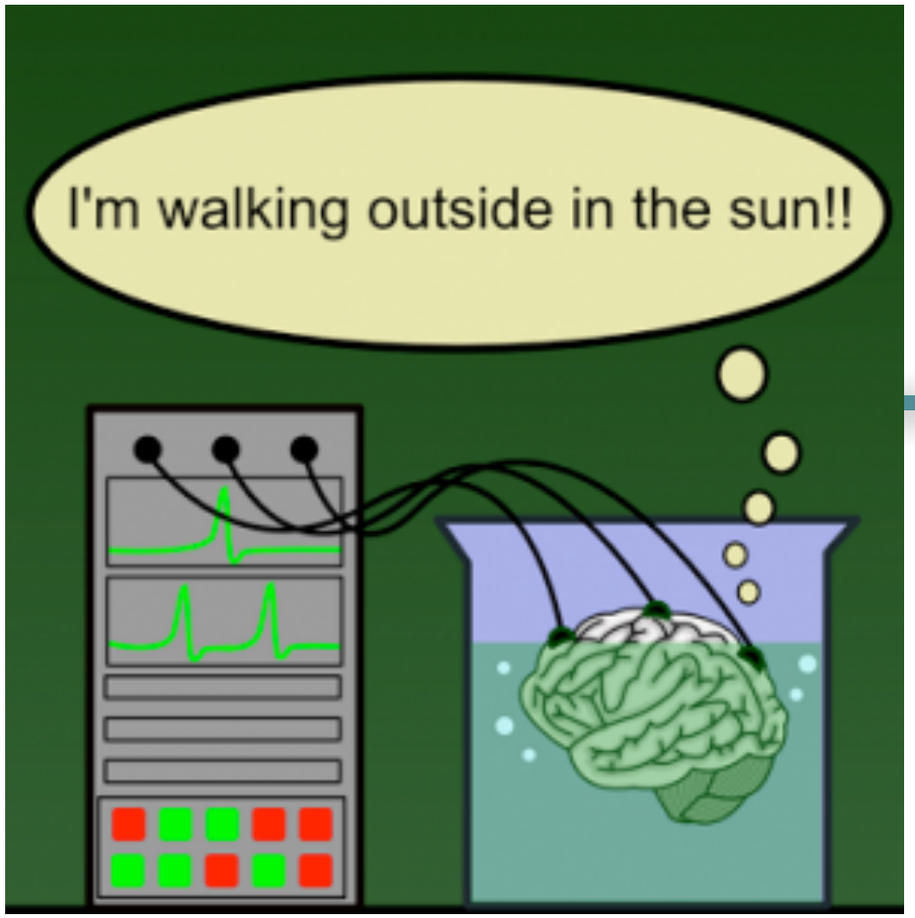
## Karakuri Dolls

Chahakobi Ningyo (Tea Serving Doll) by SHOBEI Tamaya IX, and plan from 'Karakuri Zuii' ('Karakuri - An Illustrated Anthology') published in 1796.

# Issues to think about: an unfair comparison

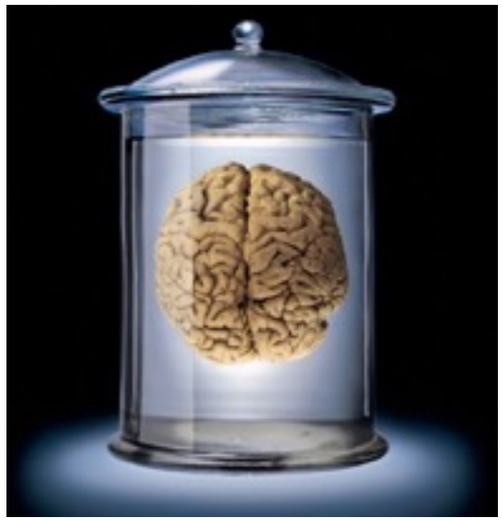
Video: an excellent robot's "bad day"

Video: "the inner life of a cell"

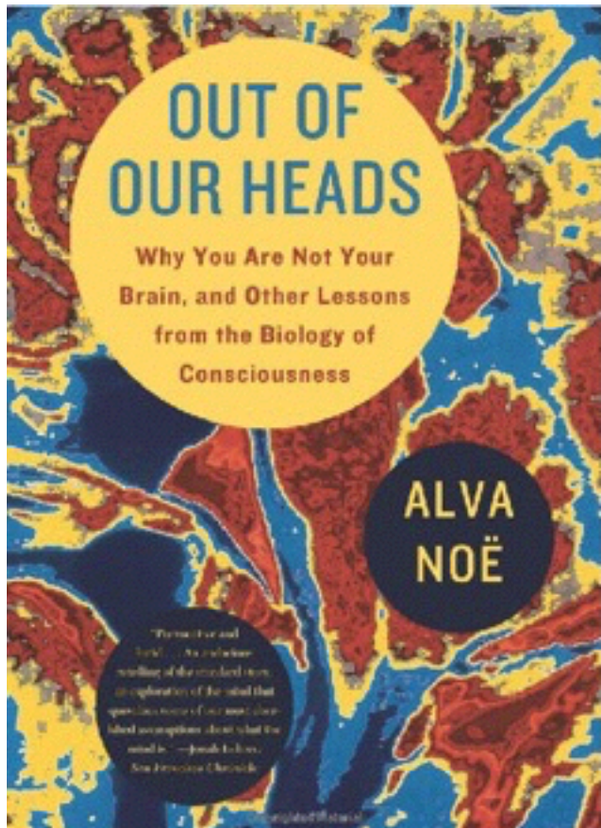



# “Brain-in-a-vat”

Alva Noë, “Out of our heads - why you are not your brain”, New York, Hill and Wang, 2009



- **supply energy**
- **flush away waste products**
- **complicated: providing stimulation comparable to that normally provided to a brain by its environmentally situated body**



# Life vs Cognition

?

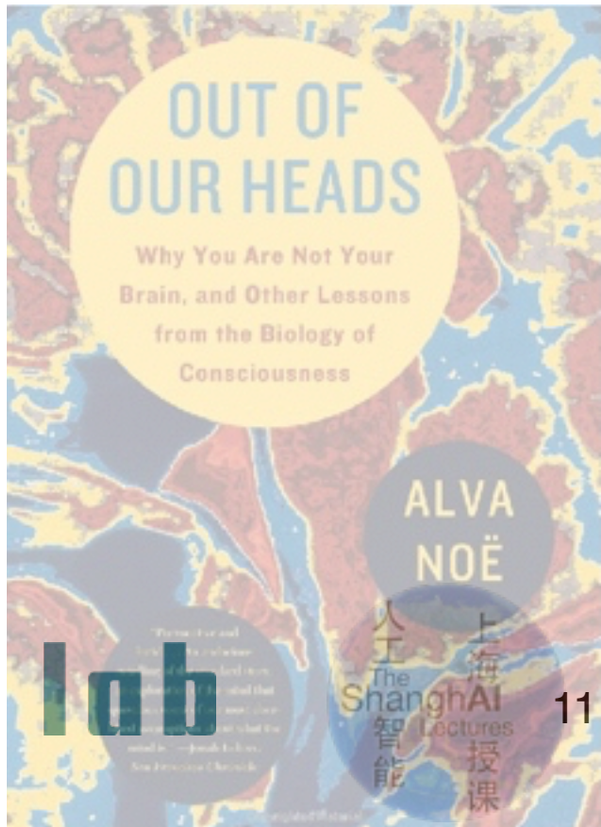

# “Brain-in-a-vat”

Alva Noë, “Out of our heads - why you are not your brain”, New York, Hill and Wang, 2009

**volunteers for short alternative prez on “Brain-in-a-vat” (Today and/or next time)**

- supply er
- flush awa
- complica

comparable to that normally provided to a brain by its environmentally situated body



# Today's topics

- short recap
- characteristics of complete agents
- illustration of design principles
- parallel, loosely coupled processes: the "subsumption architecture"
- case studies: "Puppy", "Passive Dynamic Walkers"

# Hard to agree on definitions, arguments

- **necessary and sufficient conditions?**
- **are robots, ants, humans intelligent?**

more productive question:

**“Given a behavior of interest, how to implement it?”**

# Measuring intelligence

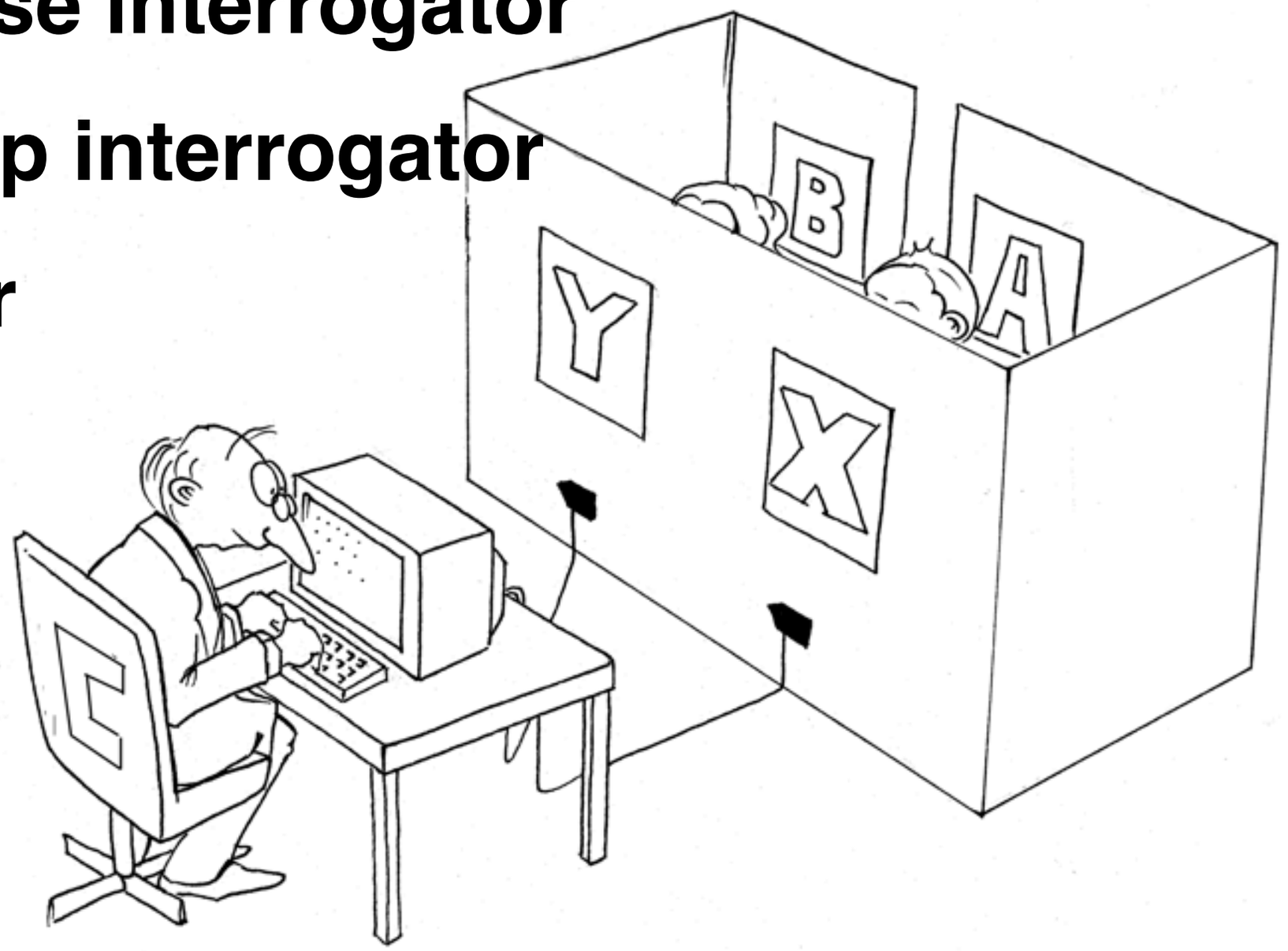
- e.g. IQ, h-index :-)
- ...

# The Turing Test

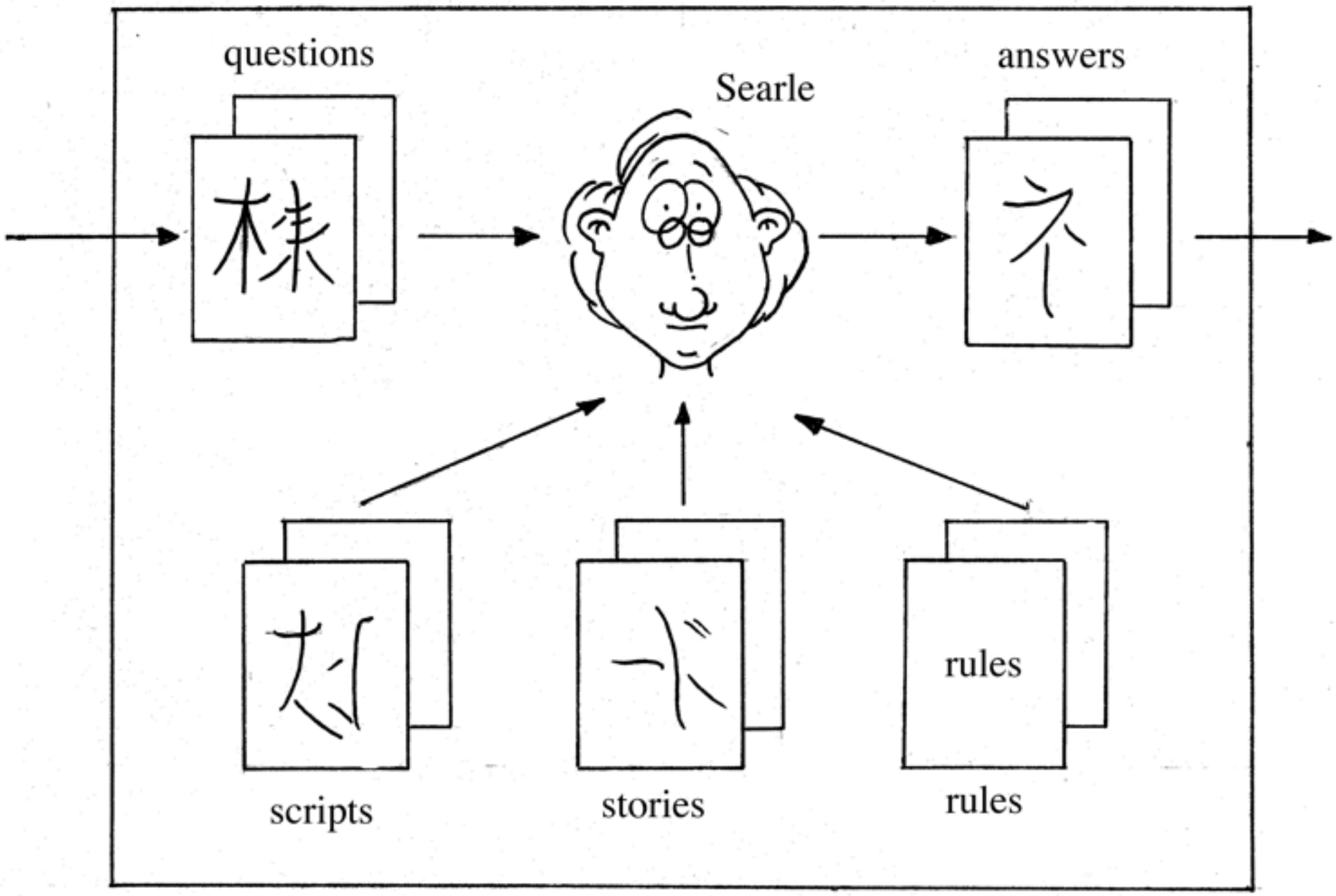
**A: man, confuse interrogator**

**B: woman, help interrogator**

**C: interrogator**



# Searle's "Chinese Room" thought experiment



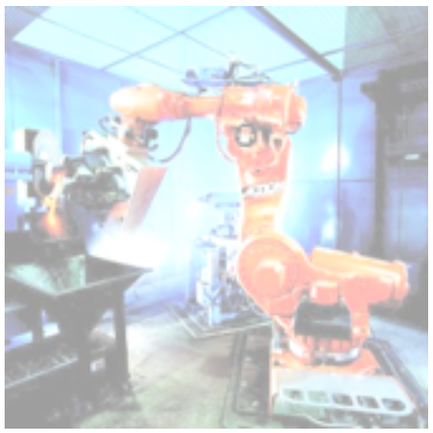
# “English Room” thought experiment

- “this is Spanish for me” (in Austria to say a speech is impossible to understand) - (funny for me, for an Italian Spanish is quite easy :-) )

# Successes and failures of the classical approach

| successes | failures |
| --- | --- |
| **applications (e.g. Google)** | **foundations of behavior** |
| **chess** | **natural forms of intelligence** |
| **manufacturing** | **interaction with real world** |
| (“controlled”artificial worlds) | |

# Industrial robots vs. natural systems



**robots**

principles:
- **low precision**
- **compliant**
- **reactive**
- **coping with uncertainty**

**humans**

→ **no direct transfer of methods**

# The “symbol grounding” problem

**real world: doesn’t come with labels …**

**How to put the labels??**

Gary Larson


"Now! ... *That* should clear up a few things around here!"

# Two views of intelligence

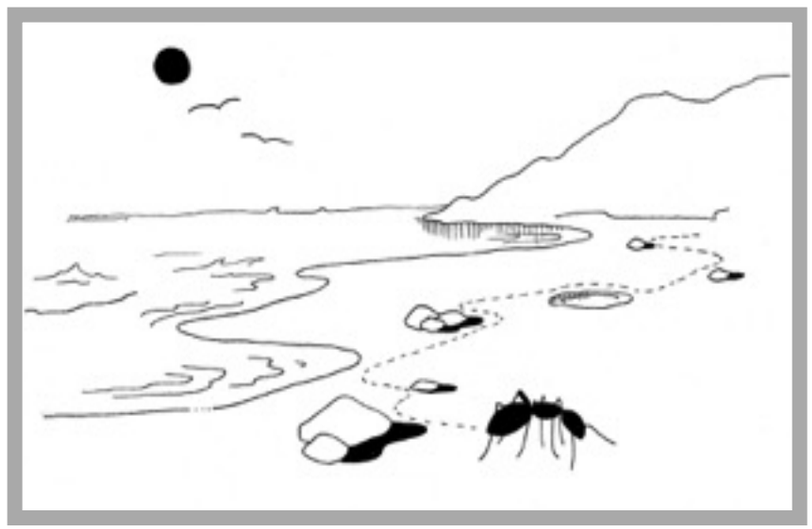
classical:
**cognition as computation**

embodiment:
**cognition emergent from sensory-motor and interaction processes**

# The need for an embodied perspective

- **“failures” of classical AI**
- **fundamental problems of classical approach**
- **Wolpert’s quote: Why do plants not …? (stay tuned for Barbara Mazzolai’s lecture…)**
- **Interaction with environment: always mediated by body**

# “Frame-of-reference” Simon’s ant on the beach



- **simple behavioral rules**

- **complexity in interaction, not — necessarily — in brain**

- thought experiment: **increase body by factor of 1000**

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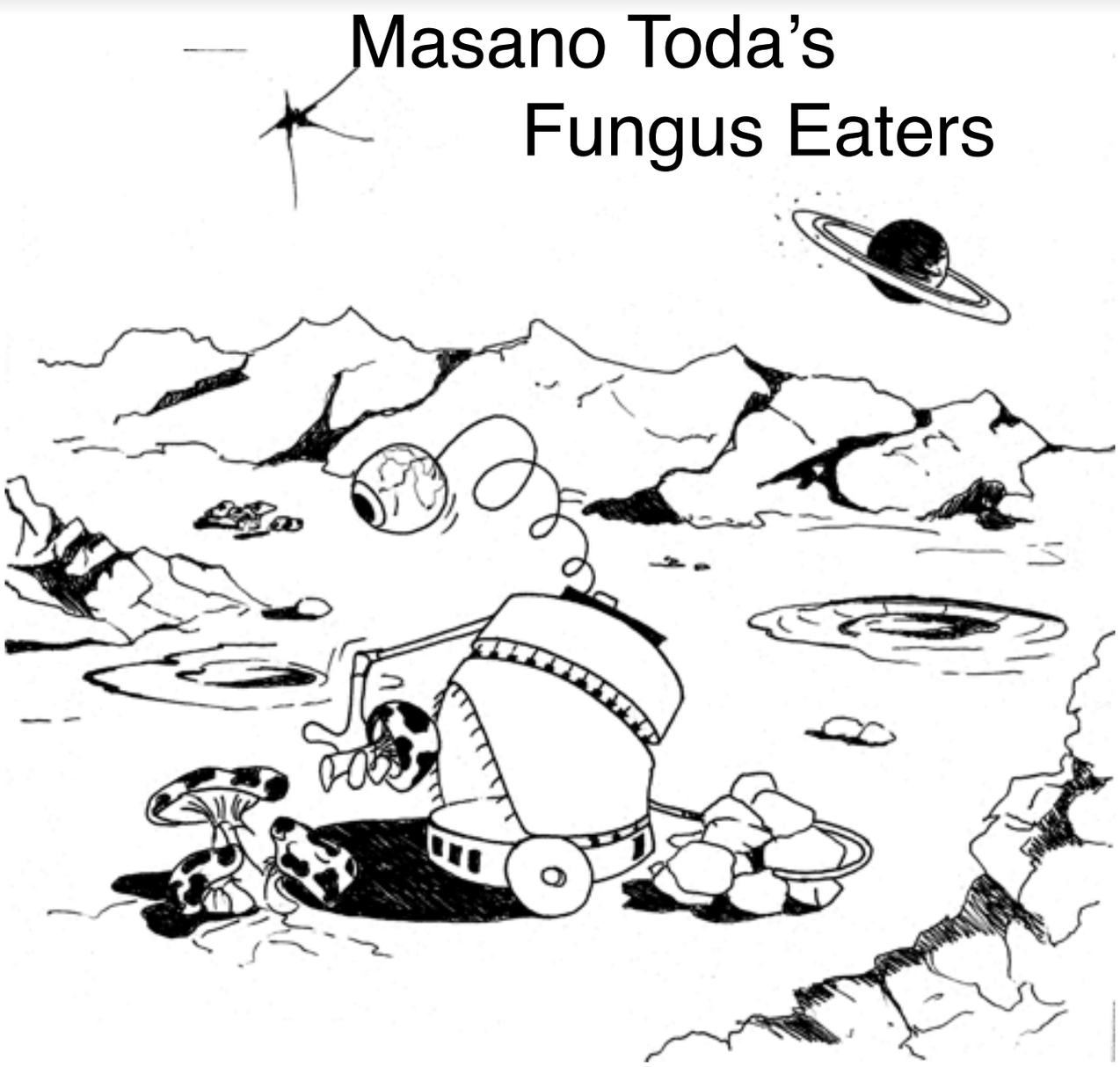
- case studies: "Puppy", biped walking
- "cheap design" and redundancy

# Complete agents



# Properties of embodied agents

- subject to the laws of physics
- generation of sensory stimulation through interaction with real world
- affect environment through behavior
- complex dynamical systems
- perform morphological computation

# Complex dynamical systems

**non-linear system - in contrast to a linear one**

**—> Any idea?**

# Complex dynamical systems

concepts: focus box 4.1, p. 93, “How the body …”

- dynamical systems, complex systems, non-linear dynamics, chaos theory
- phase space
- non-linear system — limited predictability, sensitivity to initial conditions
- trajectory

# Today's topics

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# Design principles for intelligent systems

**Principle 1: Three-constituents principle**

**Principle 2: Complete-agent principle**

**Principle 3: Parallel, loosely coupled processes**

**Principle 4: Sensory-motor coordination/ information self-structuring**

**Principle 5: Cheap design**

**Principle 6: Redundancy**

**Principle 7: Ecological balance**

**Principle 8: Value**

# Three-constituents principle

define and design

- **“ecological niche”**
- **desired behaviors and tasks**
- **design of agent itself**

design stances

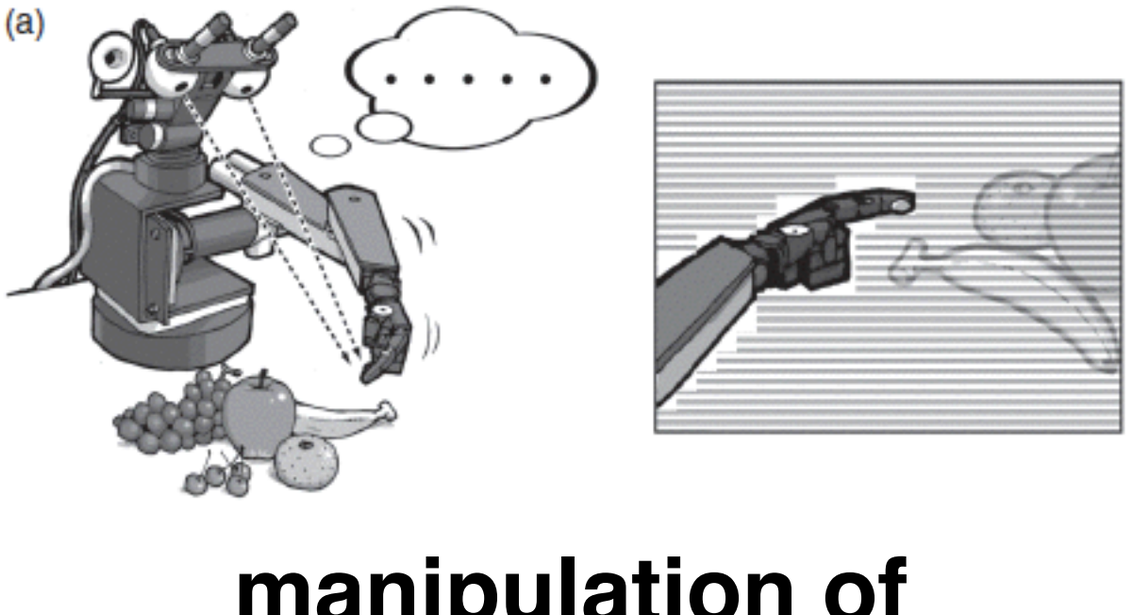
scaffolding

# Complete-agent principle

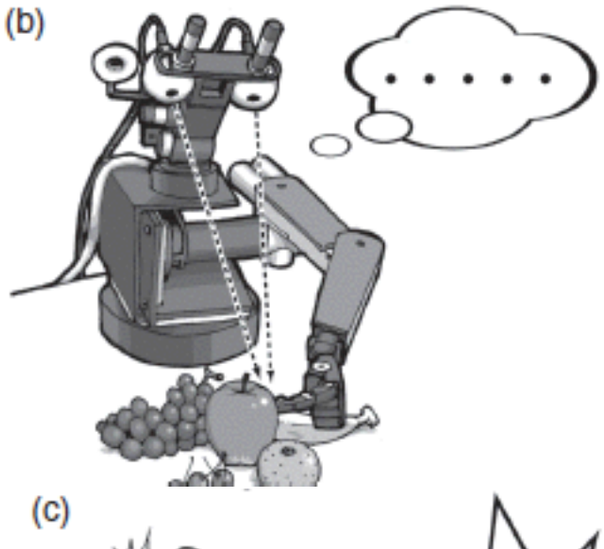
- always think about complete agent behaving in real world
- isolated solutions: often artifacts — e.g., computer vision (contrast with active vision)
- biology/bio-inspired systems: every action has potentially effect on entire system

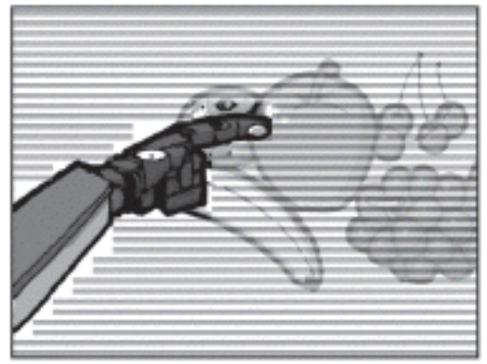
can be exploited!

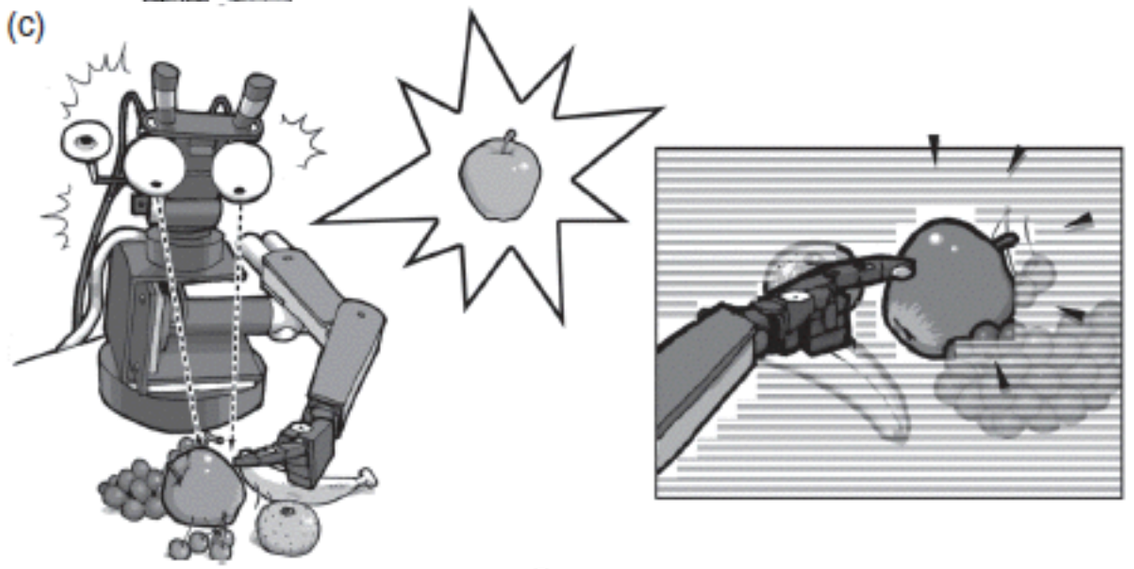
# Recognizing an object in a cluttered environment








**manipulation of environment can facilitate perception**

Experiments: **Giorgio Metta and Paul Fitzpatrick**

Illustrations by Shun Iwasawa

# Today's topics

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- case studies: "Puppy", biped walking
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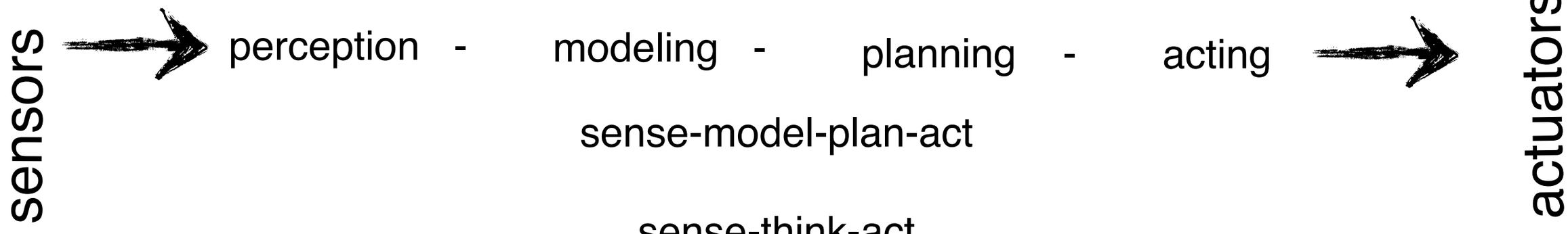
# Parallel, loosely coupled processes

intelligent behavior:

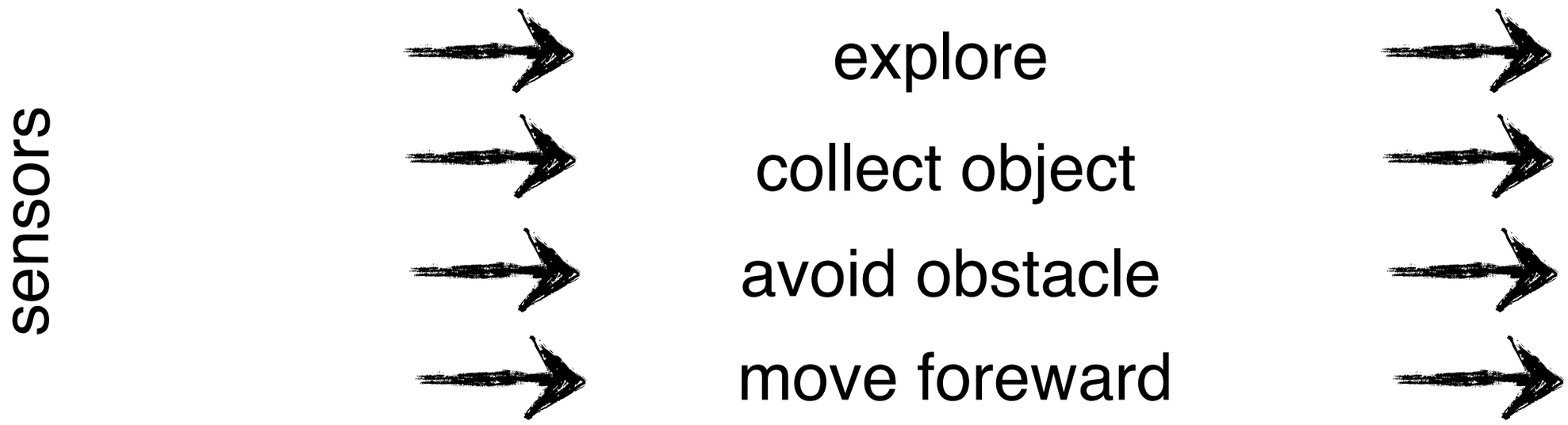
- **emergent from system-environment interaction**
- **based on large number of parallel, loosely coupled processes**
- **asynchronous**
- **coupled through agent's sensory-motor system and environment**

# The subsumption architecture

**classical, cognitivistic**



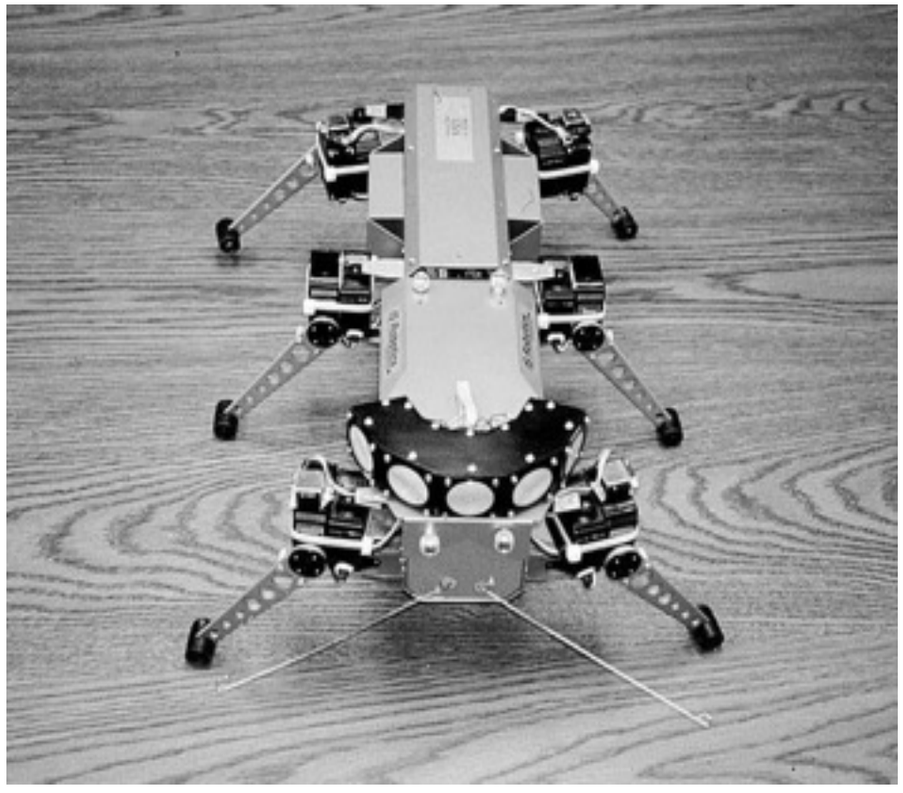

**“behavior-based”, subsumption**



# Mimicking insect walking

- **subsumption architecture well-suited**

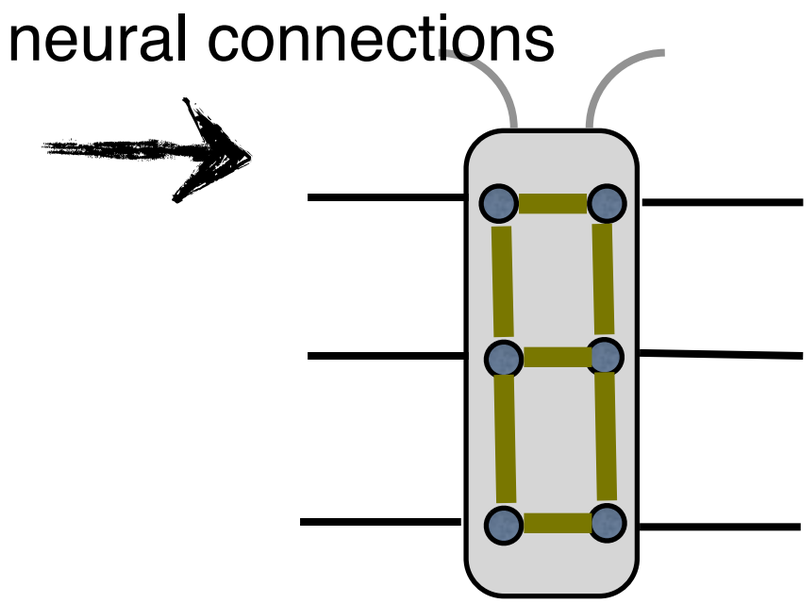
six-legged robot “Ghenghis”



# Insect walking

Holk Cruse, German biologist

- **no central control for leg coordination**
- **only communication between neighboring legs**
- **global communication: through interaction with environment**



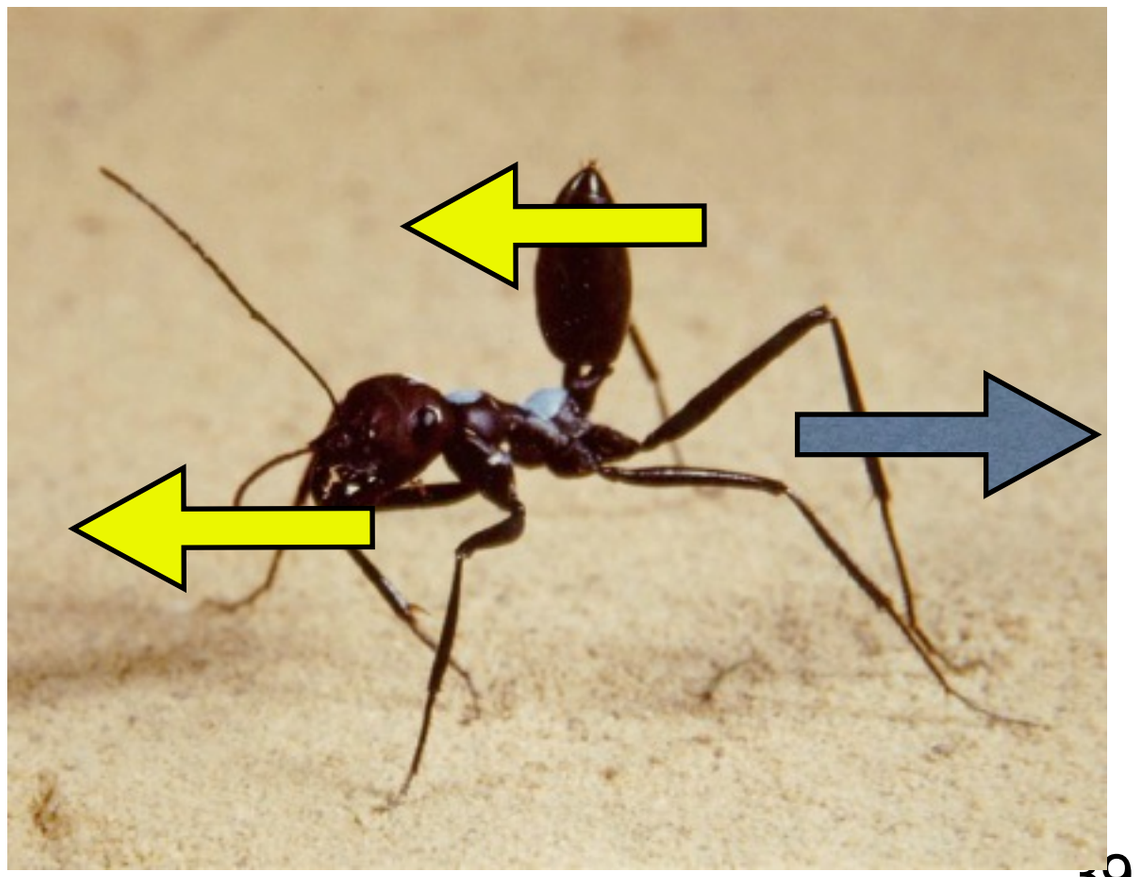
# Communication through interaction with

- **exploitation of interaction with environment**

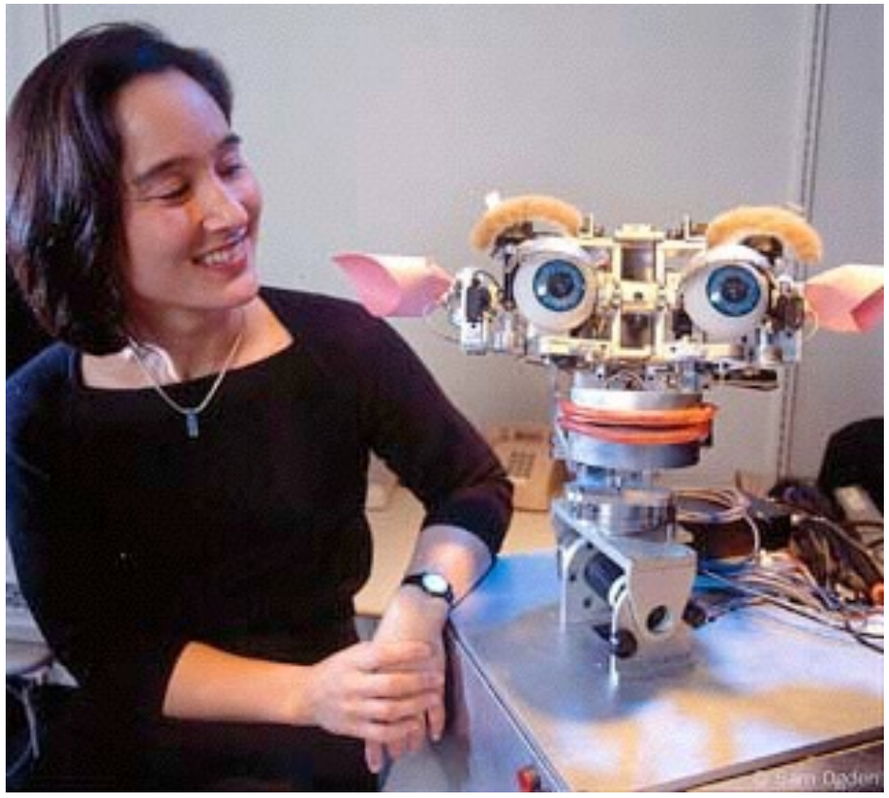
→ **simpler neural circuits**

**angle sensors in joints**

"parallel, loosely coupled processes"



# Kismet: The social interaction robot



Cynthia Breazeal, MIT Media Lab
(prev. MIT AI Lab)

# Kismet: The social interaction robot

Video “Kismet”

Cynthia Breazeal, MIT Media Lab
(prev. MIT AI Lab)

# Kismet: The social interaction robot

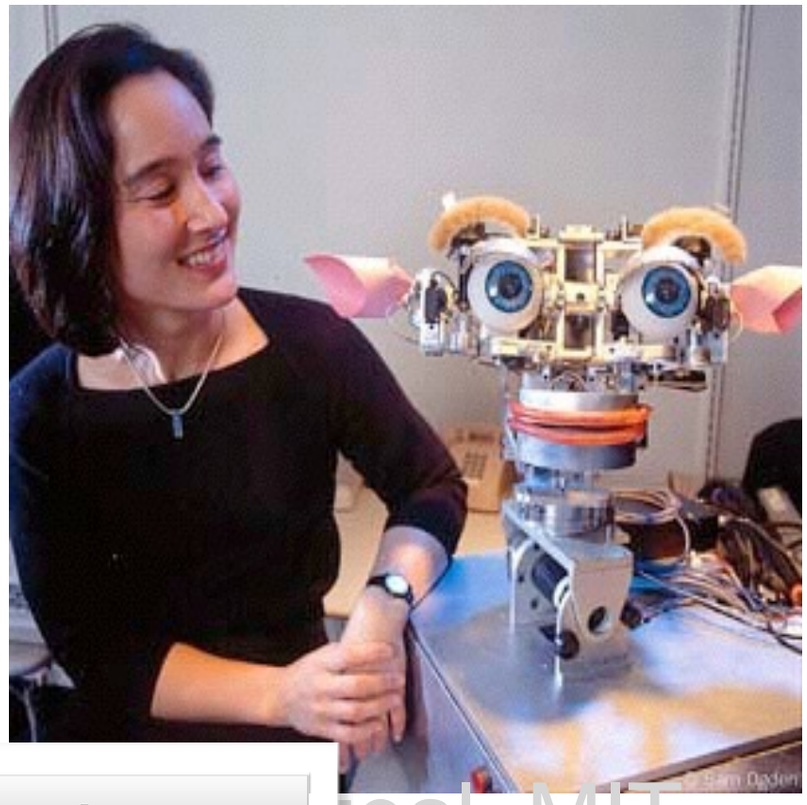
Reflexes:

**- turn towards loud noise**

**- turn towards moving objects**

**- follow slowly moving objects**

**- habituation**



principle of “parallel, loosely coupled processes”

zeal, MIT

lab (prev. MIT AI Lab)

# Kismet: The social interaction robot

Reflexes:

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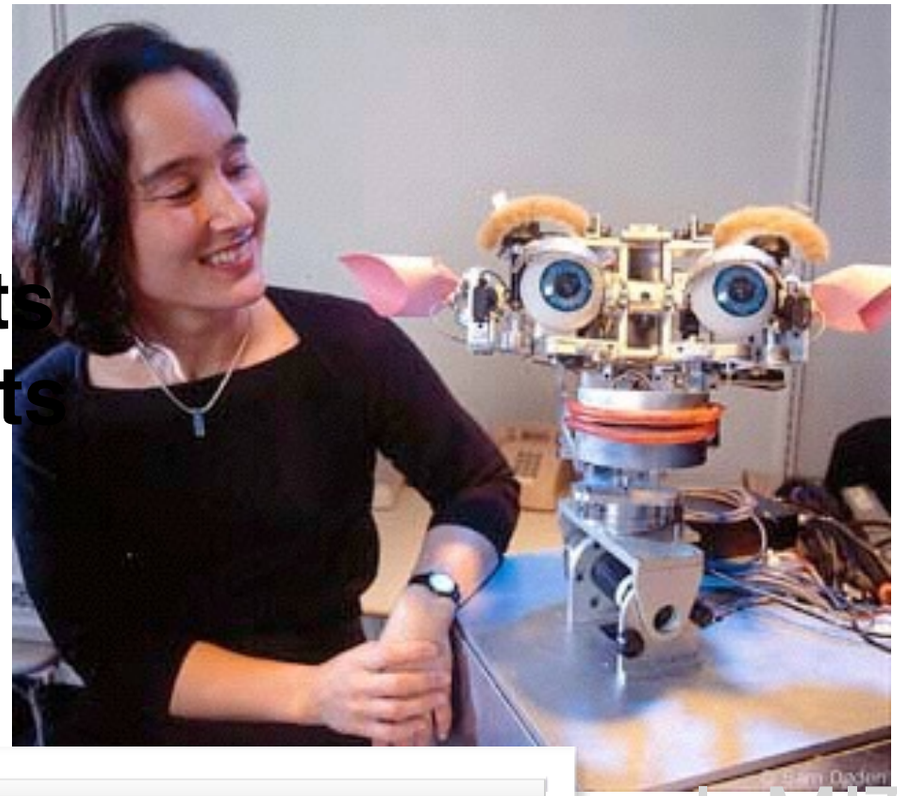


zeal, MIT

lab (prev. MIT AI Lab)

social competence: a collection of reflexes ?!?!???

# Scaling issue: the “Brooks-Kirsh” debate

**insect level —> human level?**

**David Kirsh (1991): “Today the earwig, tomorrow man?”**

**Rodney Brooks (1997): “From earwigs to humans.”**

# Scaling issue: the “Brooks-Kirsh” debate

**insect level —> human level?**

**David Kirsh (1991): “Today the earwig, tomorrow man?”**

**Rodney Brooks: “Fast, cheap and out of control” to humans**

volunteer for brief presentation on the “Brooks-Kirsh” debate - or generally, scalability of subsumption (on a later date)

# Today's topics

- short recap
- characteristics of complete agents
- illustration of design principles
- parallel, loosely coupled processes: the subsumption architecture"
- **case studies: "Puppy", biped walking**
- "cheap design" and redundancy

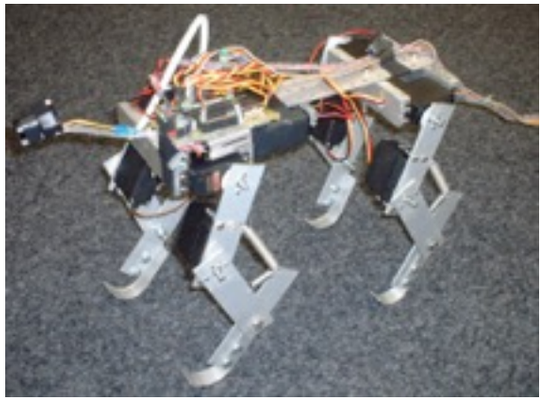
# Case study: “Puppy” as a complex dynamical

- **running: hard problem**
- **time scales: neural system — damped oscillation of knee-joint**
- **“outsourcing/offloading” of functionality to morphological/material properties**

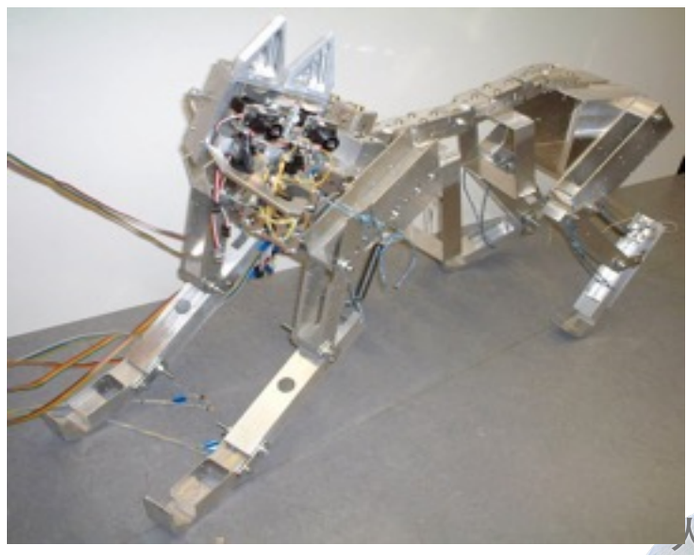
morphological computation

# Recall: “Puppy’s” simple control

**rapid locomotion in biological systems**



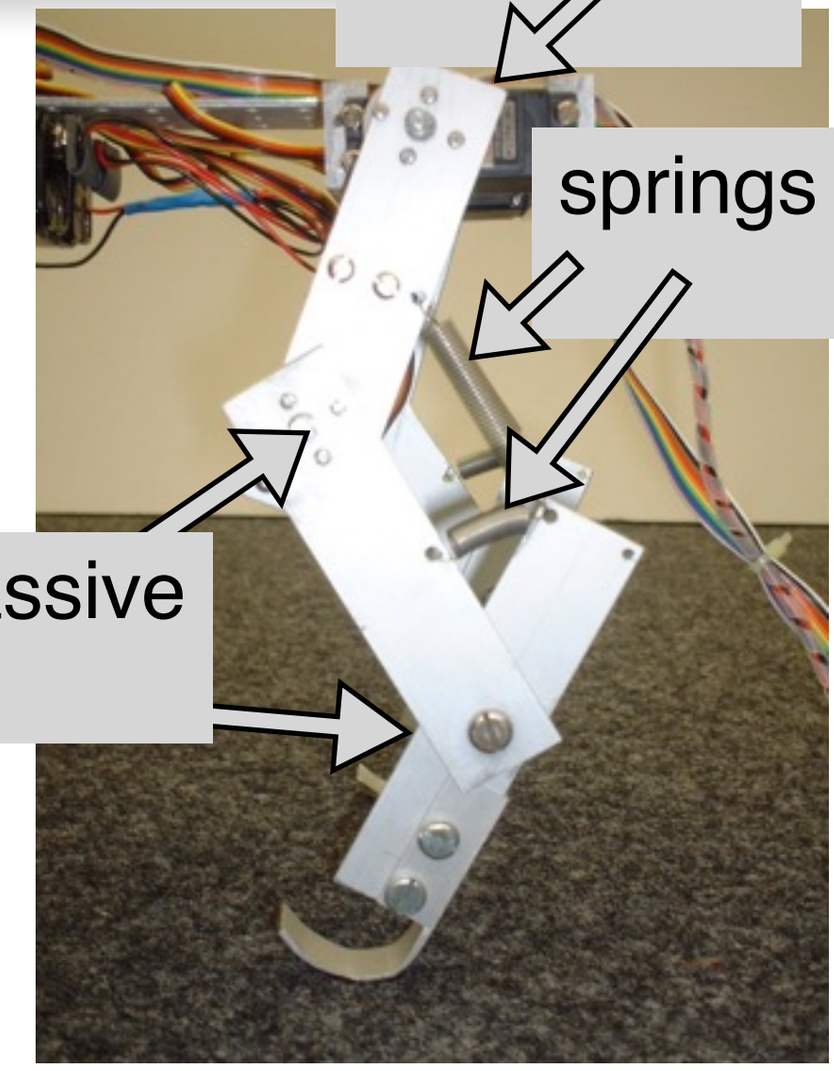
**recall: emergence of behavior**



Design and construction:
**Fumiya Iida, AI Lab, UZH and ETH-Z**

# Emergence of behavior: the quadruped “Puppy”

- **simple control (oscillations of “hip” joints)**
- **spring-like material properties (“under-actuated” system)**
- **self-stabilization, no sensors**
- **“outsourcing” of functionality**




→ morphological computation

# Self-stabilization: “Puppy” on a treadmill

Video “Puppy” on treadmill

# Self-stabilization: “Puppy” on a treadmill

Video “Puppy” on treadmill slow motion

- **no sensors**
- **no control**

self-stabilization

# Self-stabilization: “Puppy” on a treadmill

Video “Puppy” on treadmill slow motion

- **no sensors**
- **no control**

→ self-stabilization

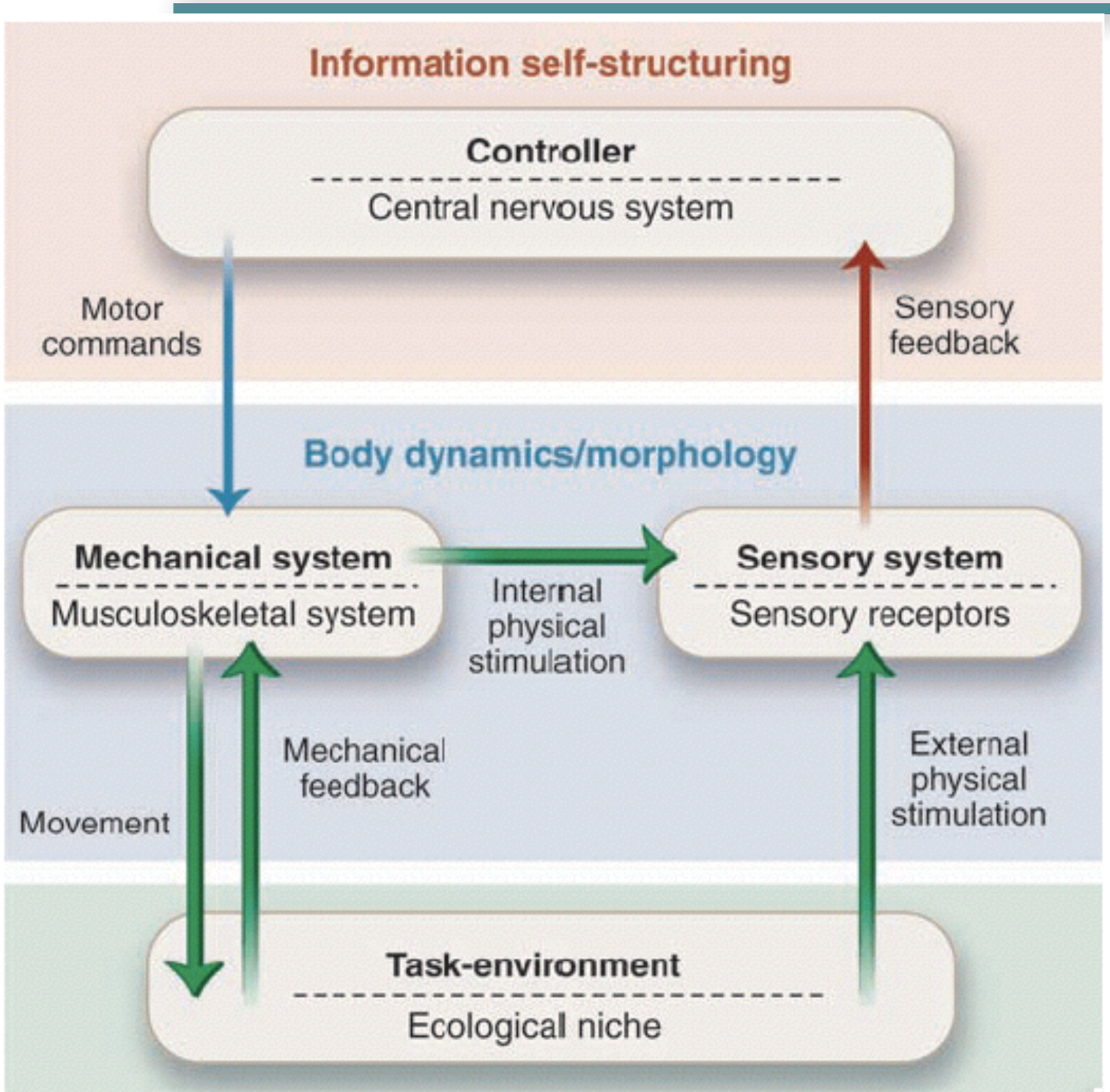
principle of “cheap design”

# The memory of the aplysia

Video “the memory of the aplysia”

a small brain in a vat?

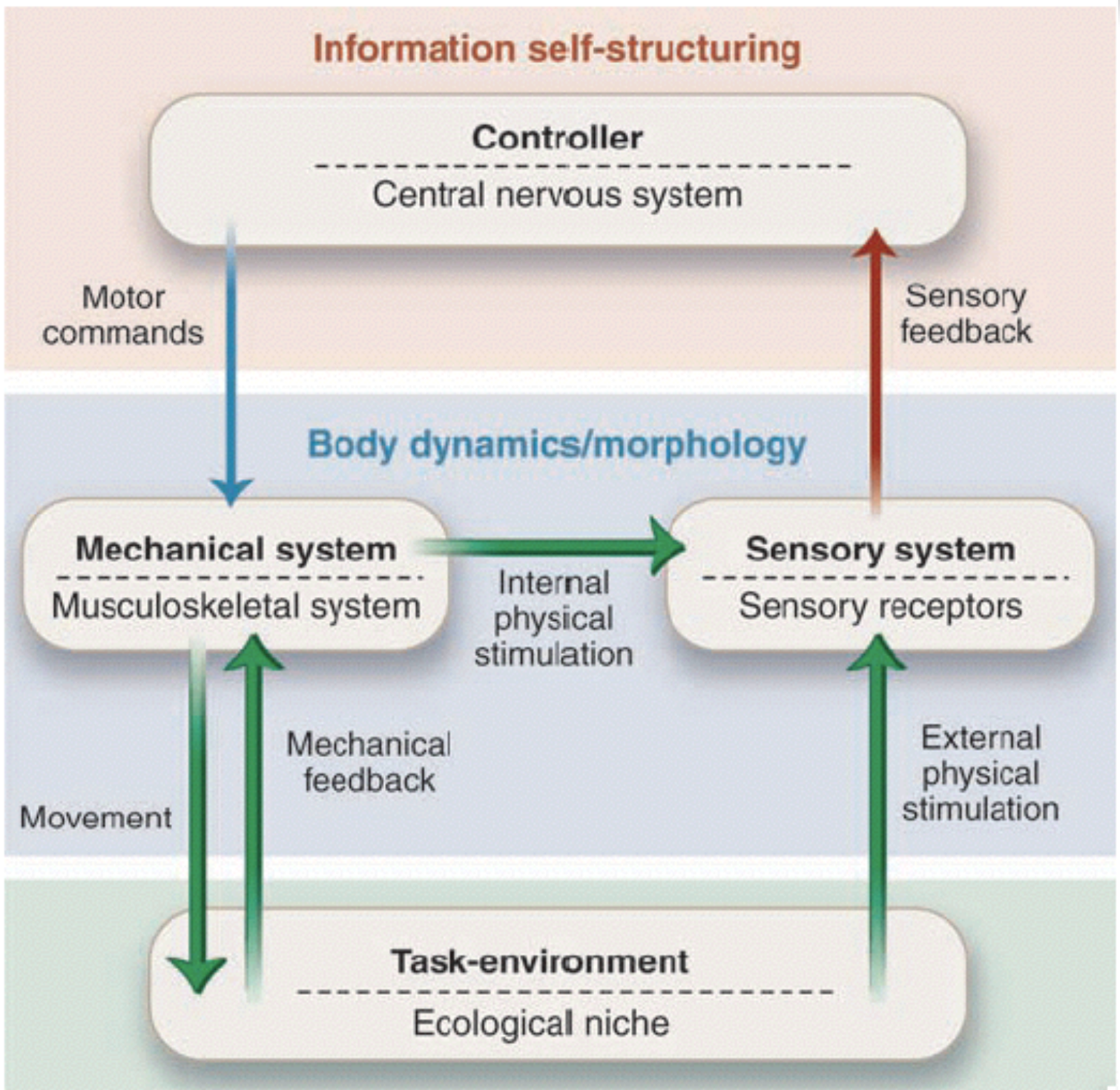
# Implications of embodiment




“Puppy”

Pfeifer et al.,Science, 16 Nov. 2007

# Implications of embodiment




"Puppy"

**which part of diagram is relevant?**

**—>**

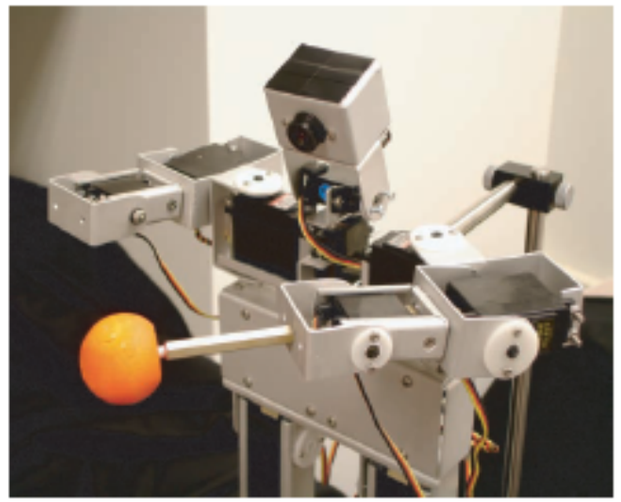
Pfeifer et al.,Science, 16 Nov. 2007

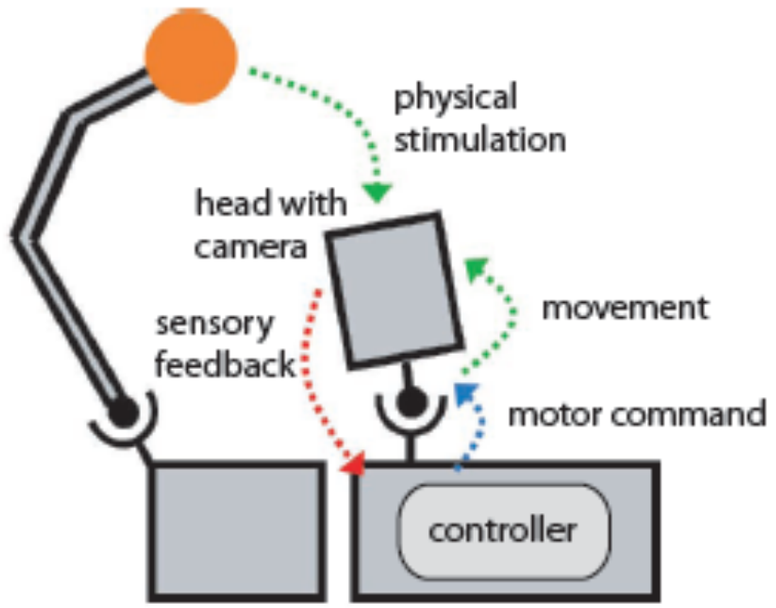
# How to quantify?

# Information self-structuring

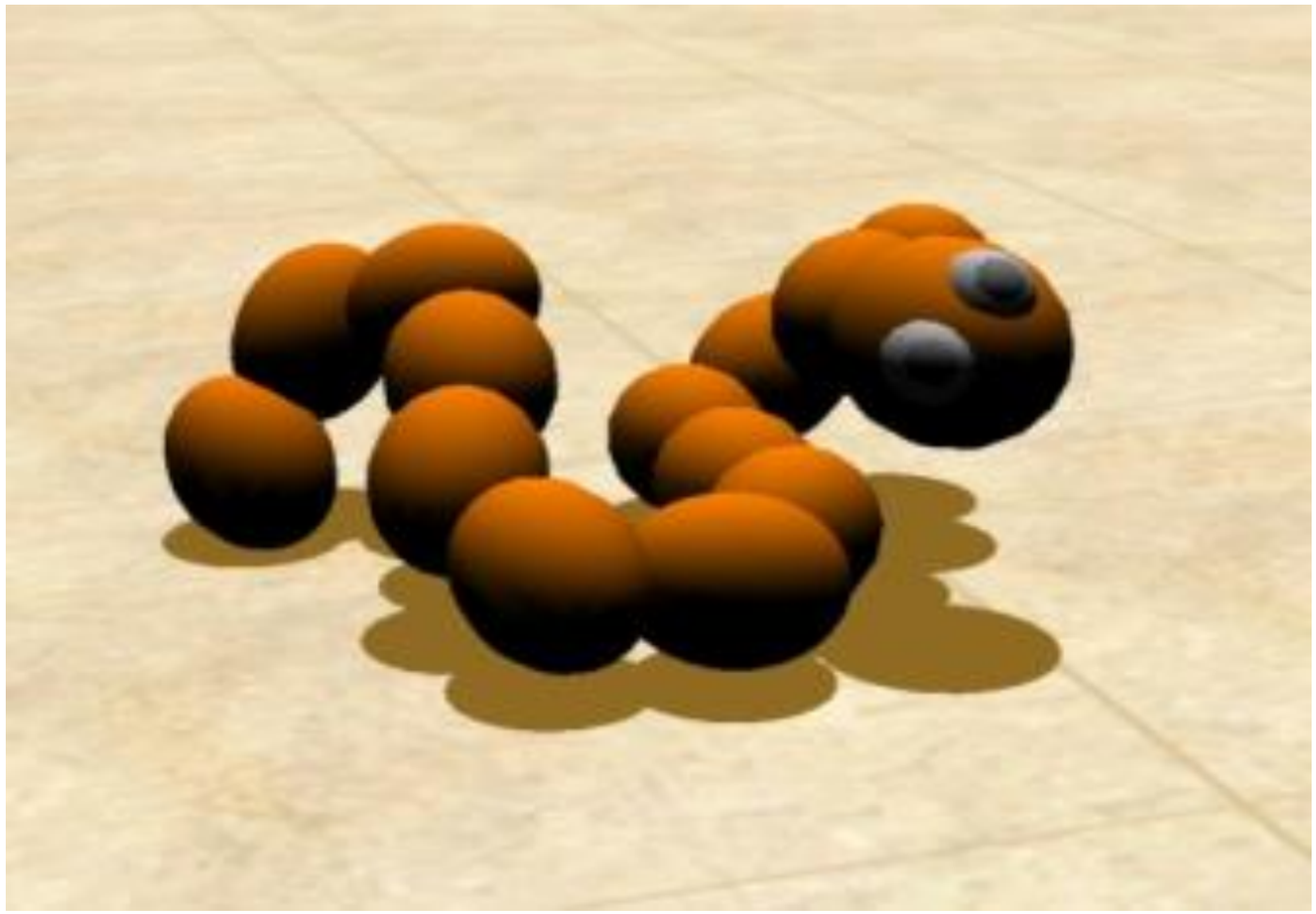
Experiments:

Lungarella and Sporns, **2006**
**Mapping information flow in sensorimotor networks**
**PLoS Computational Biology**



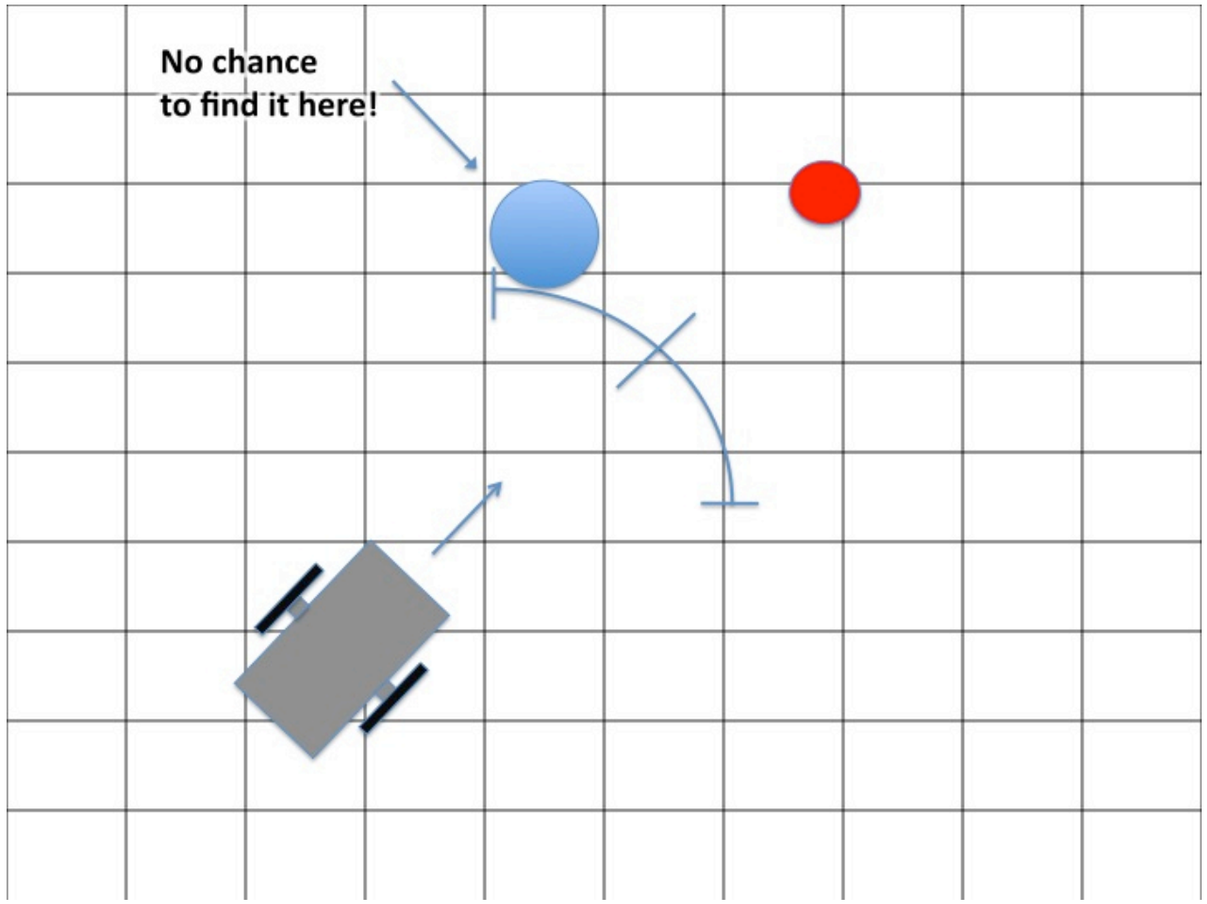


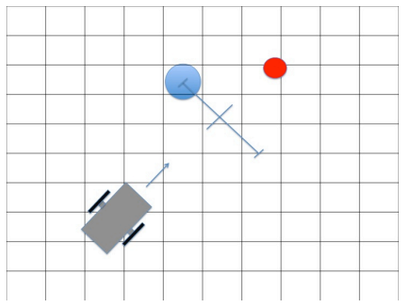
# Snakebot



see: **Tanev et. al, IEEE TRO, 2005**

# Maybe not GOF Euclidean space? :-)



see: **Bonsignorio, Artificial Life, 2013**

# Next lecture: From locomotion to cognition

- Check chapters 4 and 5 in “How the body …”

# End of lecture 3

**Thank you for your attention!**

**stay tuned for Lecture 4**

## “Cognition from scratch”