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The BioRobotics Institute

Scuola Superiore Sant'Anna, Pisa

Embodied Intelligence in Natural and Artificial Agents

Robotics is coming of age

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RoboCom++ Embodied Intelligence in Natural and Artificial Agents WG Leader¹

SPARC TG Benchmarking and Competitions²

IEEE RAS TC-PEBRAS³

Member SPARC Board of Directors⁴

The BioRobotics Institute, SSSA⁵
and Heron Robots⁶



The second wave: the success stories

DARPA (American Defense Advanced Research Projects Agency) challenges have demonstrated how current robots are becoming **more accurate, fast and dexterous in structured and unstructured environments.**

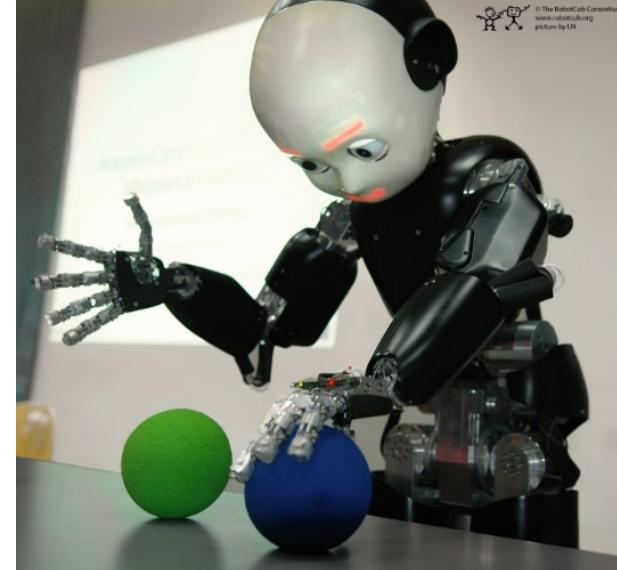
According to H.Yanco a minimum of 9 people were needed to teleoperate latest DRC's robots!!! And...



Pursuing new frontiers: The robotics bottleneck

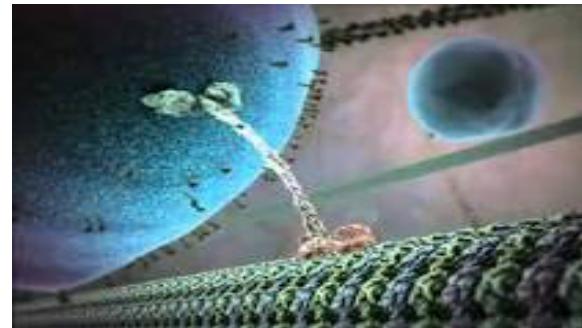
Today, more functionality means:

- **more** complexity, energy, computation, cost
- **less** controllability, efficiency, robustness, safety



Is It Alive?

Big Questions lie in front of us!



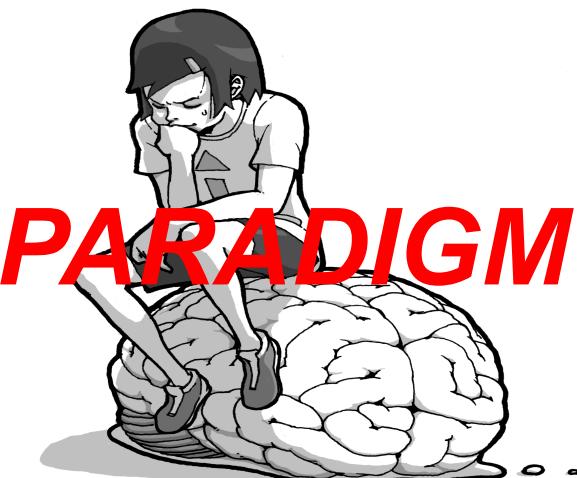
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Embodied Intelligence or Morphological Computation: the modern view of Artificial Intelligence

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



Definitions of intelligence

“... there seem to be almost as many definitions of intelligence as there were experts asked to define it.” R.J. Sternberg

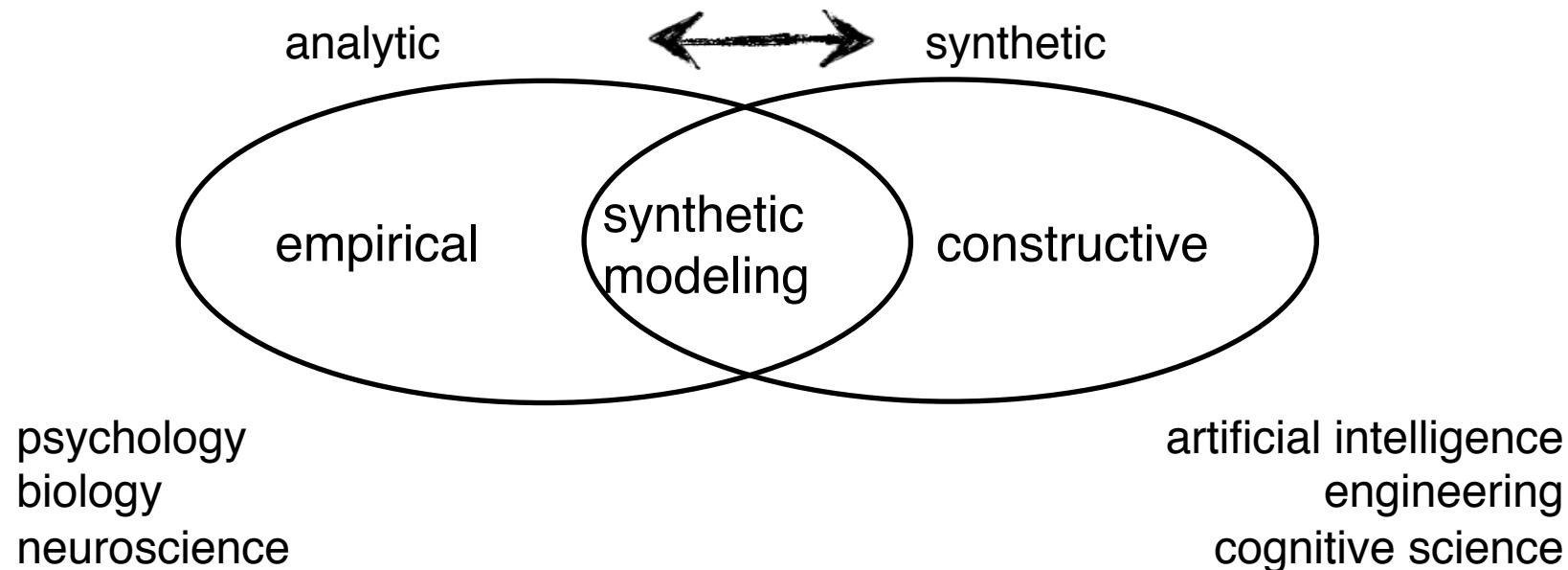
(Robert J. Sternberg, distinguished psychologist; famous book “Beyond IQ: A triarchic theory of human intelligence”, 1985)



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How to study intelligence?



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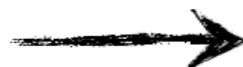


The synthetic methodology

Slogan:

“Understanding by building”

modeling behavior of interest
abstraction of principles



robots as tools for scientific investigation

abstractions, NOT copies of nature

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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Life vs Cognition

?



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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



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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



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Embodiment examples

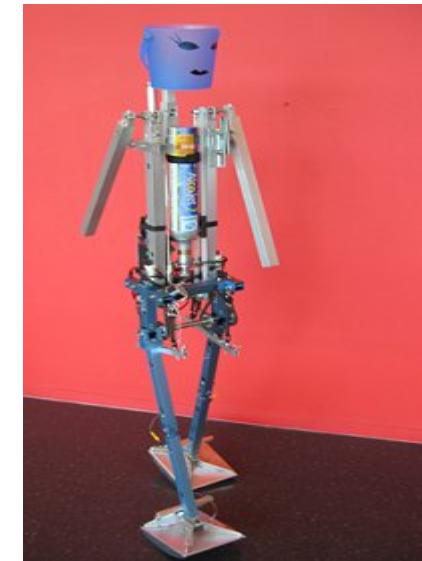
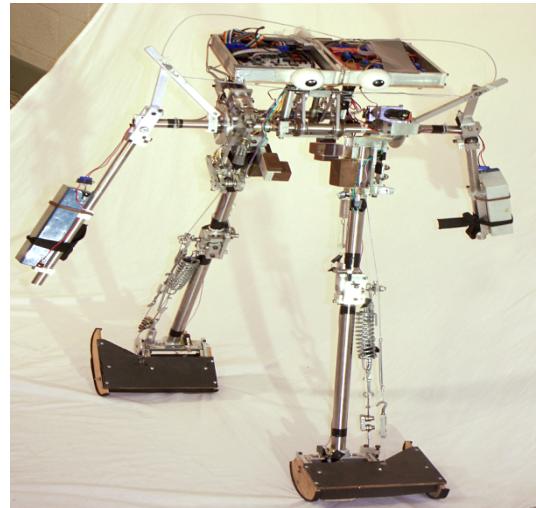
Conceptually different
humanoid designs (mainly research)



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Embodiment

Does it mean ‘intelligence requires a body’???

The ‘intelligent’ behavior results from the *interaction* of brain (biological neural processing), morphology, dynamics, materials, environment



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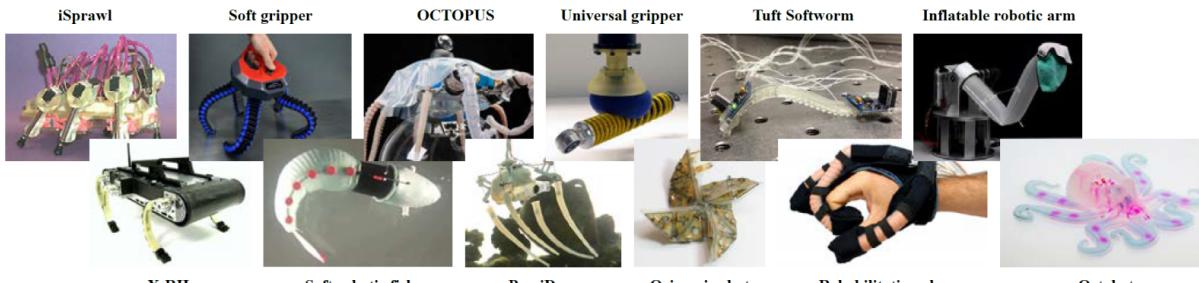
How to quantify?



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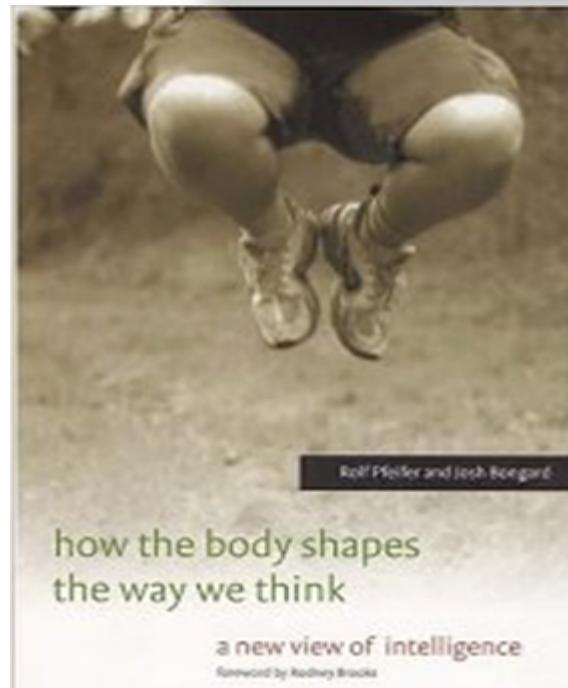
The marvellous progress of Robotics and AI...'Look Ma, No Hands' syndrome?



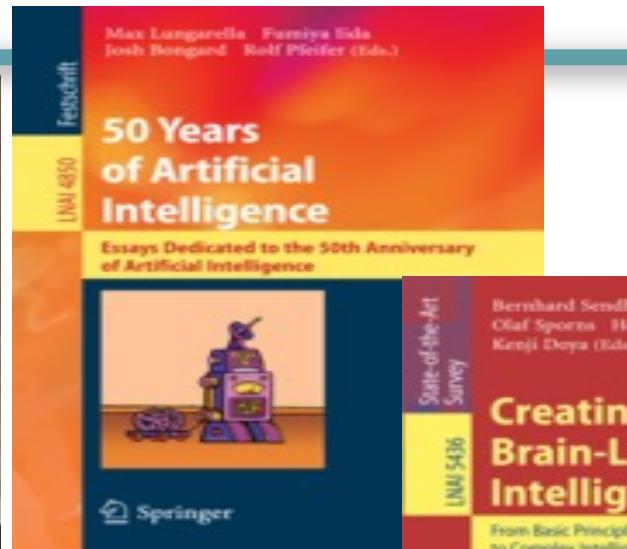
Mostly stiff
Few selectively compliant elements

Entirely soft





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**Thank you for your
attention**

