Lecture 7. The Road Ahead

Fabio Bonsignorio
The BioRobotics Institute, SSSA, Pisa, Italy and Heron Robots

Old ideas

The part of the quote "or even of its own accord" is elsewhere translated as "or by seeing what to do in advance" etc. (you may find many translations).

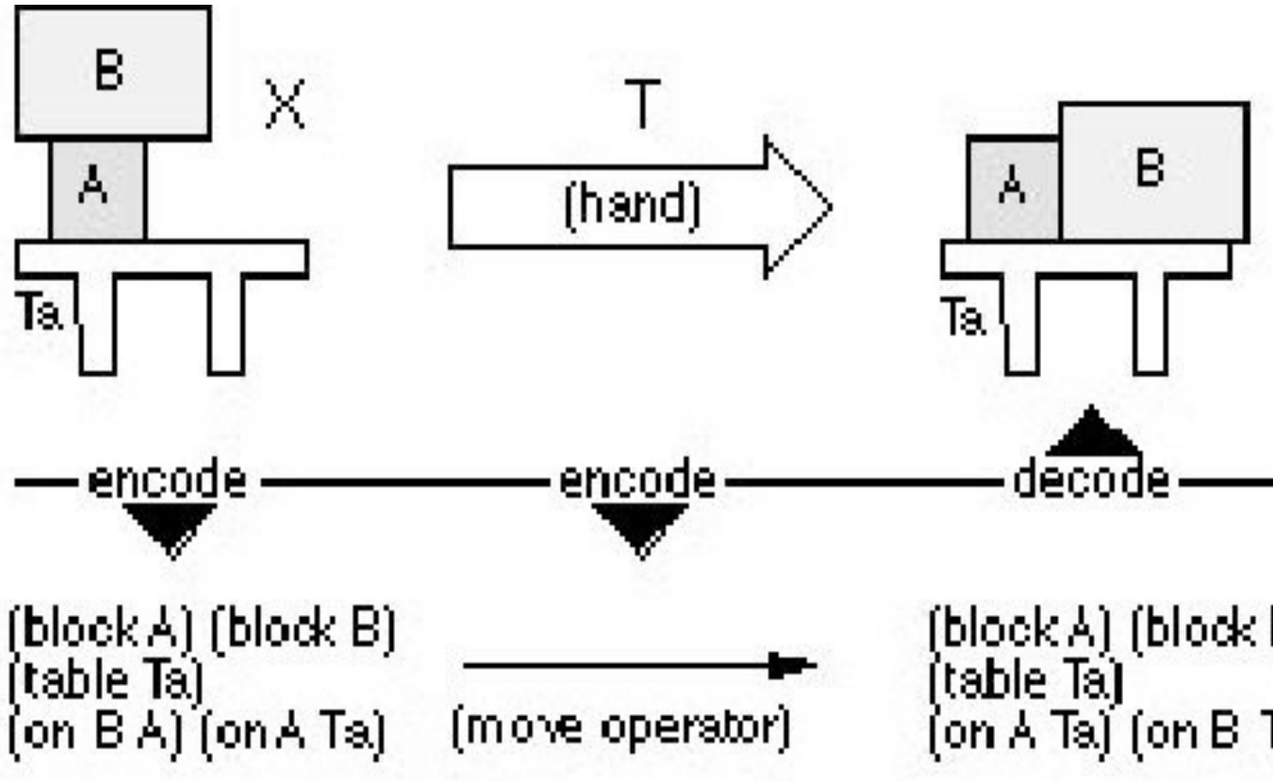
I think this is an important part of the quote, so it's good to go back to the original text:

Aristotle uses the word "προαισθανόμενον" – proaisthanomenon this means literaly: pro = before, aisthanomenon = perceiving, apprehending, understanding, learning (any of these meanings in this order of frequency) in my view it is clearly a word that is attributed to intelligent, living agents....i.e. ones with cognitive abilities (!)

personal communication, Dr. Katerina Pastra
Research Fellow
Language Technology Group
Institute for Language and Speech Processing
Athens, Greece

The “frame problem”
Maintaining model of real world

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



Summary of Dennett's points

- obvious to humans, not obvious to robots (robot only has symbolic model/representation of world)
- vast number of potential side effects, mostly irrelevant
- distinction between relevant an irrelevant inferences
- must test all

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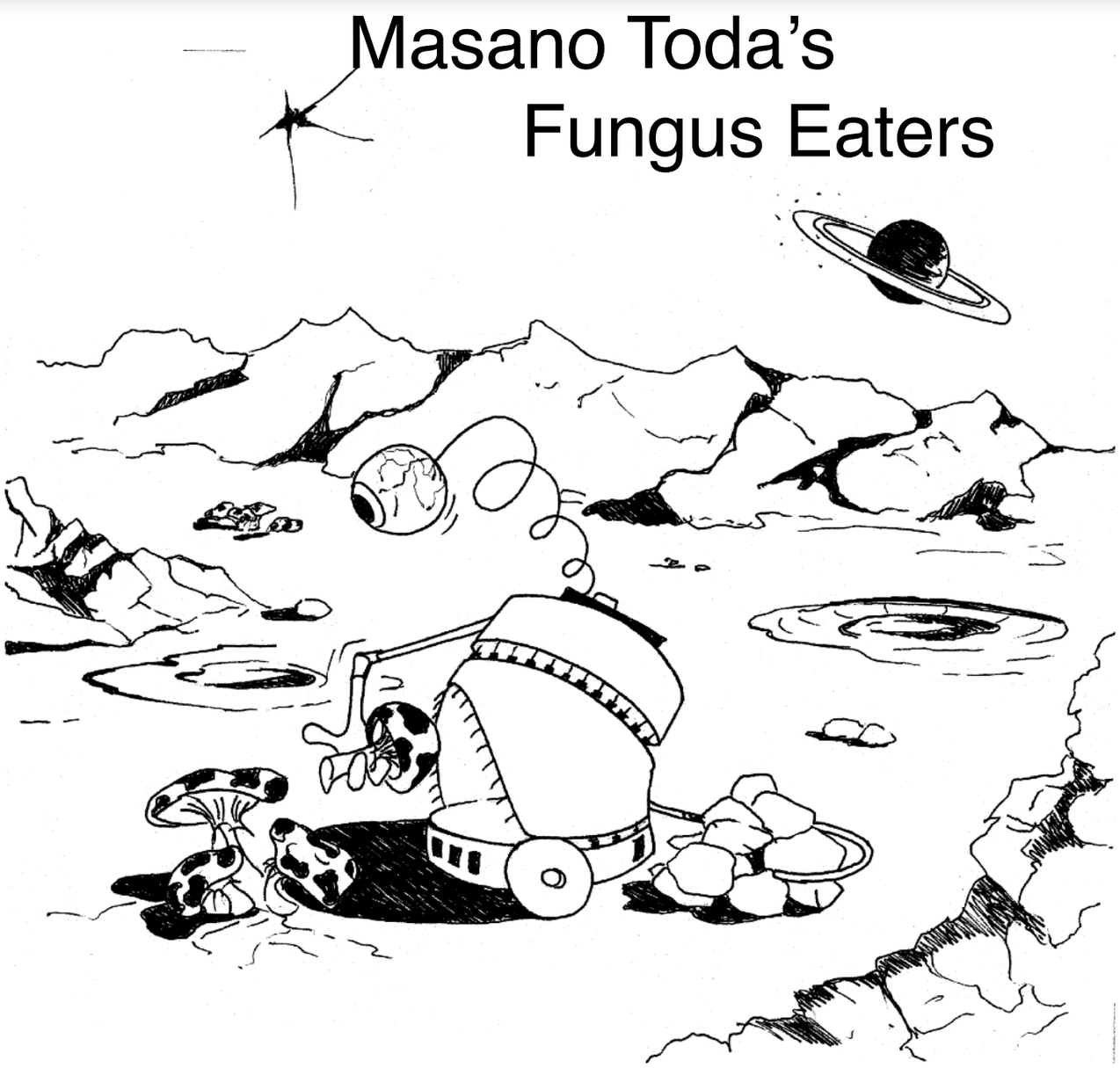
Complete agents



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

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

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Three-constituents principle

define and design

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

design stances

scaffolding

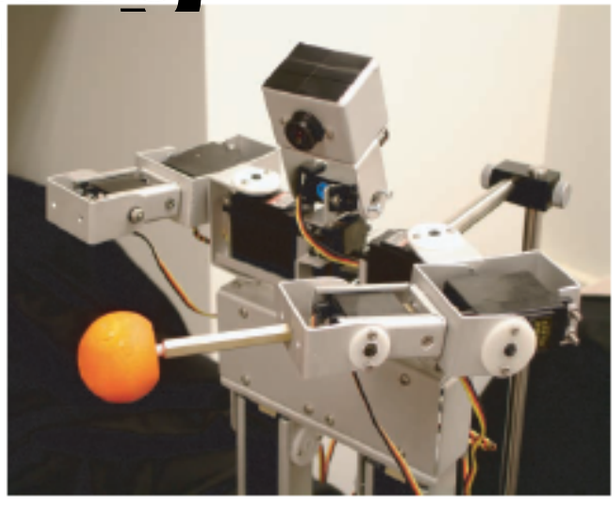
Probabilistic Model Of Control

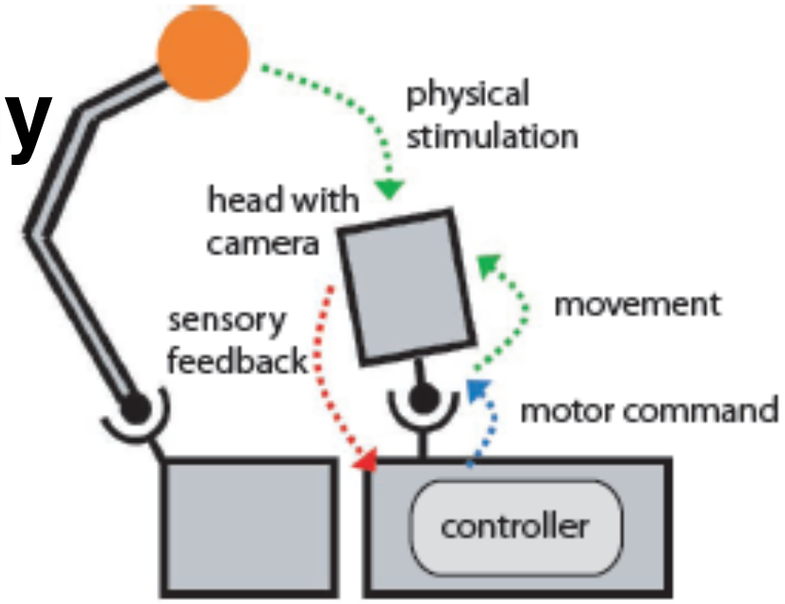
- Although it may seem strange only in recent times the classical results from Shannon theory, have been applied to the modeling of control systems.
- As the complexity of control tasks namely in robotics applications lead to an increase in the complexity of control programs, it becomes interesting to verify if, from a theoretical standpoint, there are limits to the information that a control program must manage in order to be able to control a given system.

Information self-structuring

Experiments:

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





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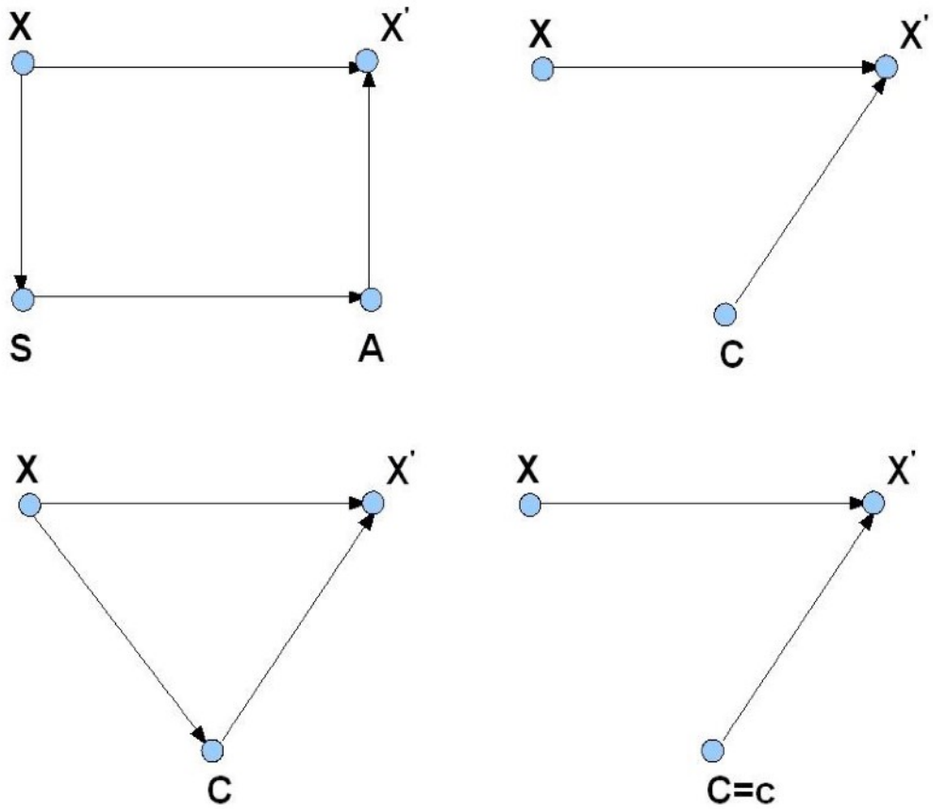
Probabilistic Model Of Control

Touchette, Lloyd (2004)



Directed acyclic graphs representing a control process. (Upper left) Full control system with a sensor and an actuator. (Lower left) Shrinked Closed Loop diagram merging sensor and actuator, (Upper right) Reduced open loop diagram. (Lower right) Single actuation channel enacted by the controller's state C=c.

Models of ‘Morphological Computation’

$$K(X) \overset{+}{\leq} \log \frac{W_{closed}}{W_{open}^{closed}} \qquad (I)$$

Relation (I) links the complexity ('the length') of the control program of a physical element to the state available in closed loop and the non controlled condition.
This show the benefits of designing stuctures whose 'basin of attractions' are close to the desired behaviors in the phase space.

Models of ‘Morphological Computation’

$$\Delta HN + \sum_{i}^{n} \Delta H_i - \Delta I \leq I\left(X;C\right) \quad \text{(II)}$$

Relations (II) links the mutual information between the controlled variable and the controller to the information stored in the elements, the mutual information between them and the information stored in the network and accounts for the redundancies through the multi information term *ΔI*.

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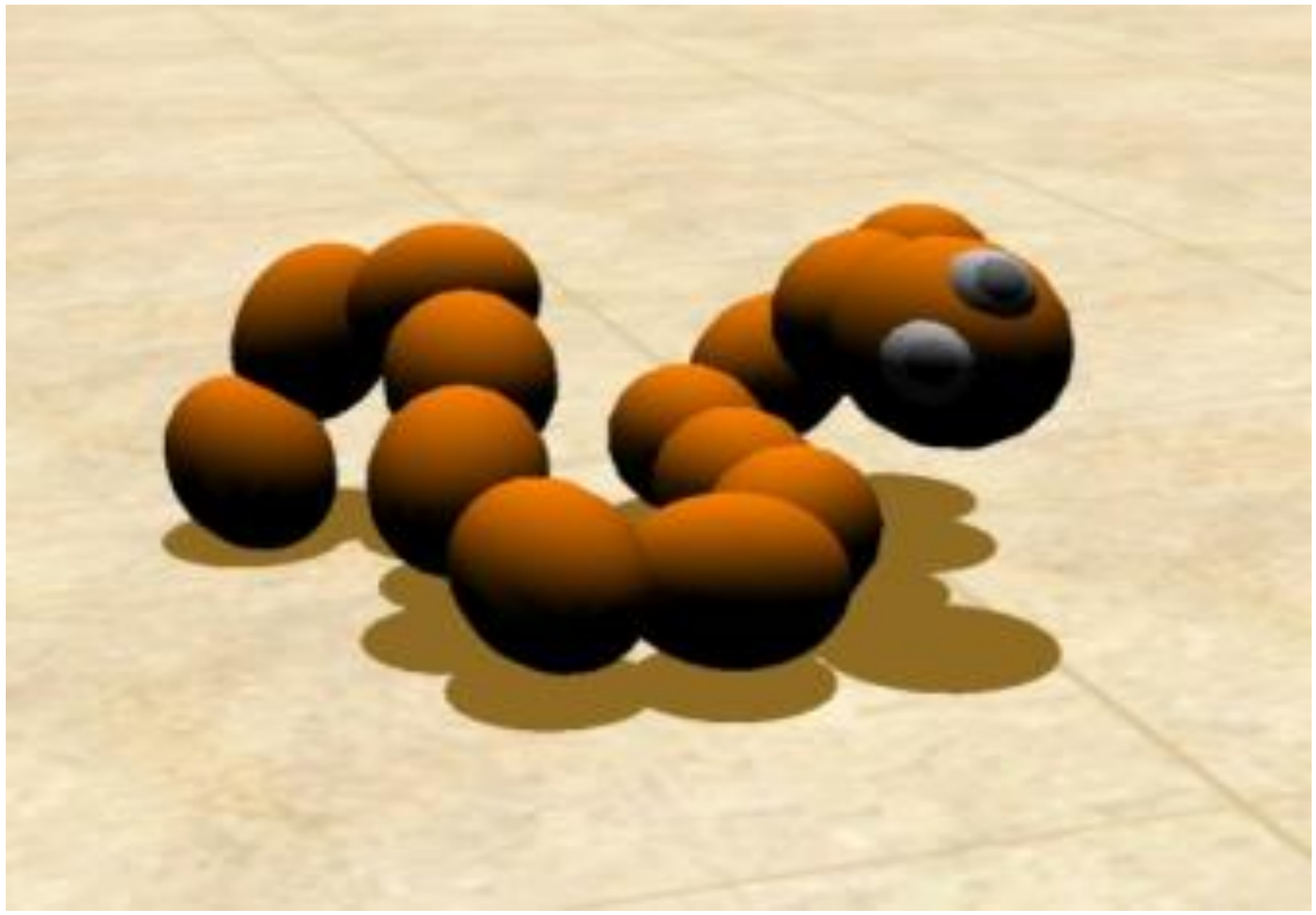
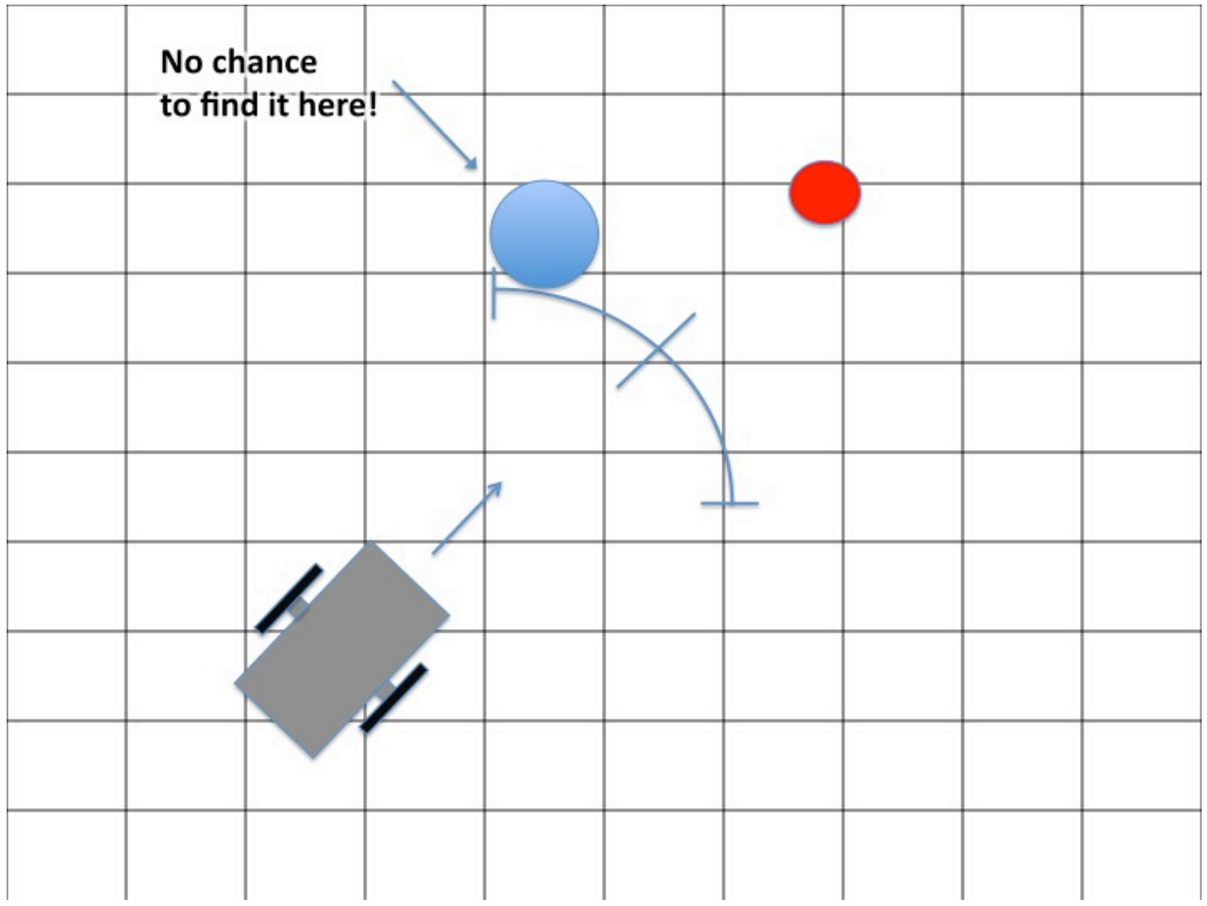
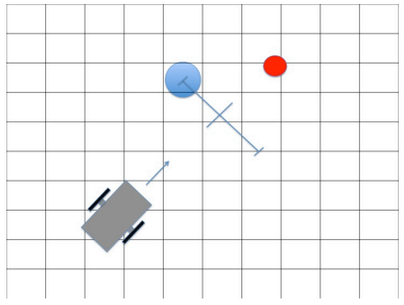
Snakebot



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

Maybe not GOF Euclidean space? :-)





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

Synthetical methodology

In order to understand (and design)
the behaviors of this kind of systems…

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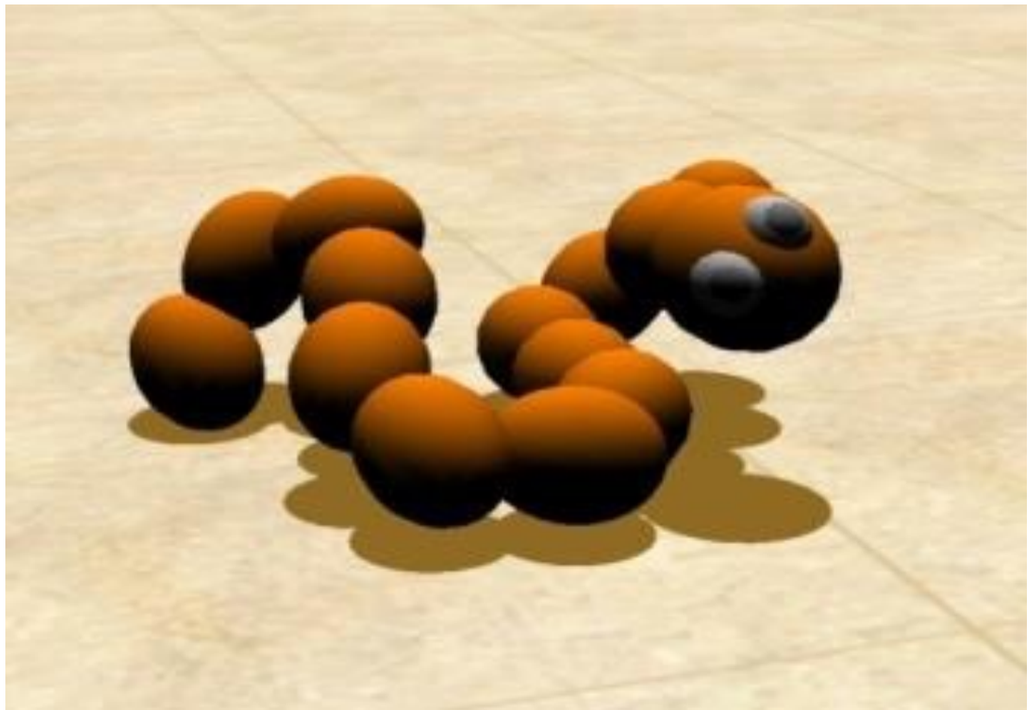
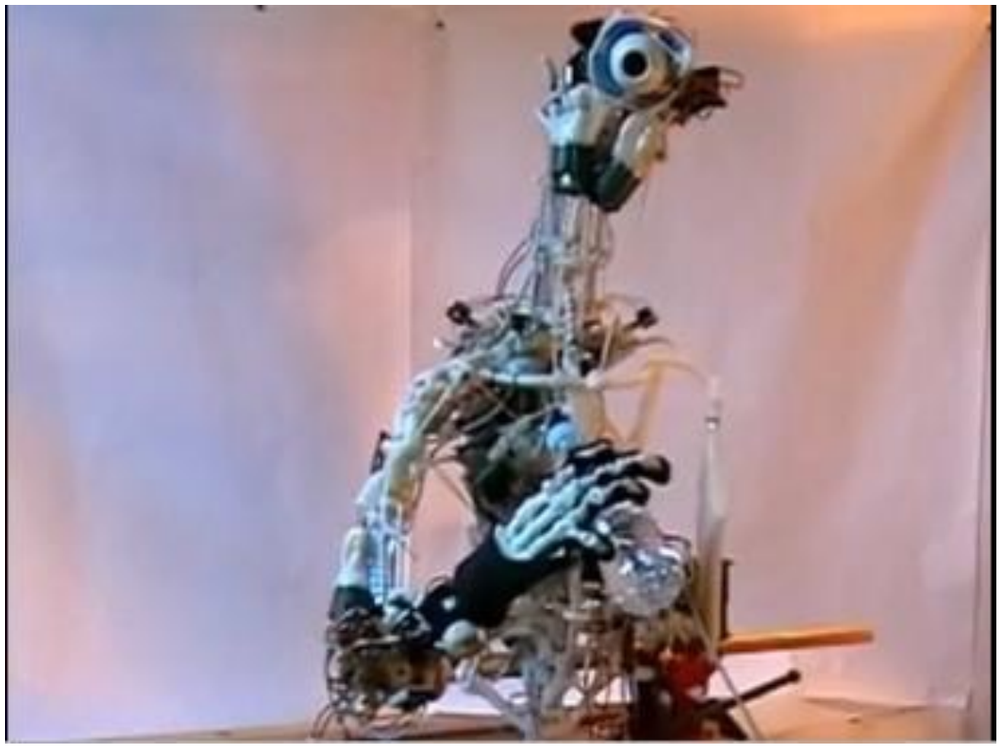
Synthetical methodology

We may build, and mathematically model, simpler ones…





and design discriminating experiments…

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Embodied Intelligence or Morphological Computation: the modern view of Artificial Intelligence

Classical approach

The focus is on the brain and central processing

Modern approach

The focus is on interaction with the environment. Cognition is emergent from system-environment interaction

PARADIGM CLASHES

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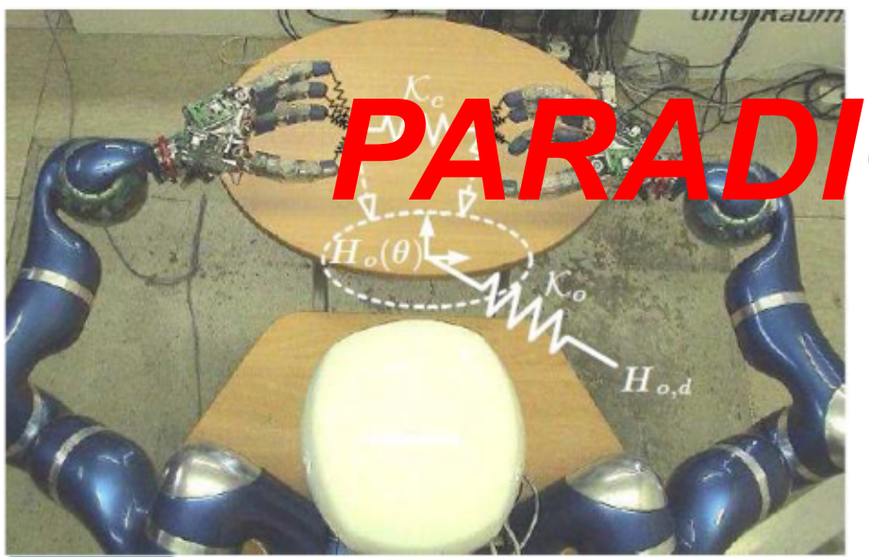
Rolf Pfeifer and Josh C. Bongard, *How the body shapes the way we think: a new view of intelligence*, The MIT Press, Cambridge, MA, 2007

Soft Robotics: a working definition

Variable impedance actuators and stiffness control

* Actuators with variable impedance
* Compliance/impedance control
* Highly flexible (hyper-redundant or continuum) robots



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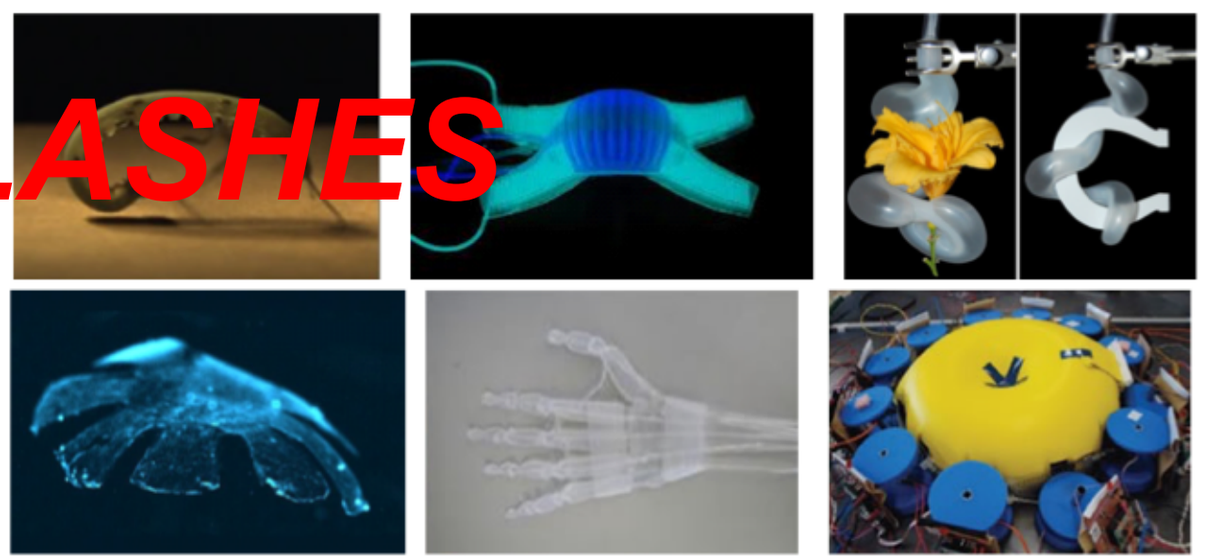
IEEE Robotics and Automation Magazine, Special Issue on Soft Robotics, 2008
A. Albu-Schaffer et al. (Ed.s)

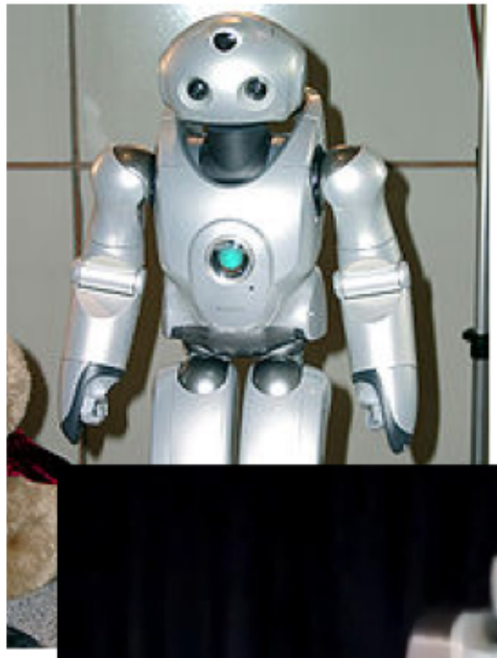
Use of soft materials in robotics

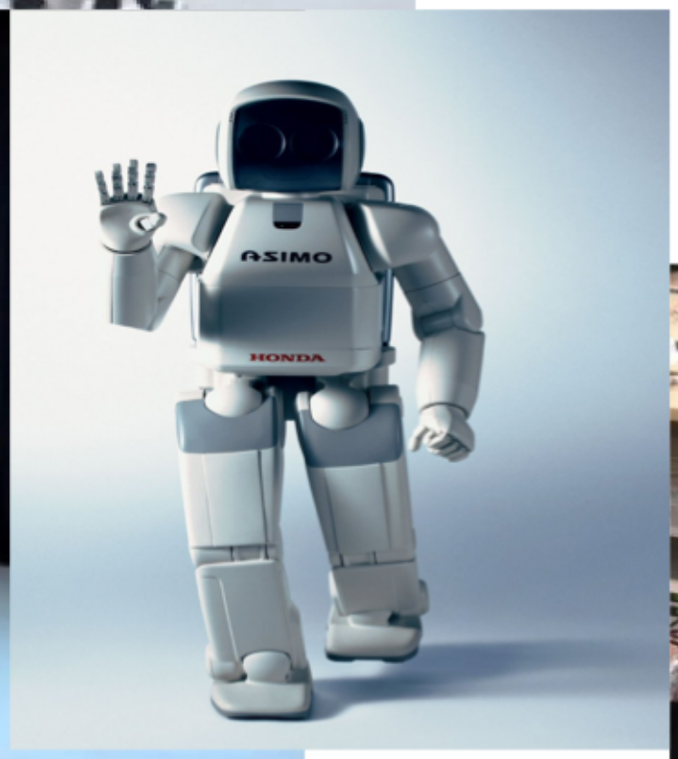
* Robots made of soft materials that undergo high deformations in interaction
* Soft actuators and soft components
* Control partially embedded in the robot morphology and mechanical properties

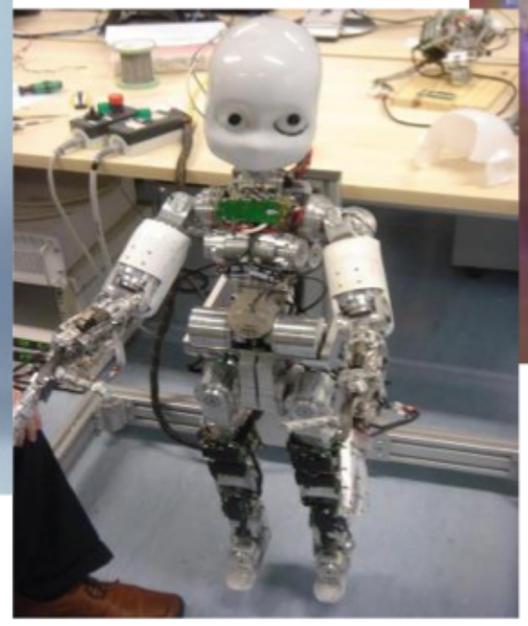


Kim S., Laschi C., and Trimmer B. (2013) Soft robotics: a bioinspired evolution in robotics, *Trends in Biotechnology*, April 2013.
Laschi C. and Cianchetti M. (2014) "Soft Robotics: new perspectives for robot bodyware and control" *Frontiers in Bioengineering and Biotechnology*, 2(3)

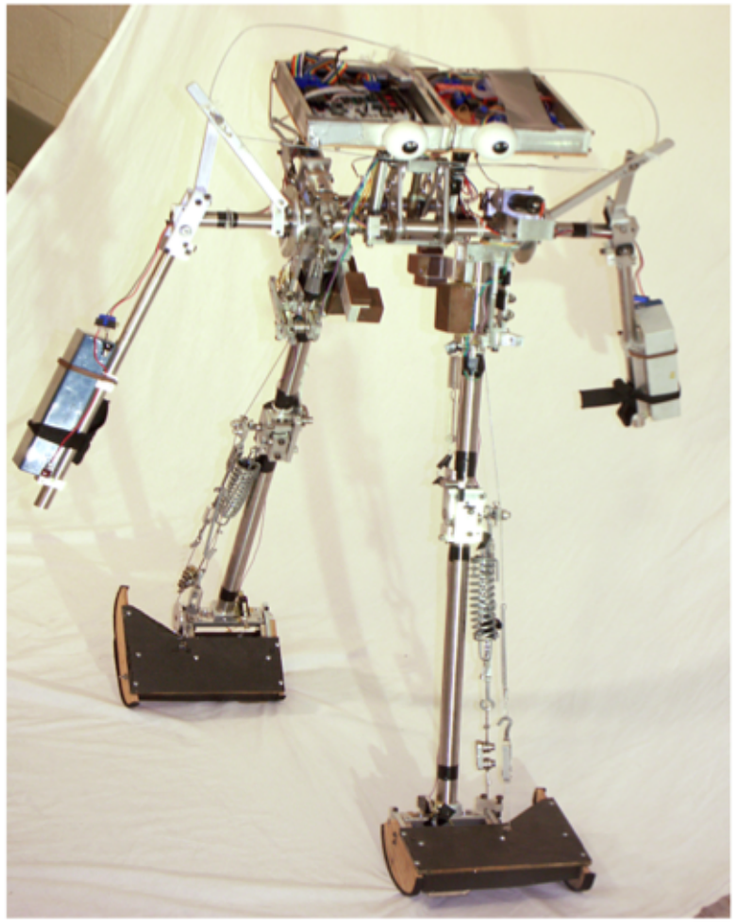
Today's humanoids







Conceptually different humanoid designs (mainly research)



How to build a ‘new paradigm’ robot like the Cornell Ranger able to wave the hands like NAO? (and manipulate…)

a) Cornell ranger

b) Nao walking down a ramp

Thank you for your attention!

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