The Shanghai Lectures 2019

HeronRobots *Pathfinder Lectures*

Natural and Artificial Intelligence in Embodied Physical Agents

[redacted]

The ShanghAI Lectures

An experiment in global teaching

Fabio Bonsignorio
The ShanghAI Lectures and Heron Robots

欢迎您参与
“来自上海的人工智能系列讲座”

Lecture 2

Embodiment: Concept and Models

7 November 2019

Today’s topics

- short recap
- The classical approach: Cognition as computation
- Successes and failures of the classical approach
- Some problems of the classical approach
- The need for an embodied approach

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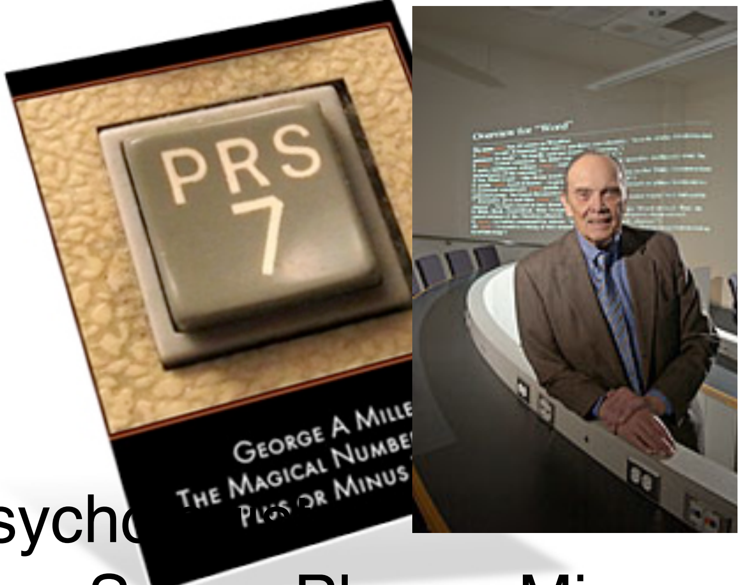
“Birth” of AI, 1956



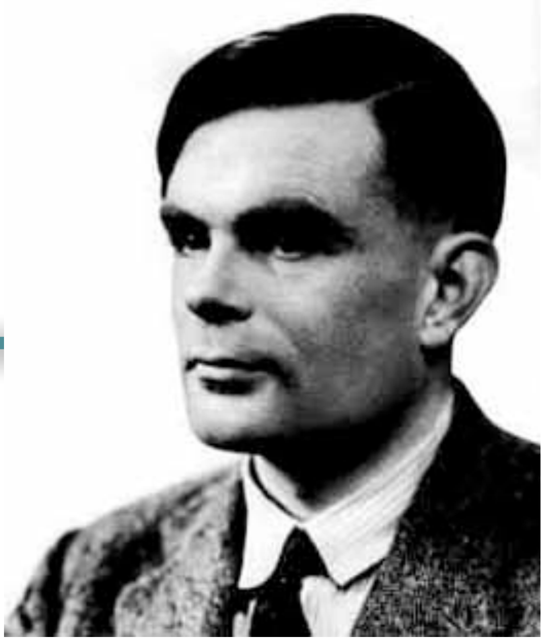
George A. Miller, Psycho
“The Magical Number Seven Plus or Minus Two”

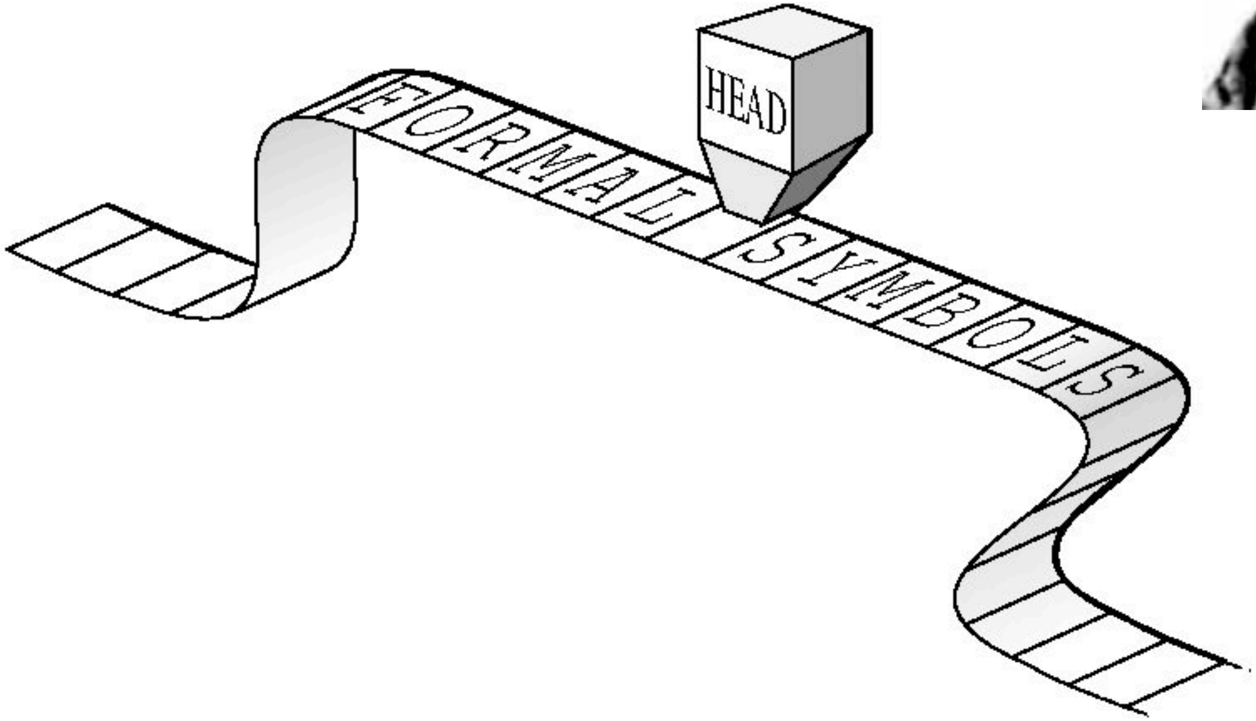
John McCarthy, Computer Scientist
Initiator of Artificial Intelligence

Herbert Simon
and Allen Newell
The “Logic Theorist”

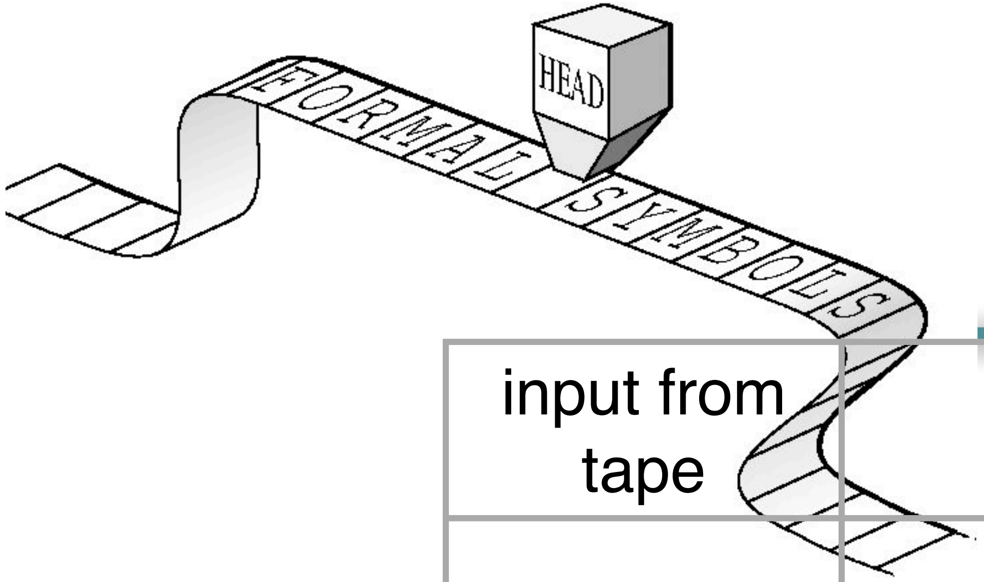
Noam Chomsky,
Linguist
“Syntactic Structures”

Turing Machine (1)





Turing Machine (2)



input from tape	1	2	state of read/write
_	_R2	HALT	
A	AL1	BR2	
B	BL1	AR2	
C	CL1	CR2	

write on tape

move tape L/R

next state of r/w head

initial situation: state r/w head = 1

initial content of tape:

.	.	.	A	A	B	A	A	C	C	C	C	A	B	A	C	C	C	C	B	B	A	B	.	.	.

r/w head initial pos.

input from tape	1	2	state of read/write
_	_R2	HALT	
A	AL1	BR2	
B	BL1	AR2	
C	CL1	CR2	

write on tape move tape L/R

next state of r/w head

Turing Machine (4)

initial situation: state r/w head = 1

initial content of tape:

		A	A	B	A	A	C	C	C	C	A	B	A	C	C	C	C	B	B	A	B					

r/w head initial pos.

input from tape	1	2	state of read/write
_	_R2	HALT	
A	AL1	BR2	
B	BL1	AR2	
C	CL1	CR2	

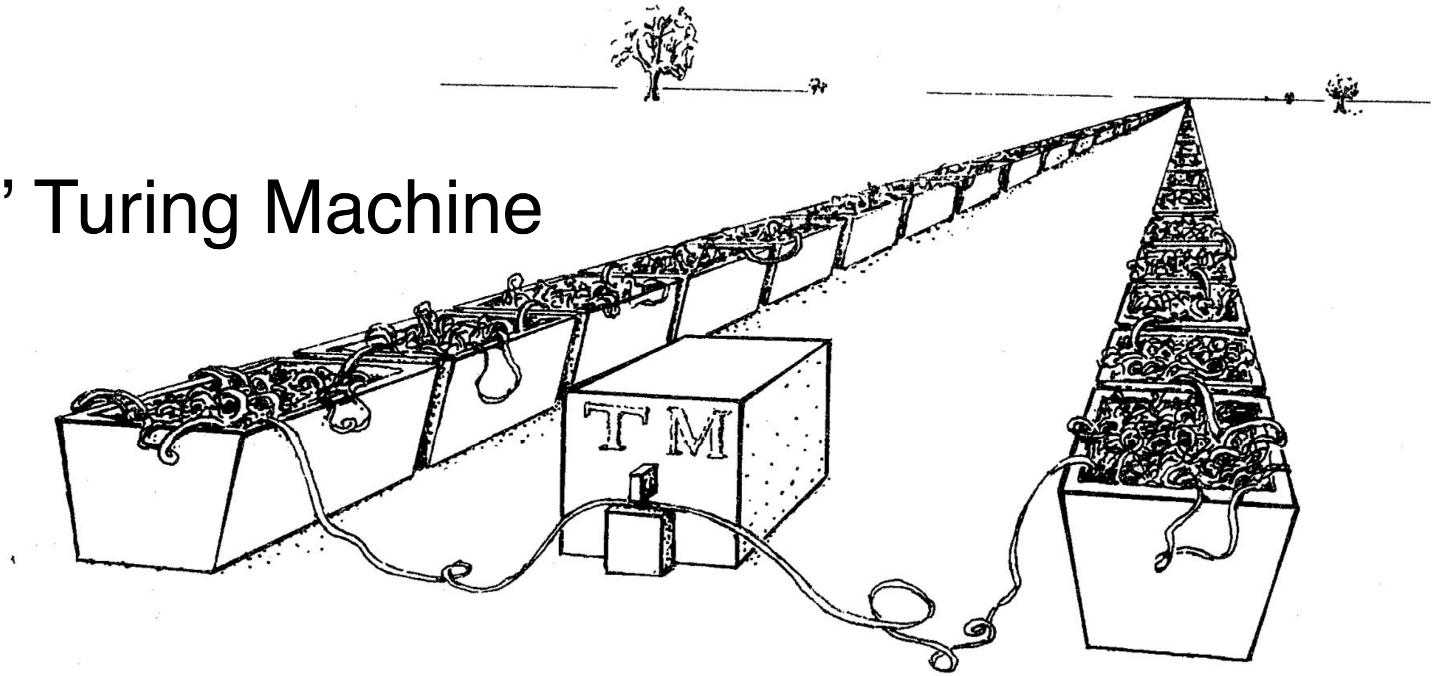
write on tape move tape L/R

next state of r/w head

The Universal Turing Machine

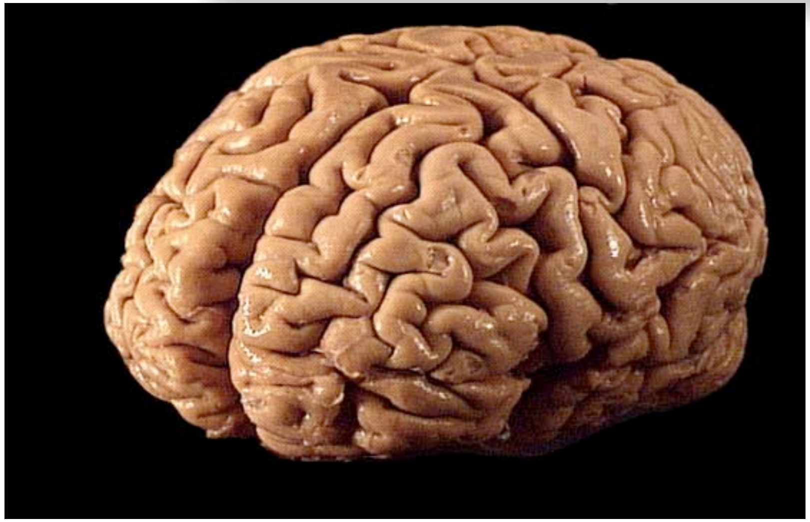
Turing Machine (5)

an “embodied” Turing Machine



Cartoon by
Roger Penrose

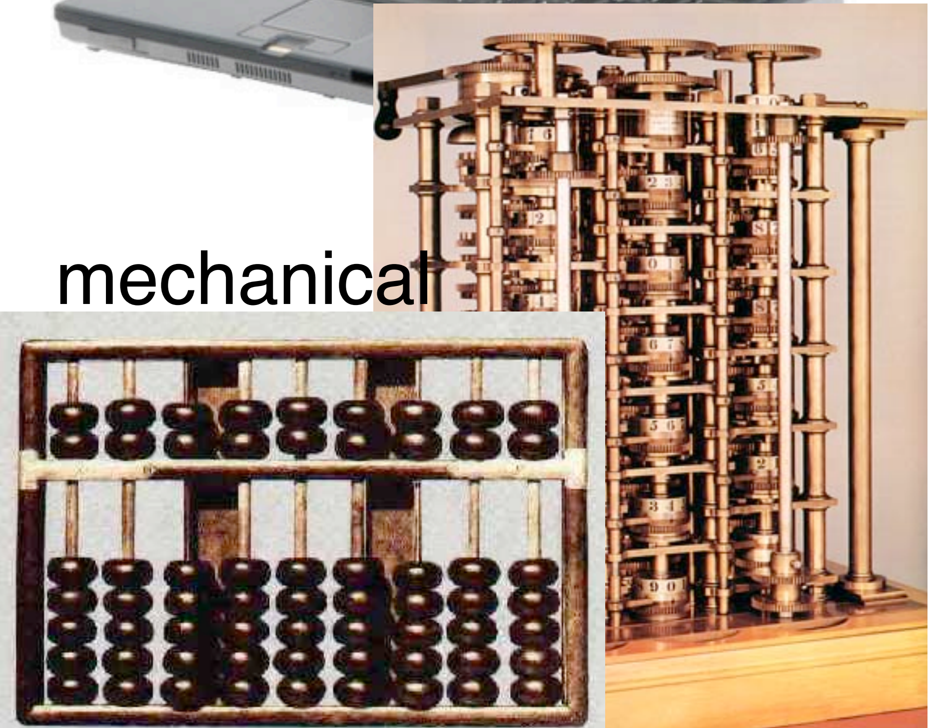
Functionalism and the “Physical Symbol Systems



biological

electronic

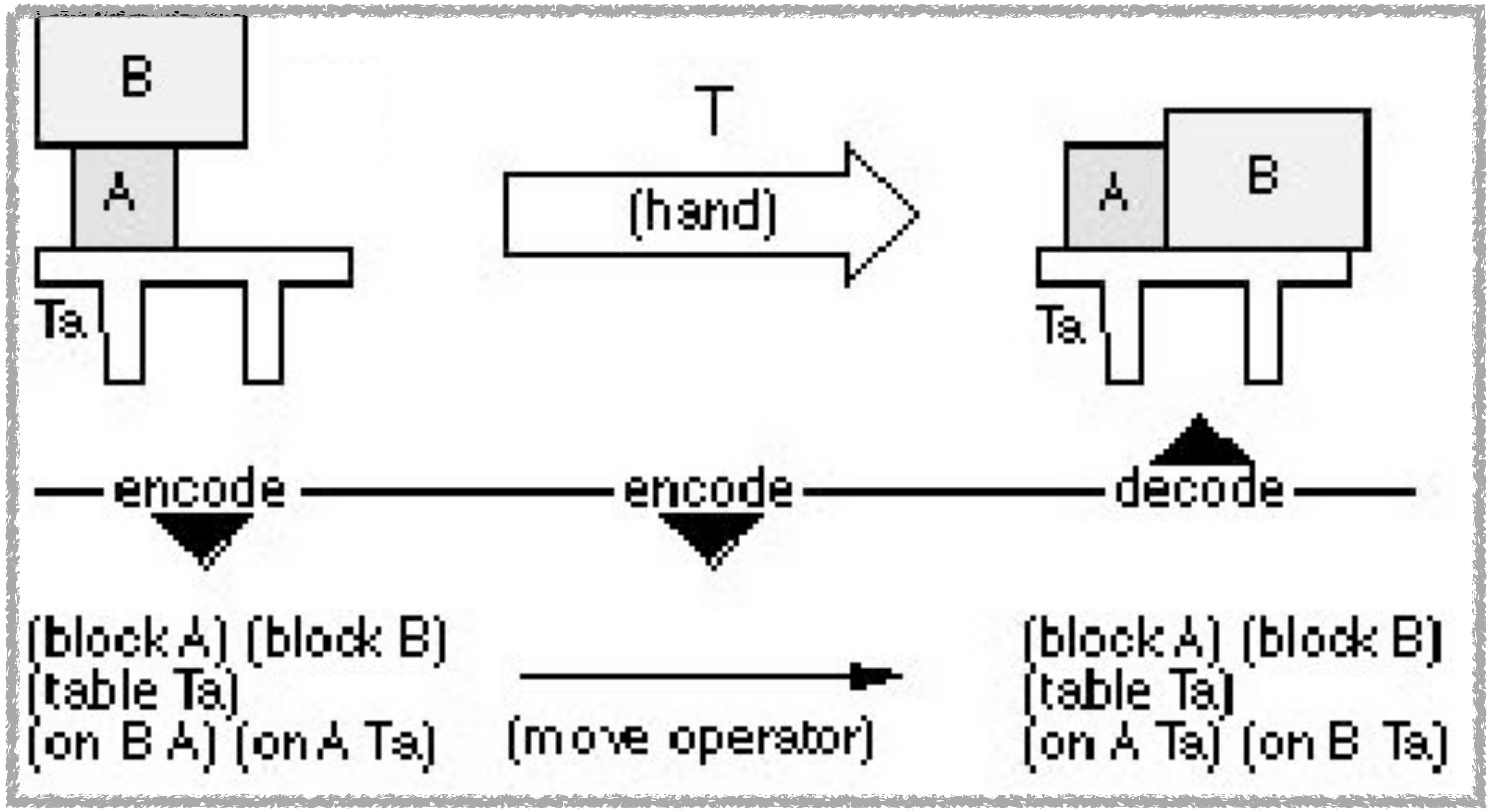
Swiss cheese
Hilary Putnam
(American
Philosopher)



mechanical

Functionalism and the “Physical Symbol Systems

Model/Representation:



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Classical AI: Research areas

- problem solving
- knowledge representation and reasoning
- acting logically
- uncertain knowledge and reasoning
- learning and memory
- communicating, perceiving and acting
- (adapted from Russell/Norvig: Artificial intelligence, a modern approach)

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Classical AI: Successes

- search engines
- formal games (chess!)
- text processing systems/translation —> next week
- data mining systems
- restricted natural language systems
- appliances
- manufacturing

Indistinguishable from computer applications in general

Chess: New York, 1997

1 win 3 draws 2 wins

Classical AI: Failures

- recognizing a face in the crowd
- vision/perception in the real world
- common sense
- movement, manipulation of objects
- walking, running, swimming, flying
- speech (everyda

in general:
more natural forms of intelligence

Why is perception hard?

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Fundamental problems of the classical approach

Monika Seps, chess maste
former master student
AI Lab, Zurich

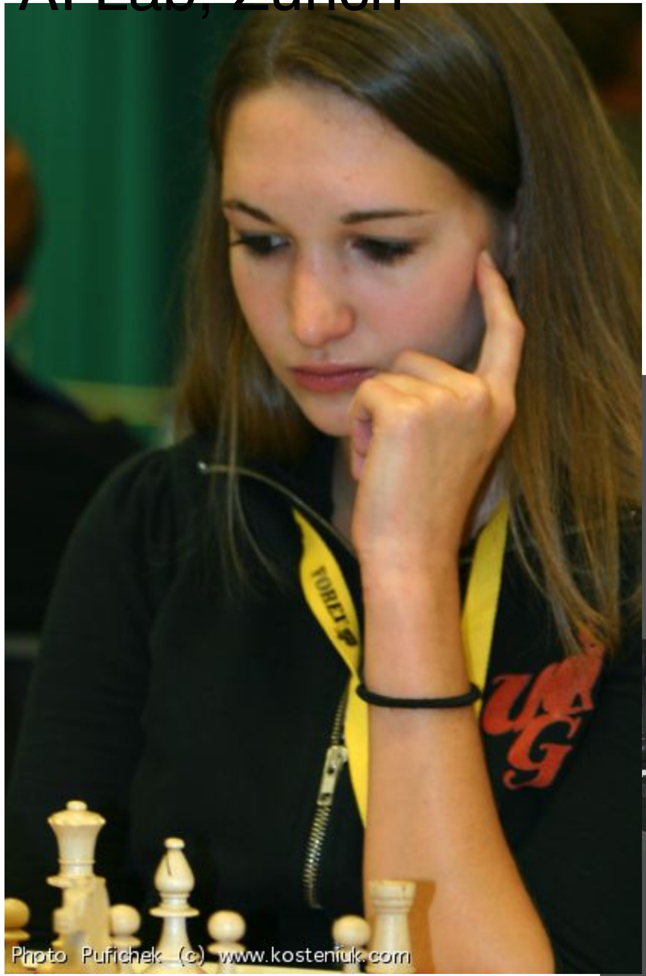
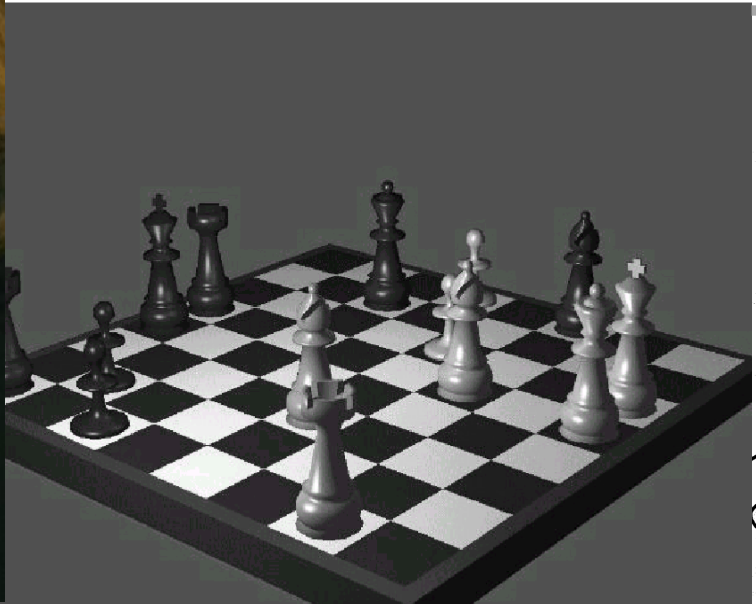


Photo Pufichek (c) www.kosteniuk.com

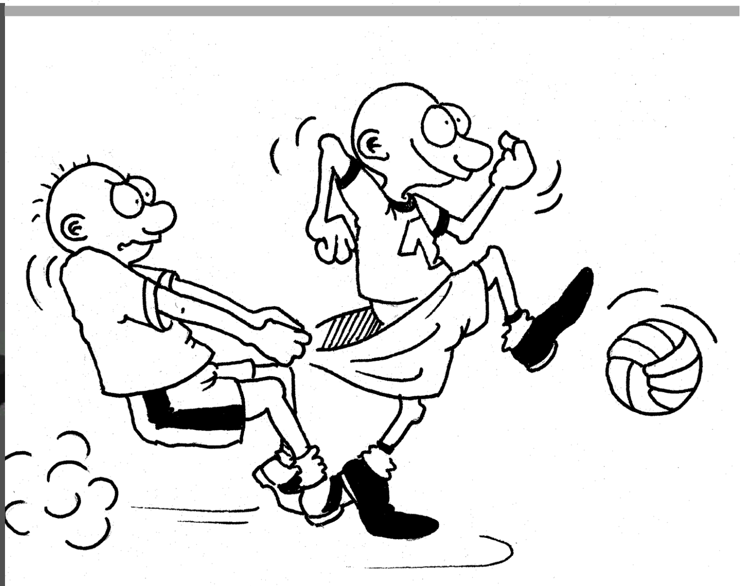
in general:
anything to do with real world interaction

fundamental differences: real — virtual

virtual, formal world



real world



Fundamental problems of the classical approach

in general:
anything to do with real world interaction

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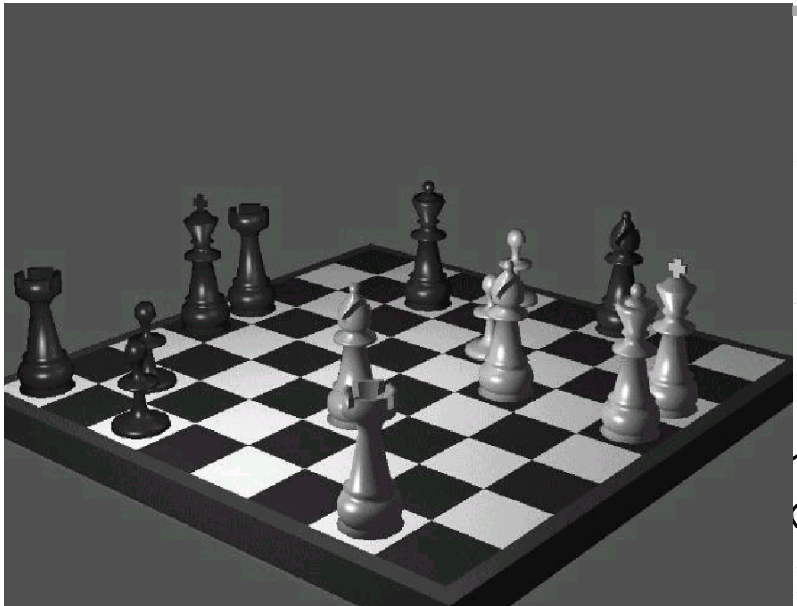
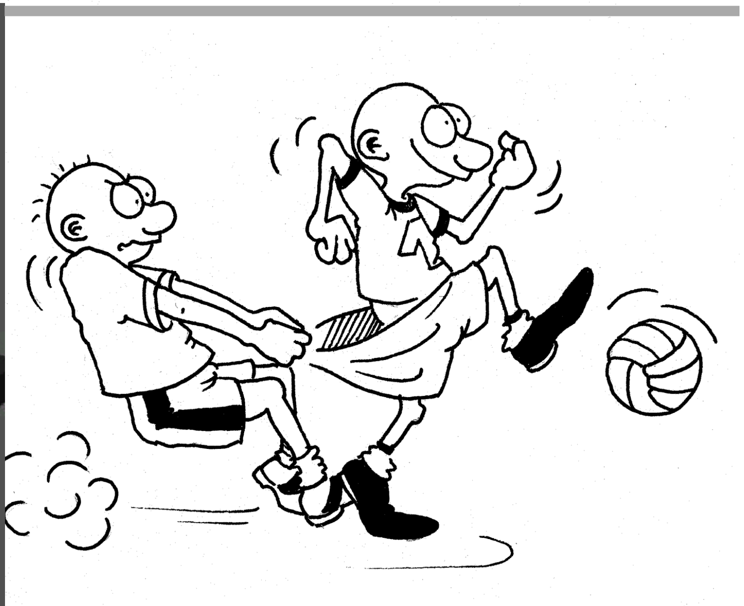


real world



Differences real vs. virtual worlds

Successes and failures of the classical approach

successes

applications (e.g. Google)

chess

manufacturing

(applications:“controlled”artificial worlds)

failures

foundations of behavior

natural forms of intelligence

interaction with real world

Industrial environments vs. real world

industrial environments

environment well-known

little uncertainty

predictability

(“controlled”artificial worlds)

real world environment

limited knowledge and predictability

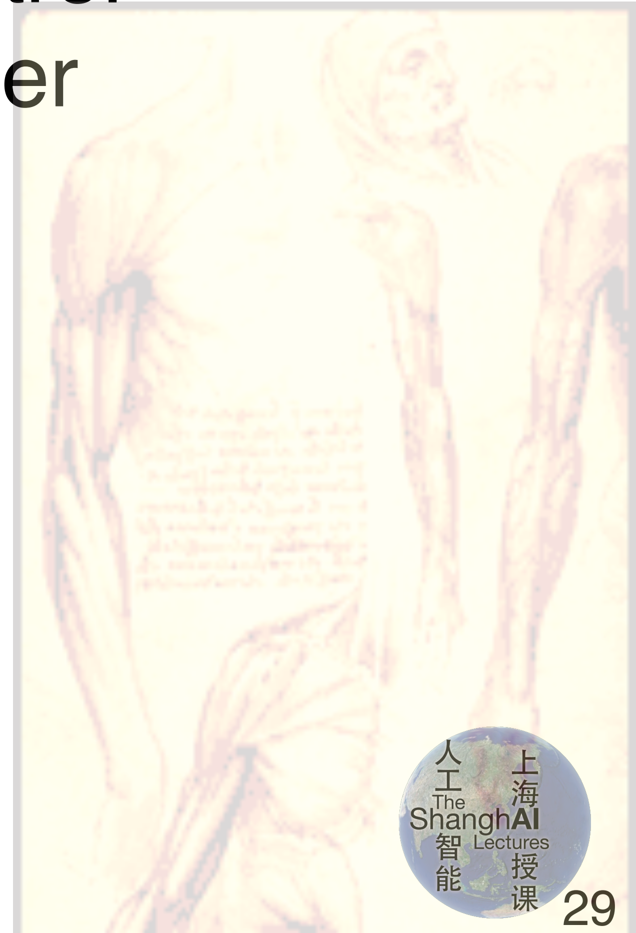
rapidly changing

high-level of uncertainty

Industrial robots vs. natural systems

Industrial robots

principles:
- strong, precise, fast motors
- centralized control
- computing power
- optimization



Industrial robots vs. natural systems

principles:

- low precision
- compliant
- reactive
- coping with uncertainty

humans

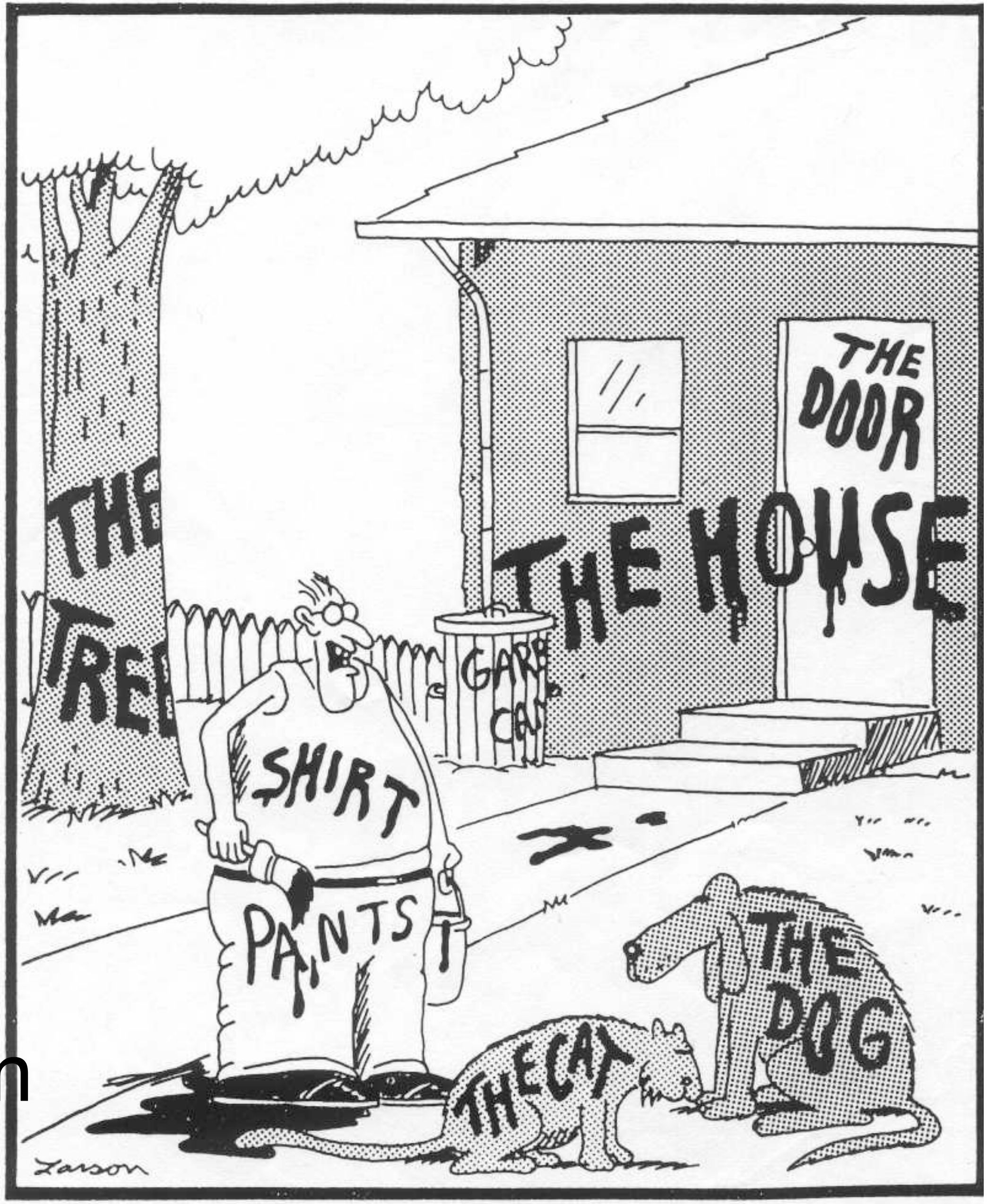
→ no direct transfer of methods

Fundamental problems of classical approach

- “symbol grounding problem”
- “frame problem”
- “homunculus problem”

The “symbol grounding” problem

real world:
doesn’t come
with labels ...

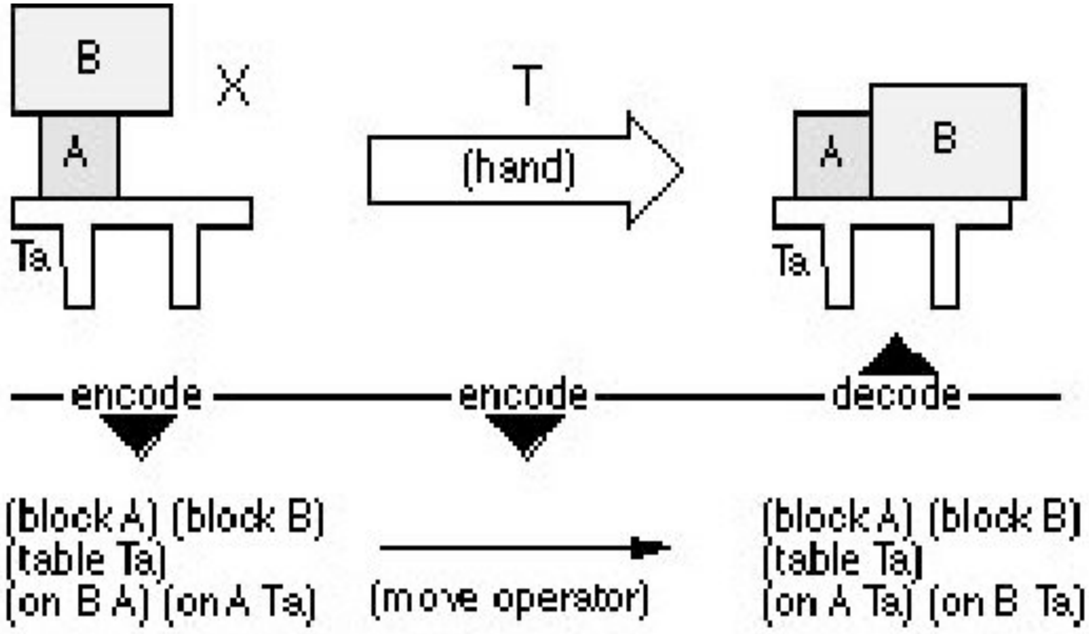


“Now! ... *That* should clear up a few things around here!”

Gary Larson

The “frame problem”
Maintaining model of real world

- the more detailed the harder
- information acquisition
- most changes: irrelevant to current situation



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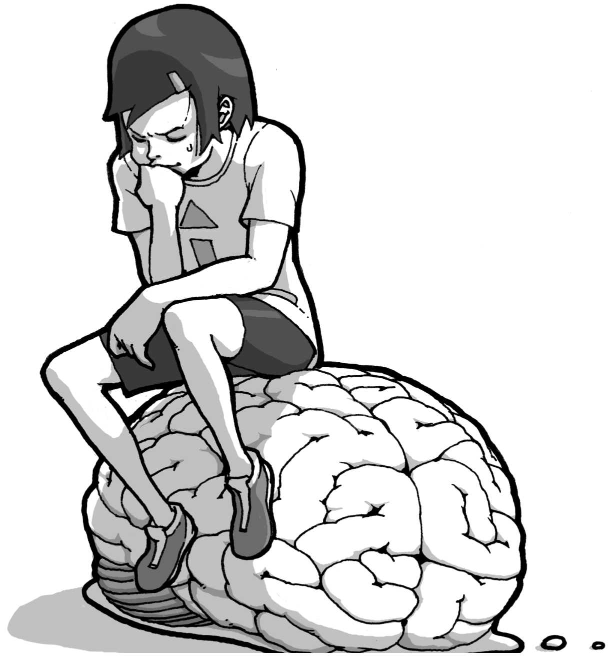
Two views of intelligence

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:

The need for an embodied perspective

“Why do plants not have brains?”

The need for an embodied perspective

“Why do plants not have brains? The answer is actually quite simple — they don’t have to move.” Lewis Wolpert, UCL

evolutionary perspective on development of intelligence/cognition

The need for an embodied perspective

- “failures” of classical AI
- fundamental problems of classical approach
- Wolpert’s quote: Why do plants not …?
- Interaction with environment: always mediated by body

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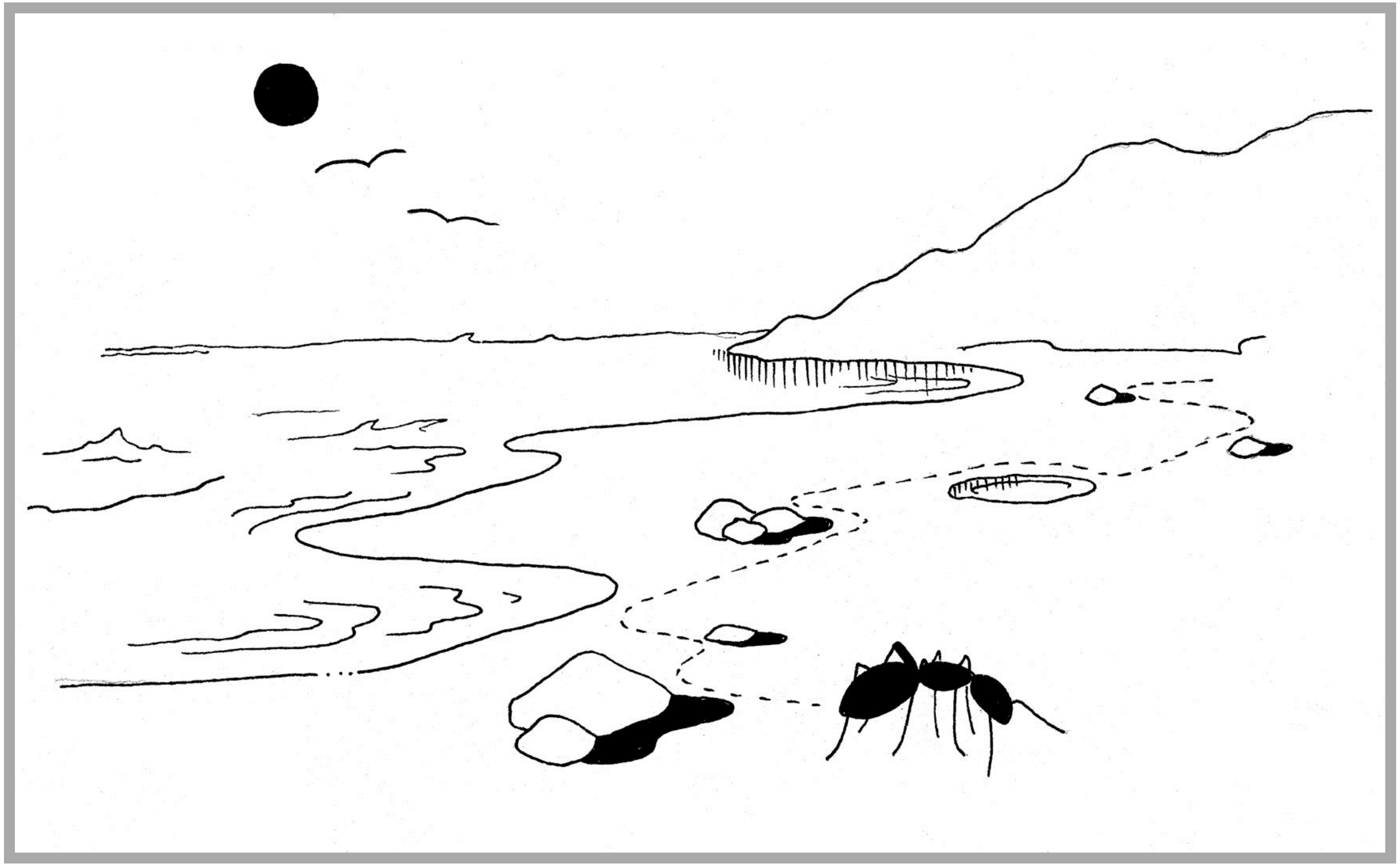
The “frame-of-reference” problem — introduction

Video “Heider and Simmel”

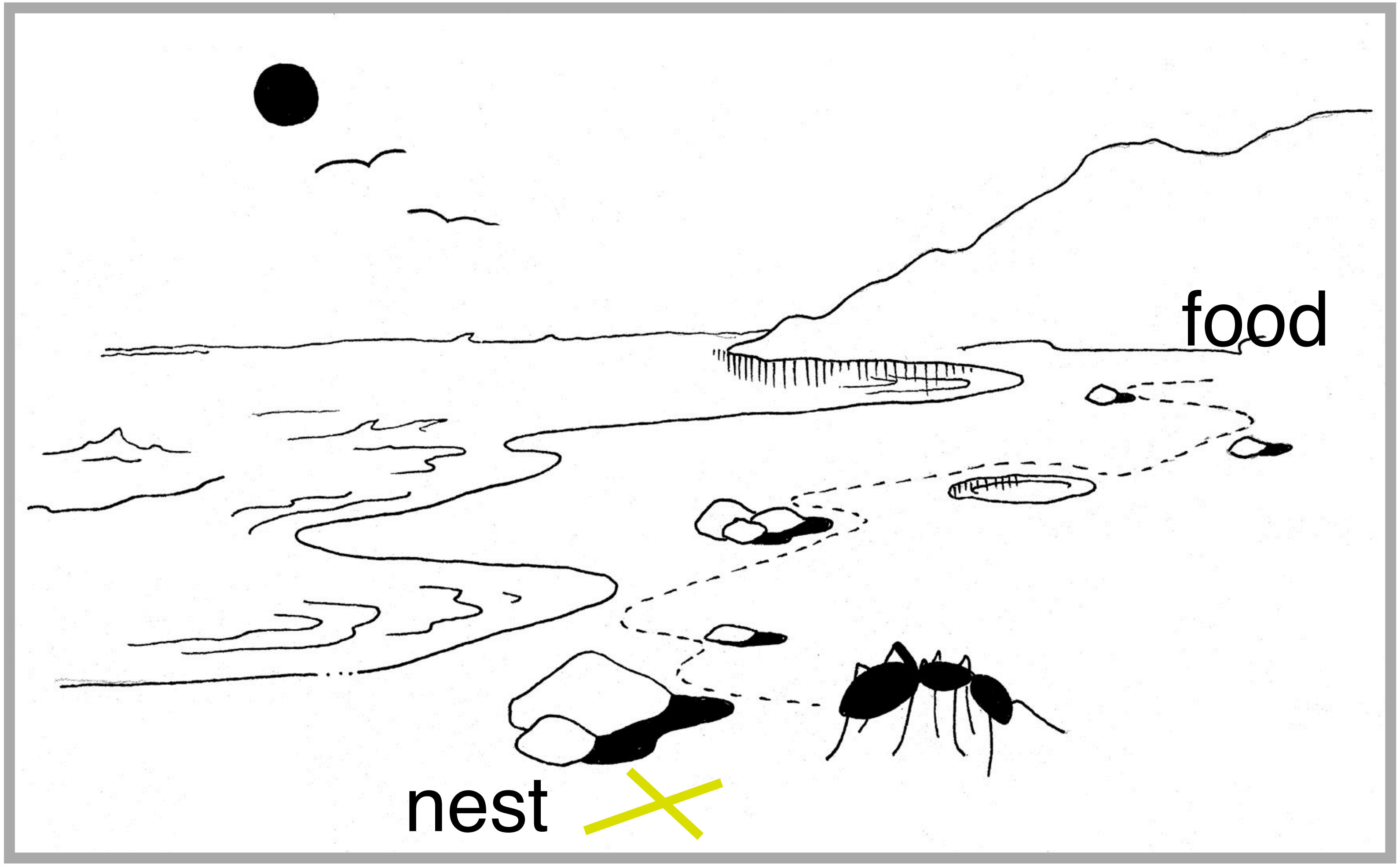
The “frame-of-reference” problem — introduction

Video “Heider and Simmel”

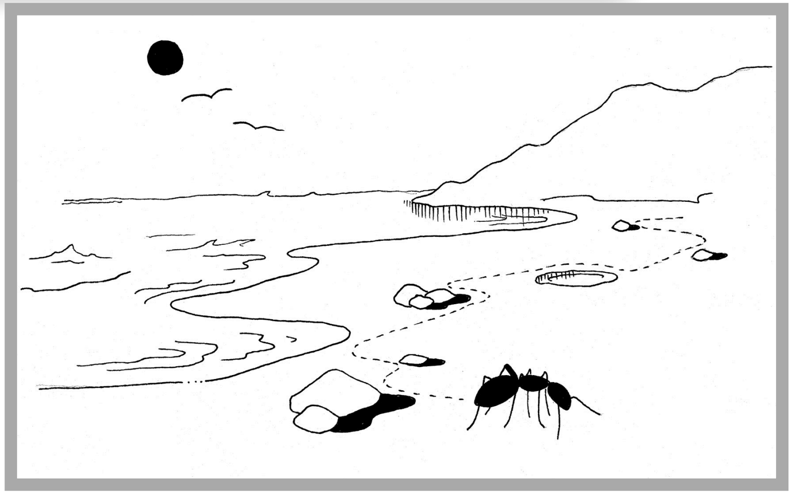
“Frame-of-reference” Simon’s ant on the beach



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

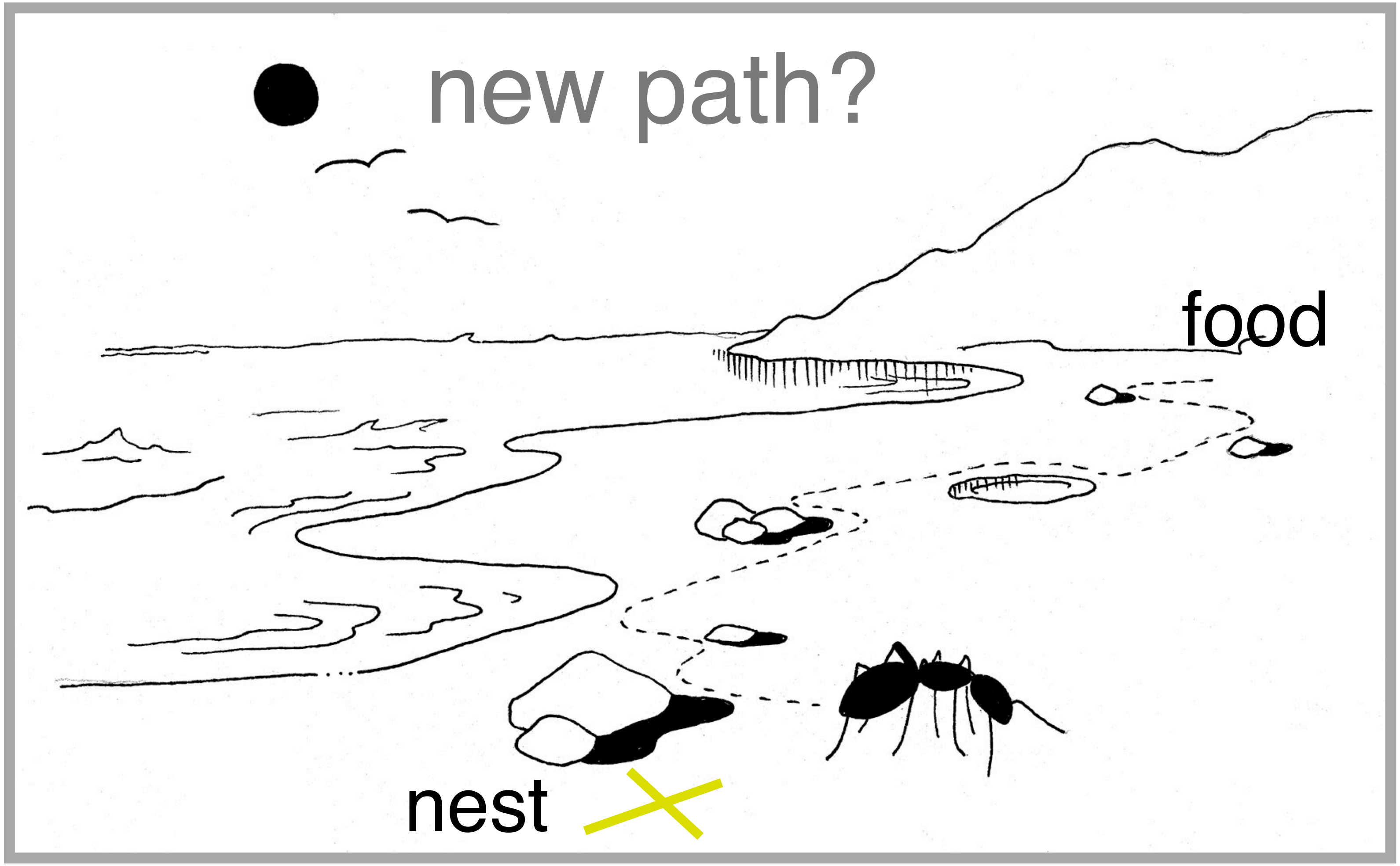


“Frame-of-reference”
Simon’s ant on the beach



- simple behavioral rules
- complexity in interaction,
  not — necessarily — in brain
- thought experiment:
  increase body by factor of 1000

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



“Frame-of-reference”
F-O-R

- perspectives issue
- behavior vs. mechanism issue
- complexity issue

“Frame-of-reference” F-O-R

- perspectives issue
- behavior vs. mechanism issue
- complexity issue

Intelligence:

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?”

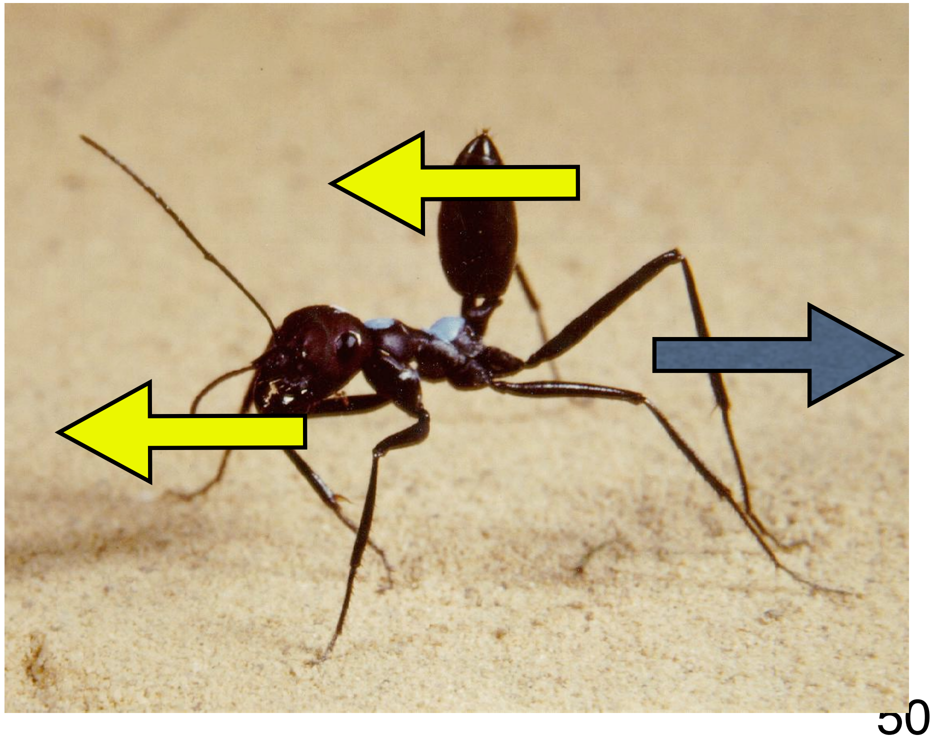
Communication through interaction with environment

- exploitation of interaction with environment

→ simpler neural circuits

angle sensors
in joints

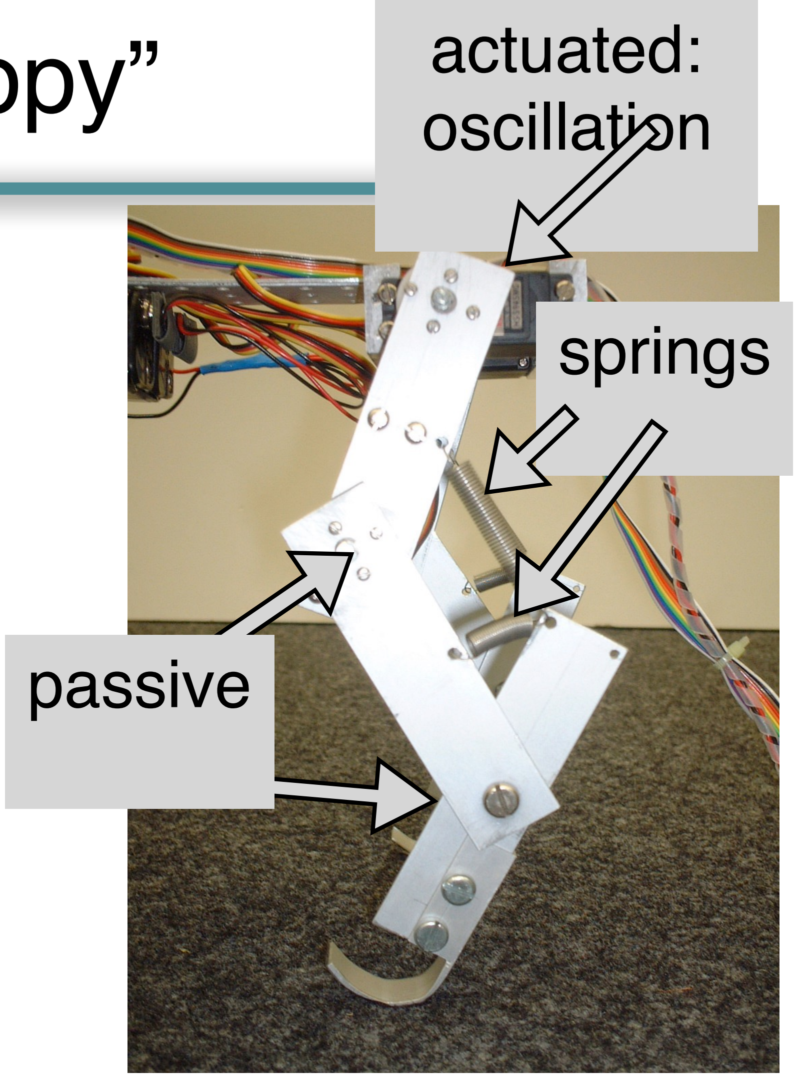
“parallel, loosely coupled processes”



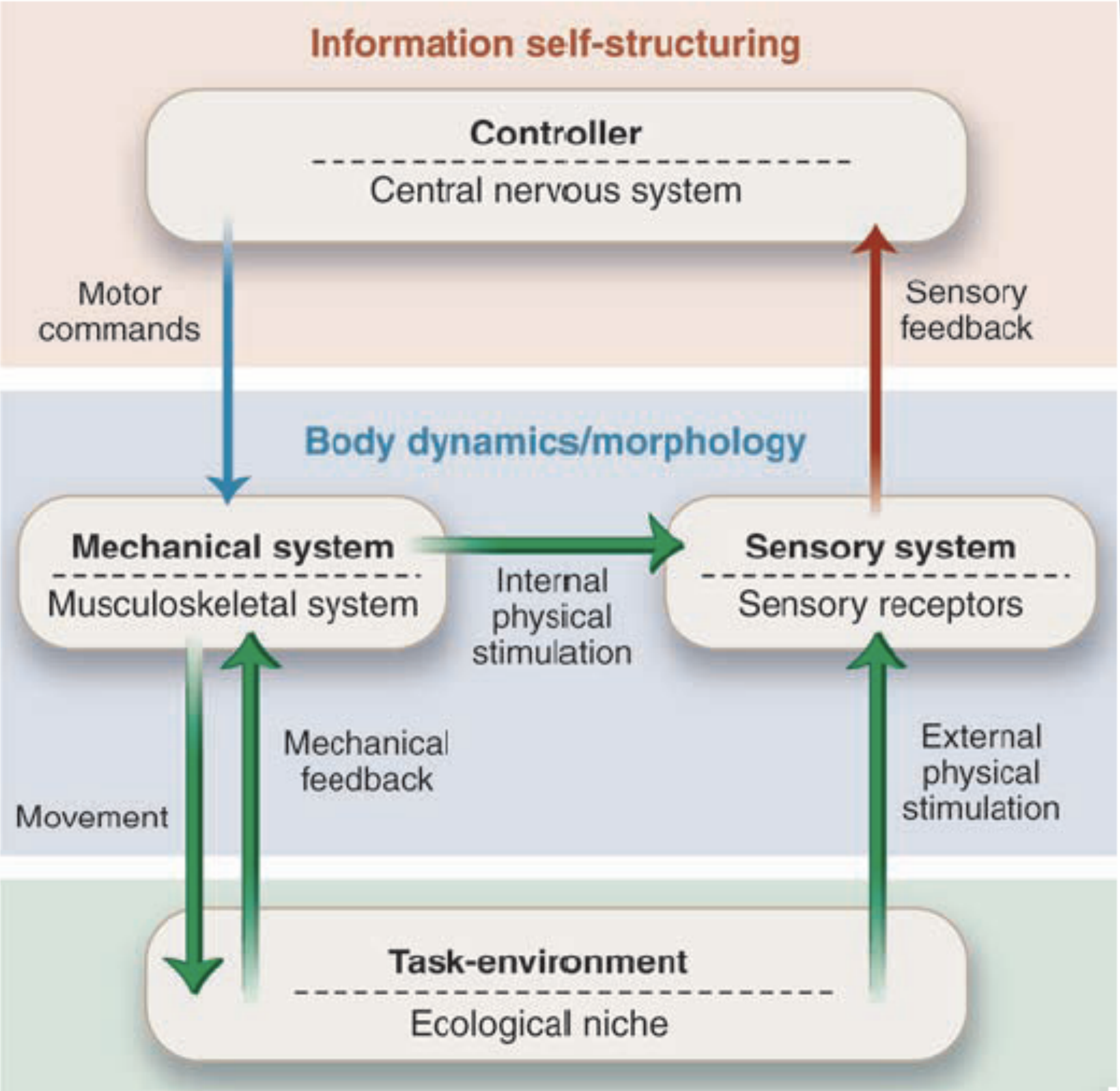
Emergence of behavior: the quadruped "Puppy"

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

→ morphological computation



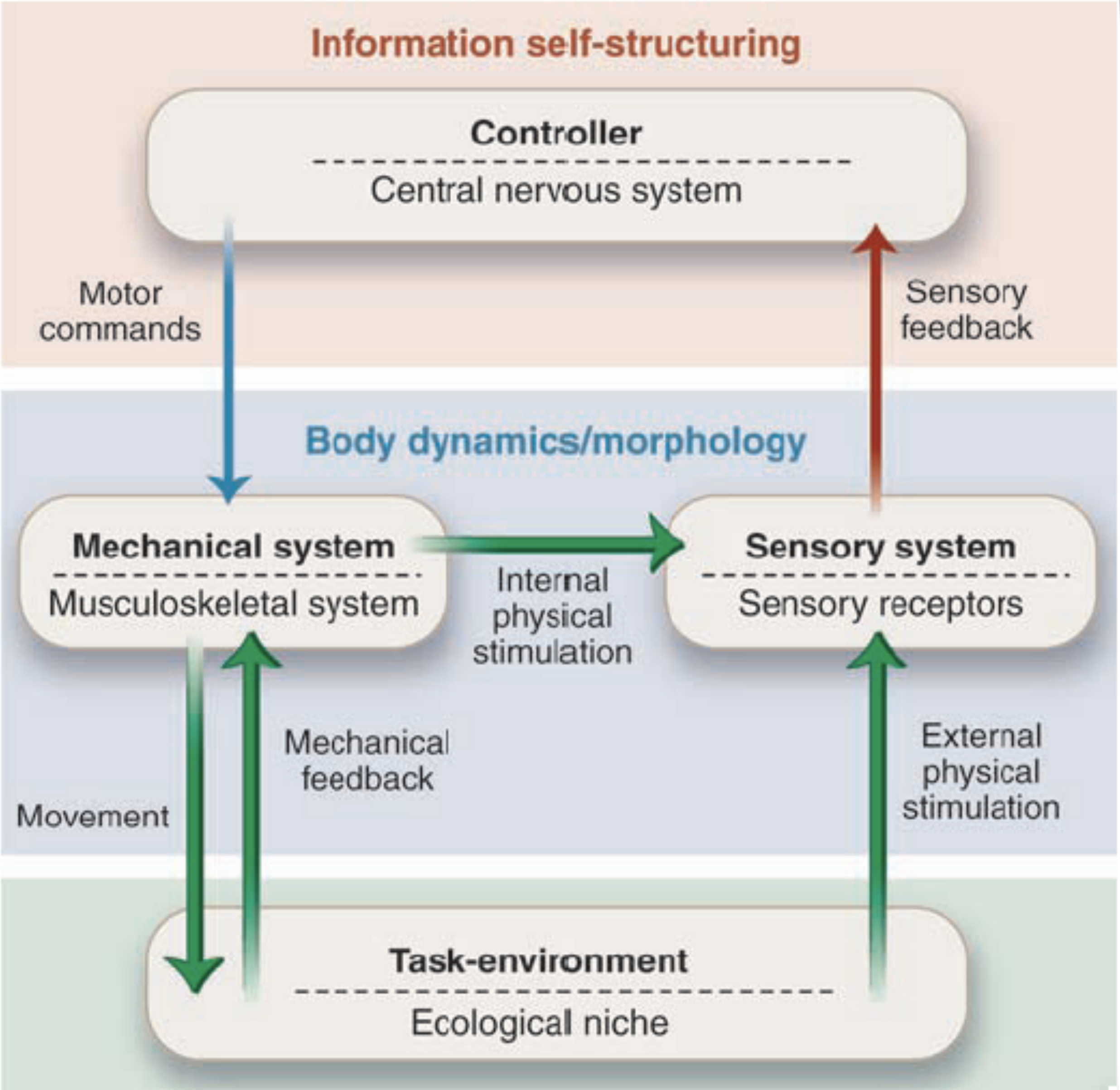
Implications of embodiment
Self-stabilization



“Puppy”, But Also Cru

Pfeifer et al.,Science, 16 Nov. 2007

Implications of embodiment
Self-stabilization

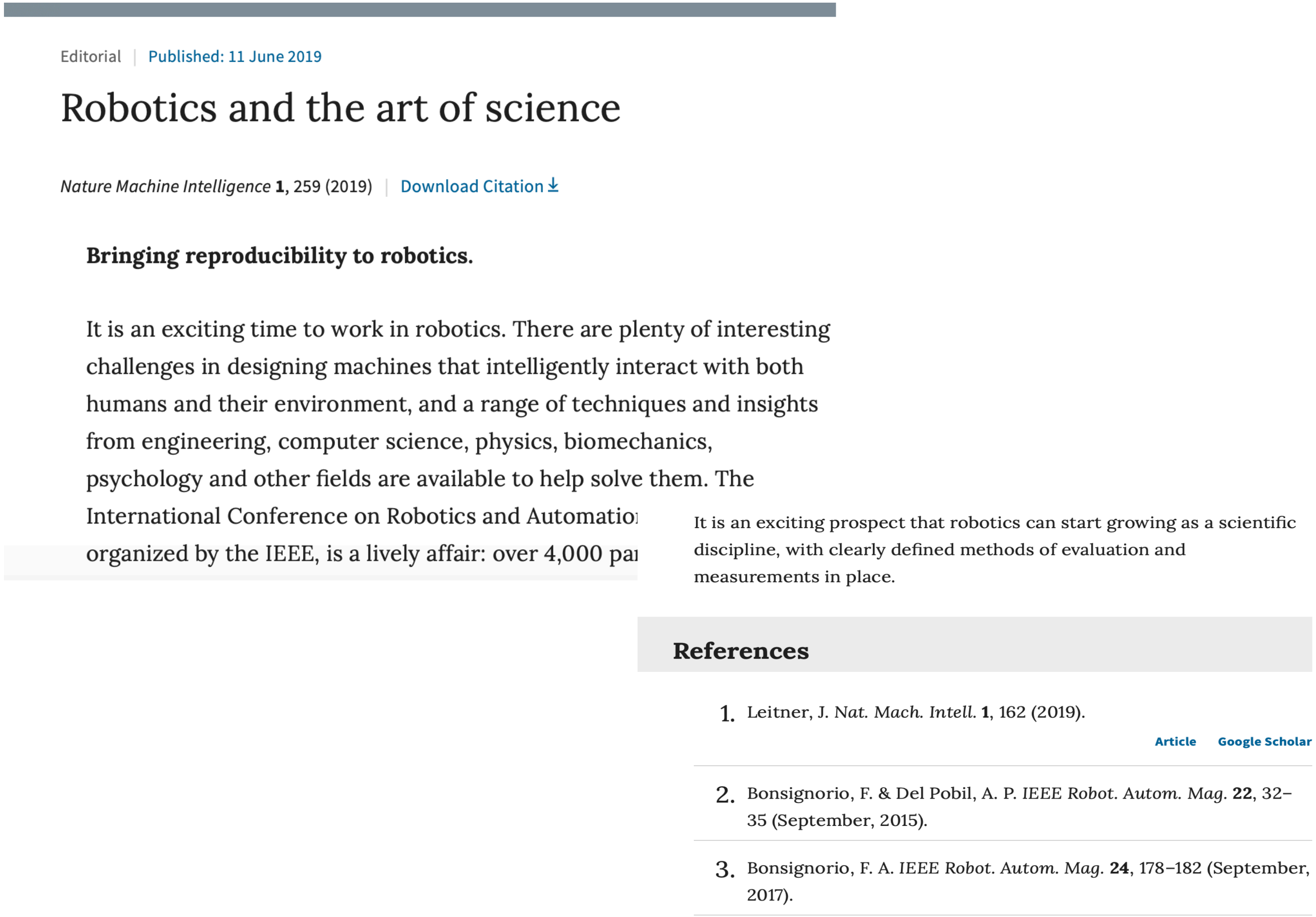


“Puppy”

which part of diagram is relevant? —>

Pfeifer et al.,Science, 16 Nov. 2007

Can be complemented by



Editorial | Published: 11 June 2019

Robotics and the art of science

Nature Machine Intelligence **1**, 259 (2019) | Download Citation

Bringing reproducibility to robotics.

It is an exciting time to work in robotics. There are plenty of interesting challenges in designing machines that intelligently interact with both humans and their environment, and a range of techniques and insights from engineering, computer science, physics, biomechanics, psychology and other fields are available to help solve them. The International Conference on Robotics and Automatio organized by the IEEE, is a lively affair: over 4,000 pa

It is an exciting prospect that robotics can start growing as a scientific discipline, with clearly defined methods of evaluation and measurements in place.

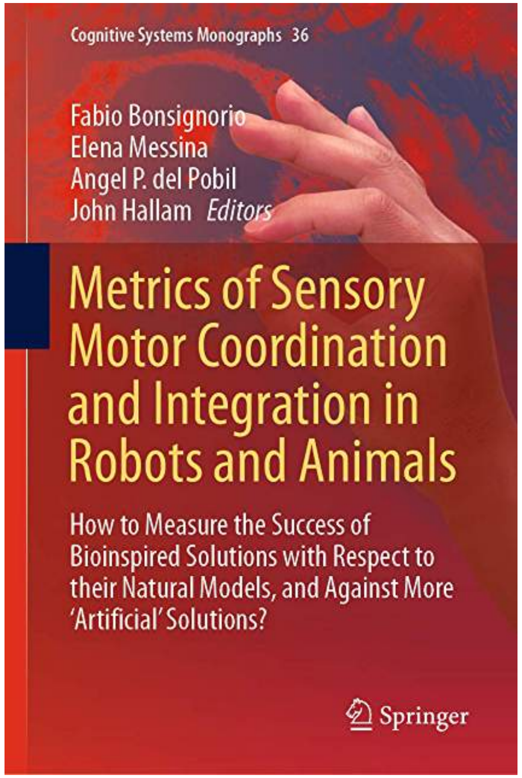
References

1. Leitner, J. *Nat. Mach. Intell.* **1**, 162 (2019).

   Article Google Scholar

2. Bonsignorio, F. & Del Pobil, A. P. *IEEE Robot. Autom. Mag.* **22**, 32–35 (September, 2015).

3. Bonsignorio, F. A. *IEEE Robot. Autom. Mag.* **24**, 178–182 (September, 2017).



Cognitive Systems Monographs 36

Fabio Bonsignorio
Elena Messina
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Metrics of Sensory Motor Coordination and Integration in Robots and Animals

How to Measure the Success of Bioinspired Solutions with Respect to their Natural Models, and Against More 'Artificial' Solutions?

Springer