

人
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智能

The
ShanghaiAI
Lectures

上
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AI
授
课

Today's schedule

09.00 - 09.02 Introductory comments

09.02 - 17.10 Design principles for intelligent systems

10.15 Break

10.20 - 11.00 Guest speaker: Prof. Toshi Nakagaki

"How do slime mold tackle a maze"

from: Hakodate Future University, Hokkaido, Japan



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The ShanghAI Lectures by the University of Zurich An experiment in global teaching

Today from Hakodate Future University, Hokkaido, Japan

27 October 2011
17.00-19.00 Local Japan Time
9.00-11.00 CET

欢迎您参与
“来自上海的人工智能系列讲座”



Lecture 4

Design principles for intelligent systems: Part I

27 October 2011



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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”
- “cheap design” and redundancy



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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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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**
- **attractor state, basin of attraction**



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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



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Three-constituents principle

define and design

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

design stances

scaffolding



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All three aspects always need to be designed, and often, by making even small changes to the environment, the design of the agents for a set of tasks can be dramatically simplified (recall the Swiss Robots).

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-mimetic systems: every action has potentially effect on entire system



can be exploited!



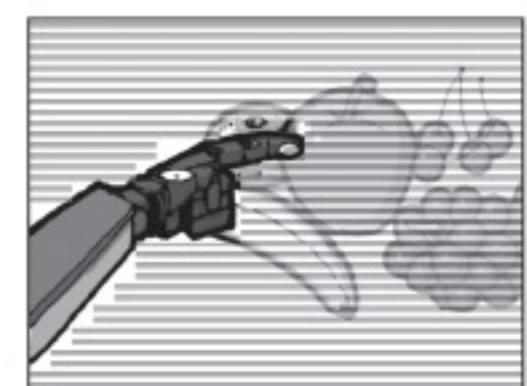
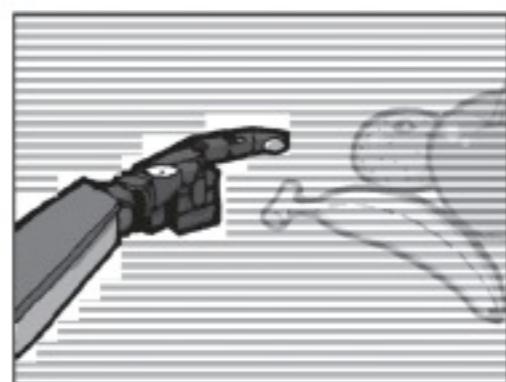
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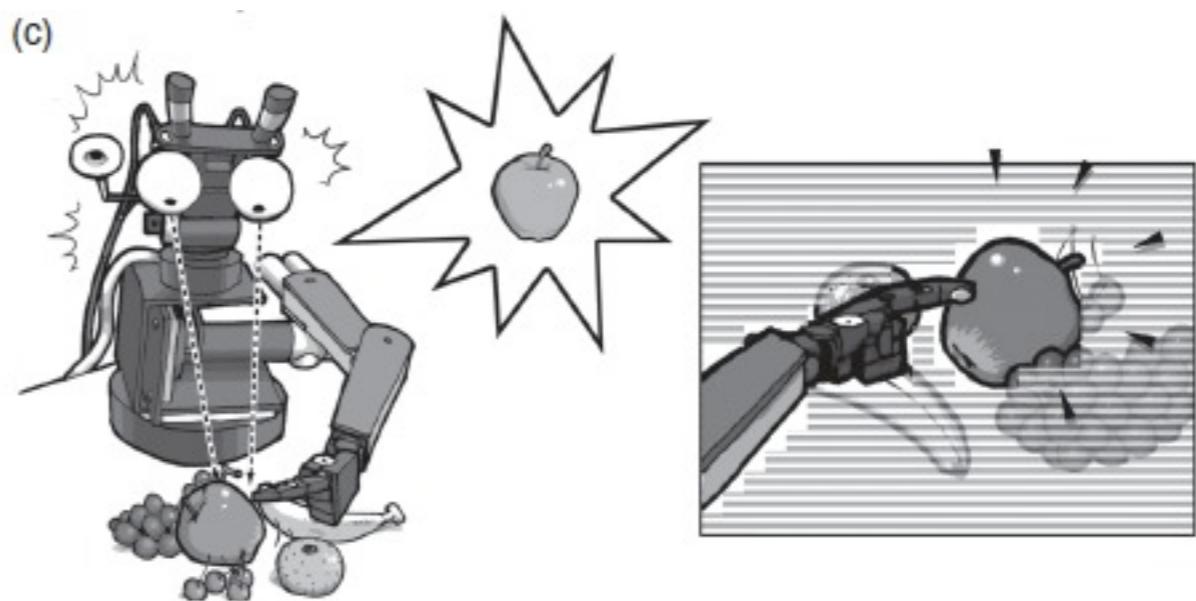


Recognizing an object in a cluttered environment



**manipulation of
environment can
facilitate perception**

Experiments by Giorgio Metta and
Paul Fitzpatrick



Illustrations by Shun Iwasawa



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figure 4.4, p. 122, “How the body ...” This robot only detects movement, not static images. By moving the arm in the environment, it can on the one hand perceive its own arm and on the other, if the arm moves and object, the objects (shown in the panel in the lower right corner).

Today's topics

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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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Recall: The “embodied turn”

Rodney Brooks, MIT



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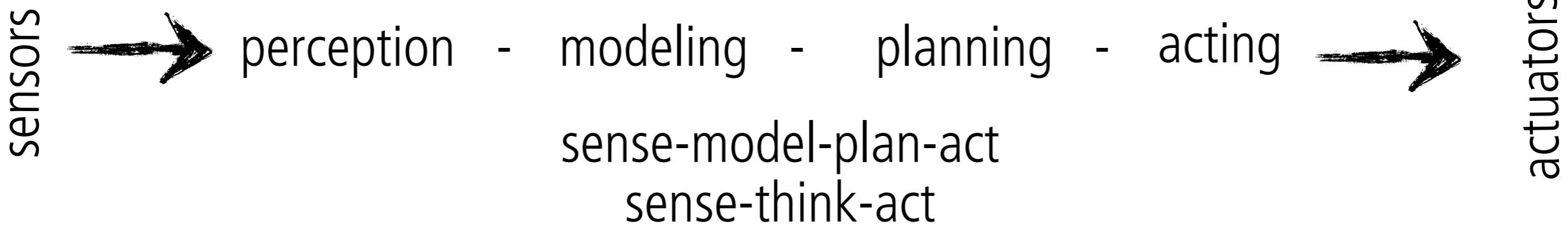


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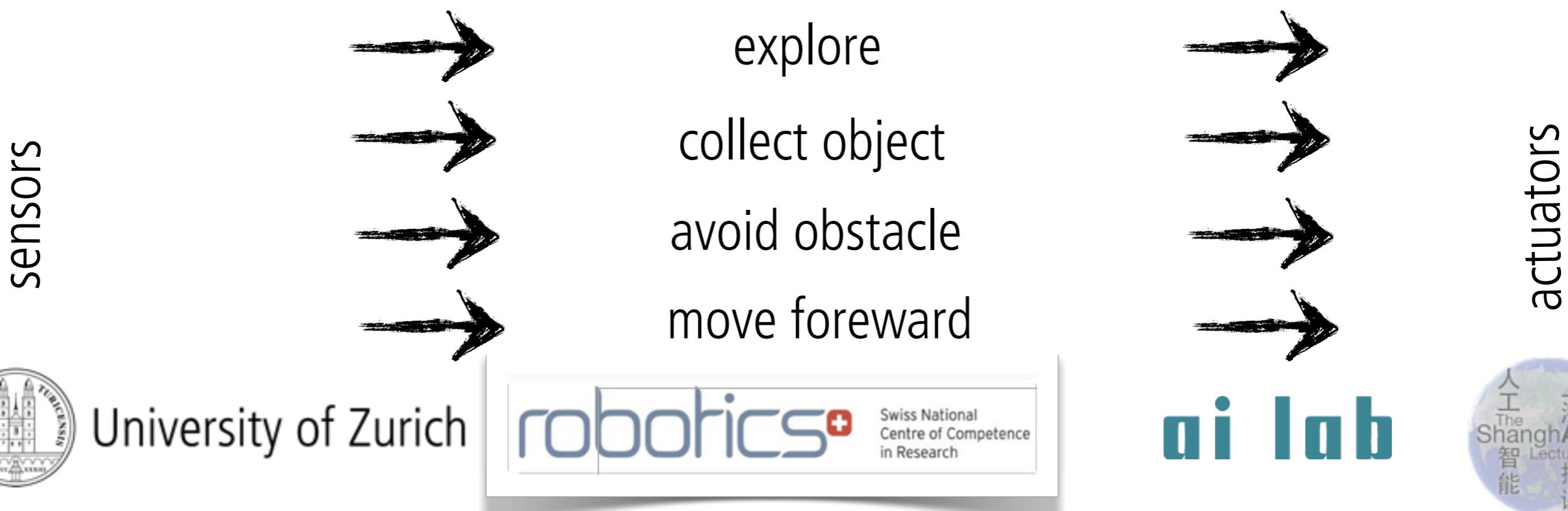


The subsumption architecture the “behavior-based” approach

classical, cognitivistic



“behavior-based”, subsumption

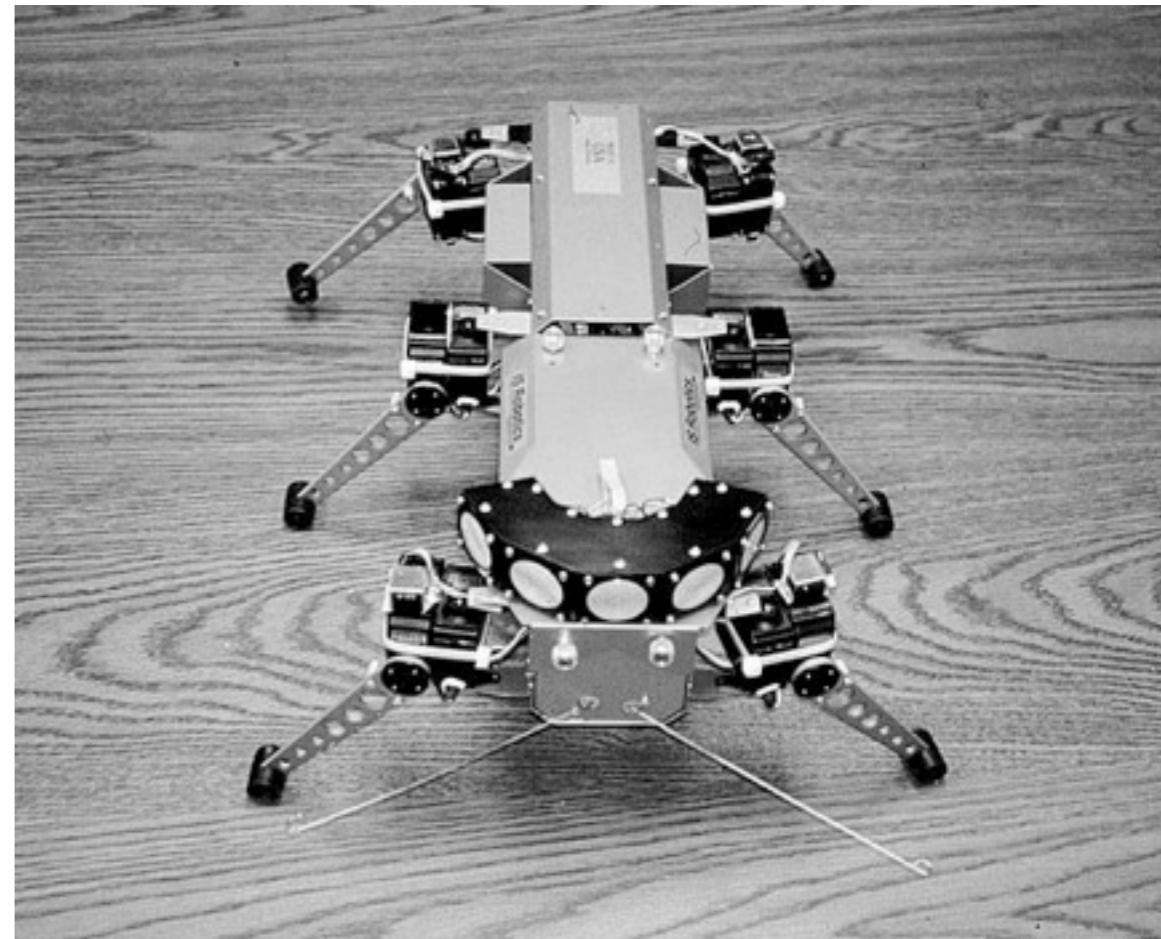


The subsumption architecture was originally proposed by Rodney Brooks as an alternative to the classical symbol-based approach, which starts from the assumption that control is hierarchical and centralized. 1986: “A robust layered control system for a mobile robot.” IEEE Journal of Robotics and Automation, TA-2. The title sounds very innocuous but it was at the time very revolutionary and went against the standard paradigms at the time (in particular the classical computational or cognitivistic paradigm).

Mimicking insect walking

- subsumption architecture well-suited

six-legged robot
"Ghenghis"



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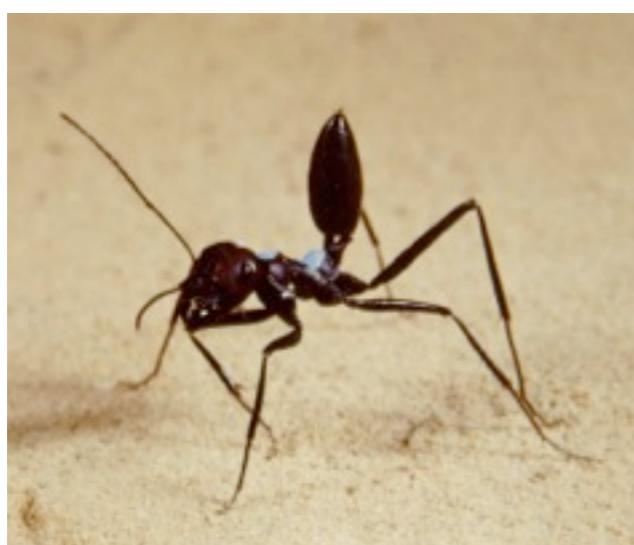


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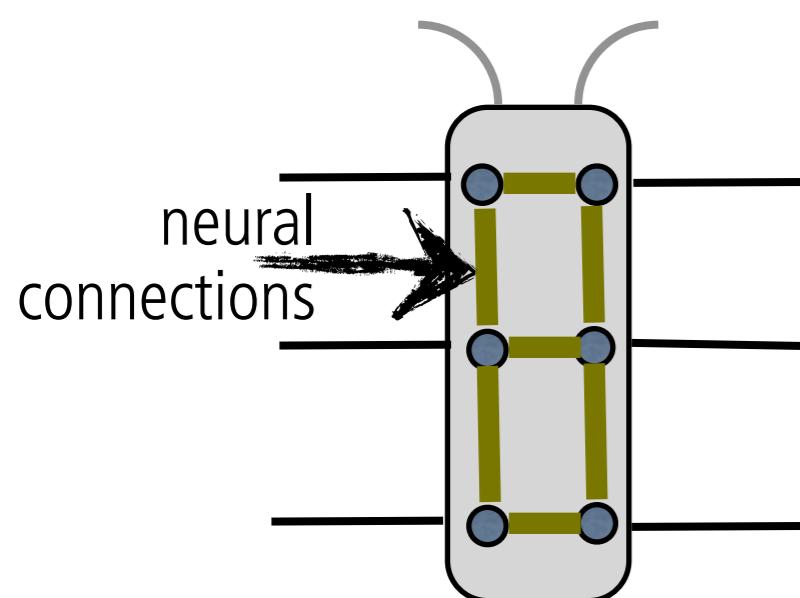
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Insect walking



Holk Cruse, German biologist

- **no central control for leg-coordination**
- **only communication between neighboring legs**



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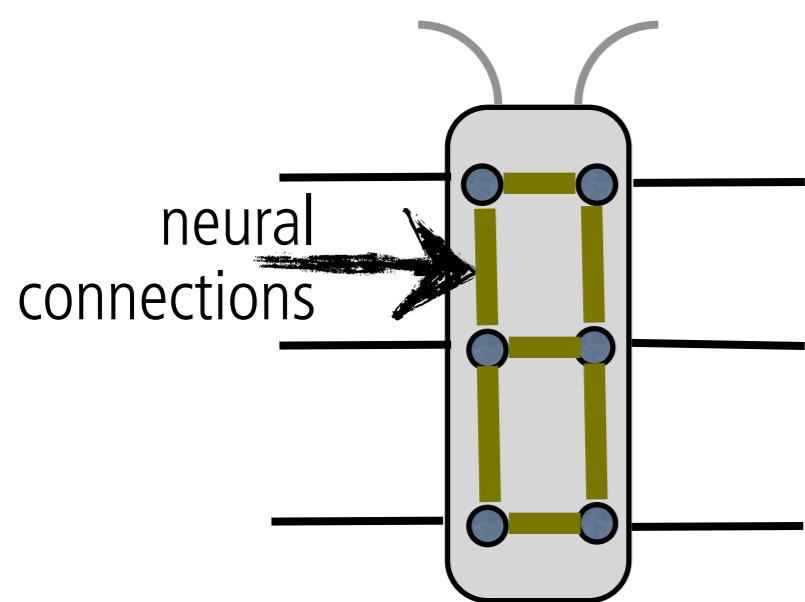
It has been known for quite some time that there is no central area in the brain of the insect controlling the coordination of the legs in walking. But then, how is coordination possible?

Insect walking



Holk Cruse, German biologist

- no central control for leg-coordination
- only communication between neighboring legs
- global communication:



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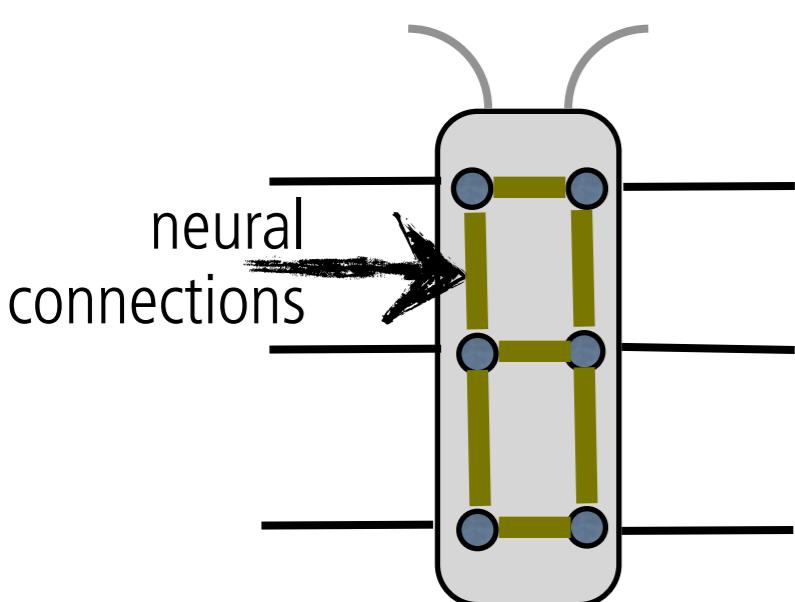


Insect walking



Holk Cruse, German biologist

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



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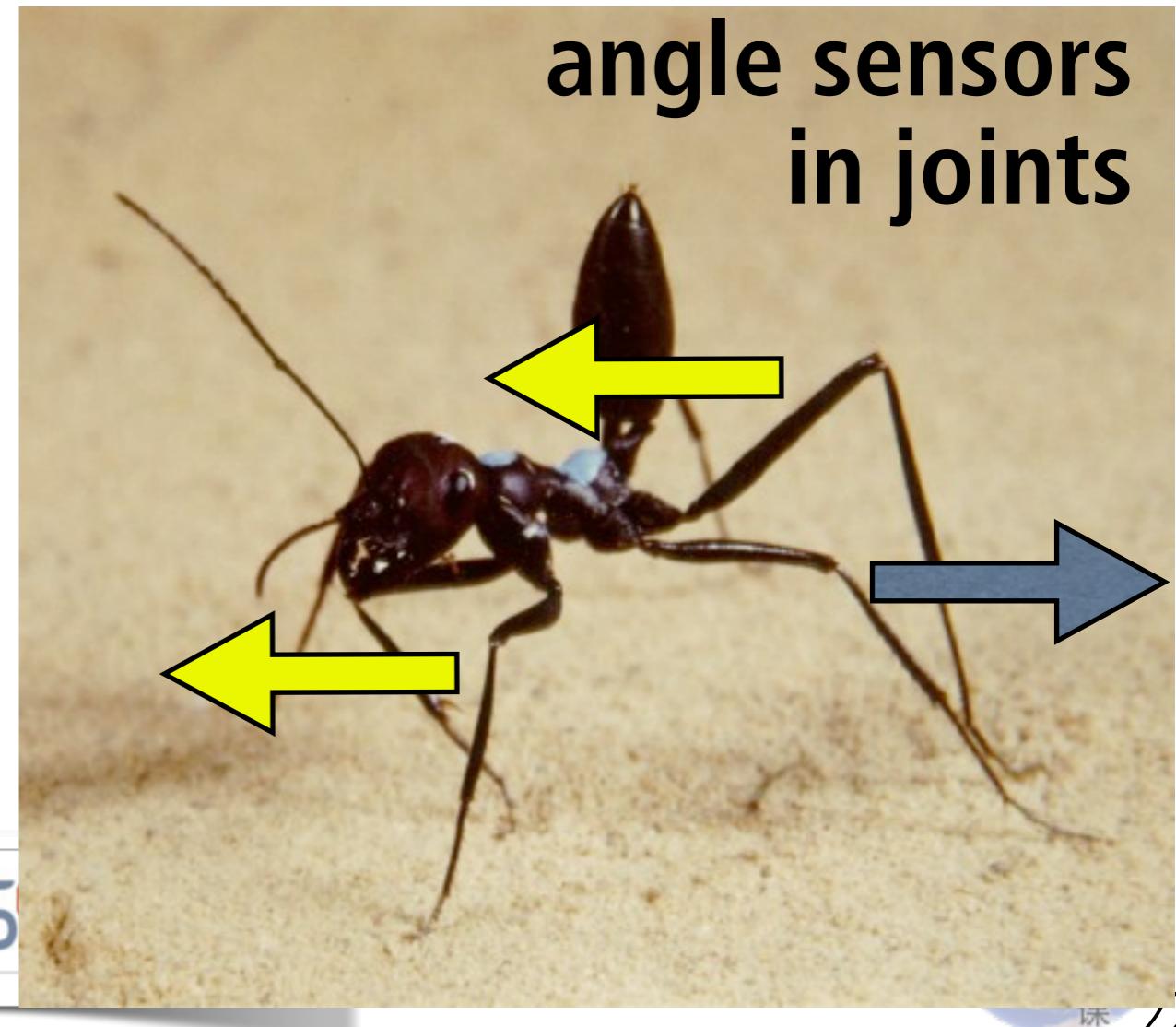
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Communication through interaction with environment

- exploitation of interaction with environment
→ simpler neural circuits

"parallel, loosely coupled processes"



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robotics

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In fact, there IS global communication but rather than through specific neural connections, it is through the interaction with the environment: because insects are embodied systems, if it pushes back with one leg, the joints of the other legs standing on the ground will be moved as well. All it needs is sensors in the joints, so these data can be exploited for leg coordination.

Subsumption: Engineering or cognitive science?



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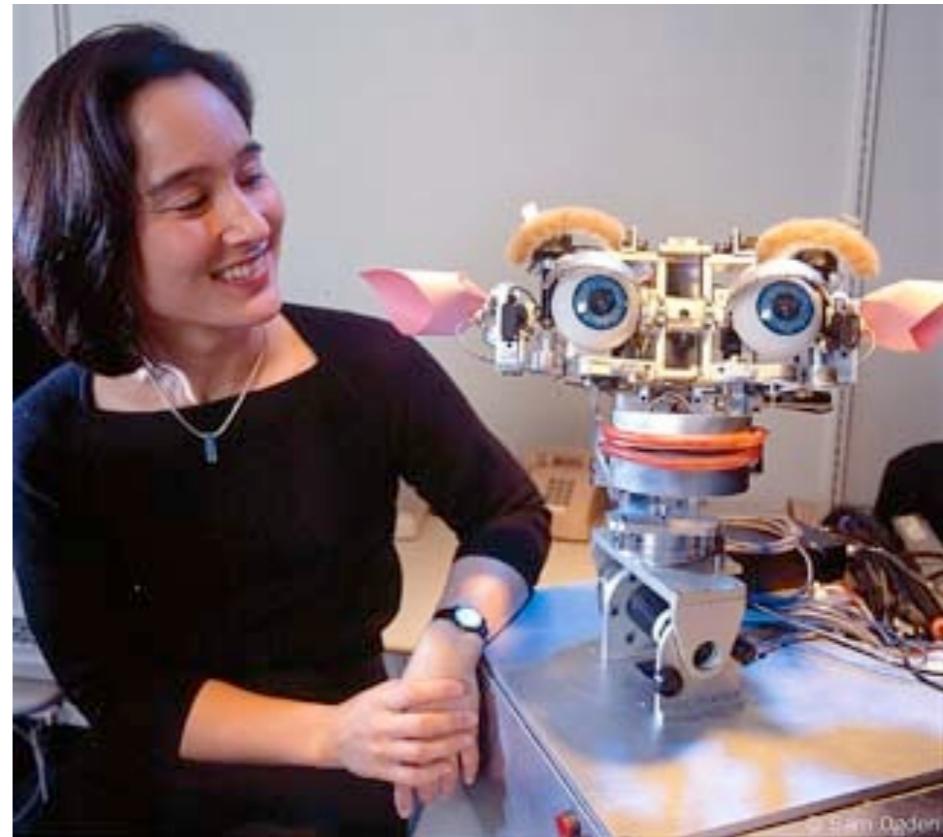
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``Subsumption is an engineering approach---it does not relate to cognitive science'' is what we often hear in informal discussions. The subsumption architecture postulates modules. Once these modules have been developed, they are not changed. They can be used as building blocks in a more complex system. Viewed in this way, subsumption indeed has a strong engineering flavor. However, the whole motivation for subsumption has its origins in cognitive science. Brooks made a strong point about AI, about building artificially intelligent systems (Brooks 1991b). He carefully analyzed the characteristics of classical systems and argued why it is not possible with the classical approach to achieve realistic levels of intelligence. Having direct sensory-motor couplings with little internal processing to achieve intelligent behavior was a new idea in the study of intelligence at the time subsumption architecture was proposed. Moreover, there is an evolutionary motivation for the architecture: Capacities, once evolved, are carried on to future generations without---or without significant---modification. We believe that, in spite of the approach's engineering flavor, it has important messages for cognitive science. (from “Understanding Intelligence”, p. 223).

Kismet: The social interaction robot



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



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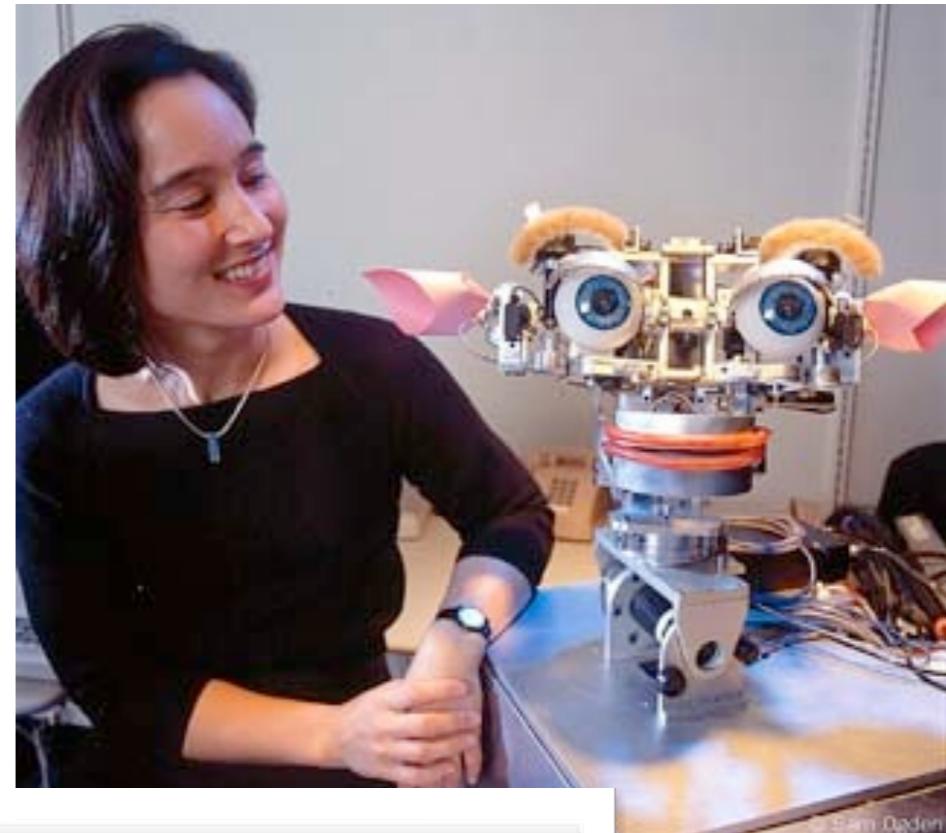
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Kismet: The social interaction robot

Reflexes:

- turn towards loud noise
- turn towards moving objects
- follow slowly moving objects
- habituation



principle of “parallel, loosely coupled processes”

MIT Media
lab (prev. MIT AI Lab)



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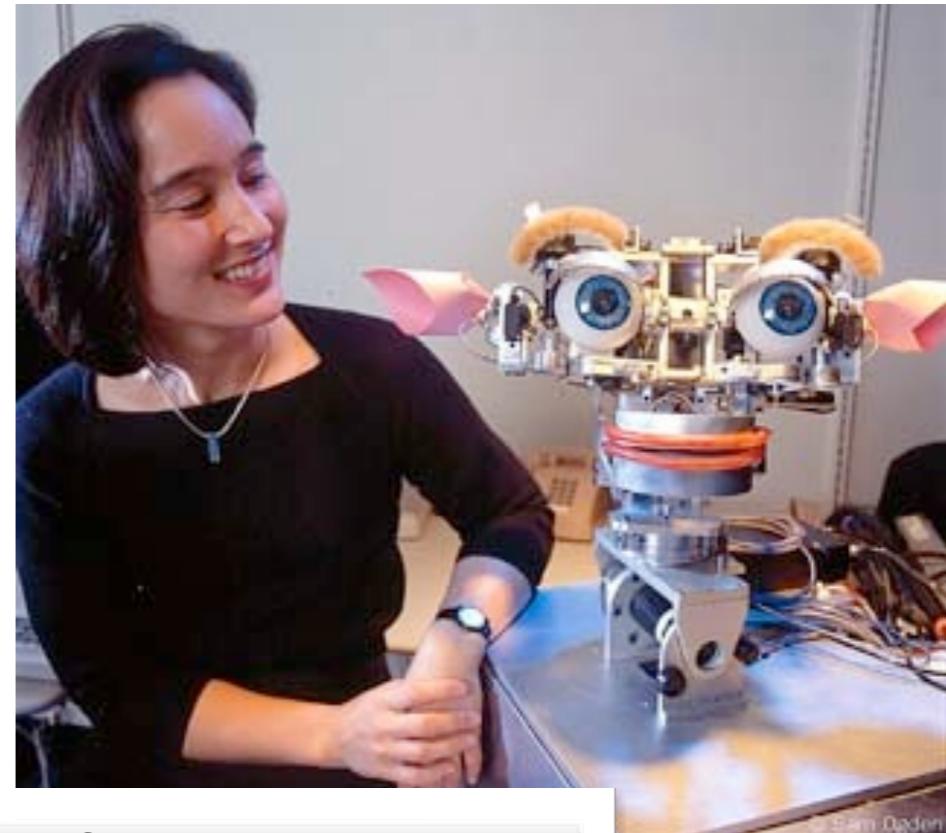
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There is in fact a frame-of-reference issue here: We observe the behavior and we are trying to figure out the underlying mechanisms.

Kismet: The social interaction robot

Reflexes:

- turn towards loud noise
- turn towards moving objects
- follow slowly moving objects
- habituation



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

, MIT Media
lab (prev. MIT AI Lab)



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Rolf: Kismet behaves “as if” it had social competence. Rodney Brooks: “what do you mean ‘as if’: this *is* social competence.

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.”



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Rodney Brooks's (1986) seminal paper on the subsumption architecture is probably the most quoted paper in embodied cognitive science. It is, in a sense, the idea with which the field embodied cognitive science started. When a scientific field undergoes a paradigm shift, critics will always try to salvage the existing positions. Most often, researchers endorsing the old paradigm acknowledge that the new ideas have interesting aspects, but also have some intrinsic limitations that will prevent them from replacing the existing ones entirely. This is precisely what David Kirsh (1991) tried to do in ``Today the Earwig, Tomorrow Man?'' in his reply to Brooks's 1986 paper. Kirsh acknowledges that, indeed, Brooks points to serious problems in traditional thinking and suggests an interesting alternative. He then argues that this approach is viable only for simple systems: For human-level intelligence, concepts and symbolic computation will be required. We might summarize his conclusion as follows: ``Today the earwig?''---yes, no problem; ``tomorrow man?''---no, never. In a later paper (1997), Brooks indirectly replied to Kirsh by proposing a route by which we might eventually indeed achieve human-level intelligence without the need to introduce symbolic concepts explicitly. We used the term ``explicitly'' to indicate that Brooks would not exclude the possibility that Cog might eventually exhibit behavior that we might want to describe by resorting to the notion ``concept.'' (See also chapter 4 on the frame-or-reference problem). As we might expect, Brooks is referring to the Cog project. We might summarize Brooks's position as follows: ``Earwigs?''---of course, we did that a long time ago; ``Humans?''---we don't know, but we have good ideas about how to make progress toward higher levels of intelligence in artificial systems.

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- **case studies: “Puppy”, biped walking**
- “cheap design” and redundancy



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Case study: “Puppy” as a complex dynamical system

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



morphological
computation



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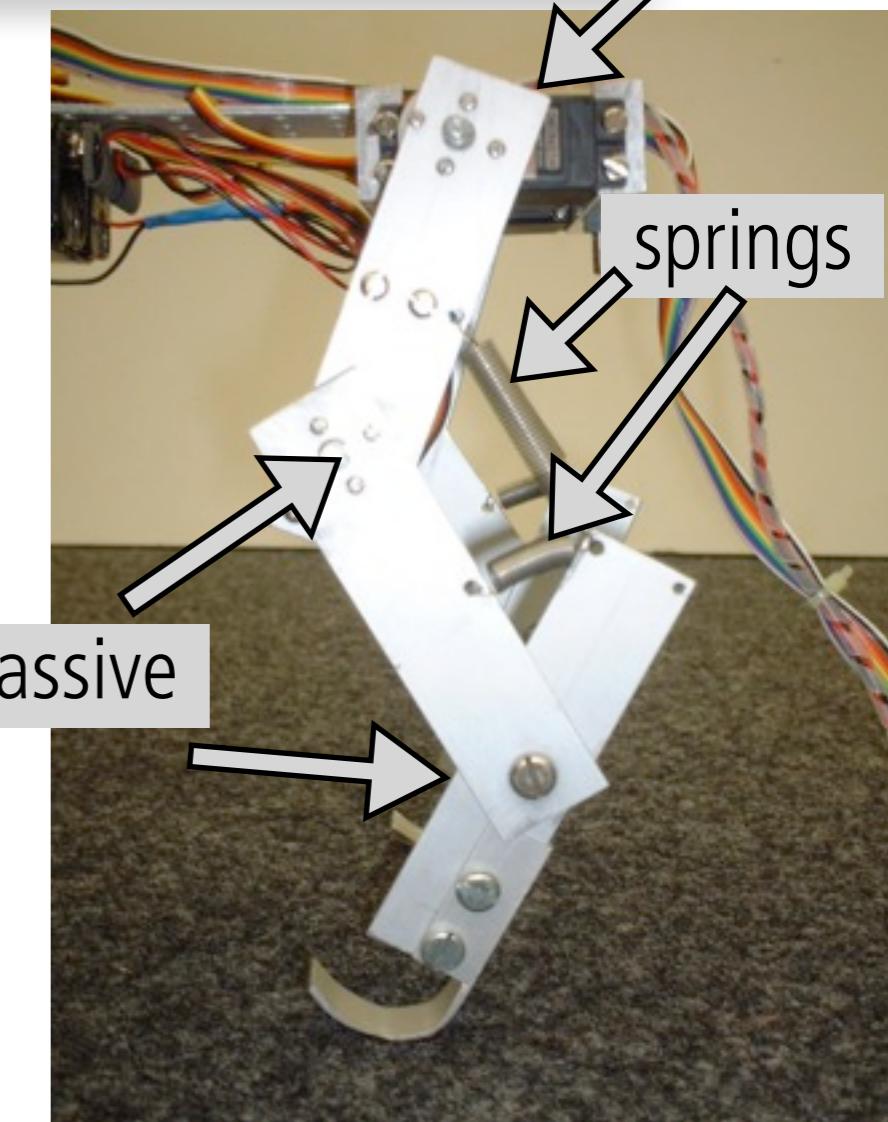


Emergence of behavior: the quadruped “Puppy”

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



morphological computation



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Self-stabilization: “Puppy” on a treadmill

Video “Puppy” on treadmill
slow motion

- no sensors
- no control



self-stabilization



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It's self-stabilization because there are no sensors, and no microprocessor; it's the dynamics of the mechanical structure together with the actuation that leads to the stable gait pattern. The system stays within an attractor state, corresponding to this particular gait pattern. We also talk about “intra-attractor dynamics”.

Self-stabilization: “Puppy” on a treadmill

Video “Puppy” on treadmill
slow motion

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

principle of
“cheap design”



self-stabilization



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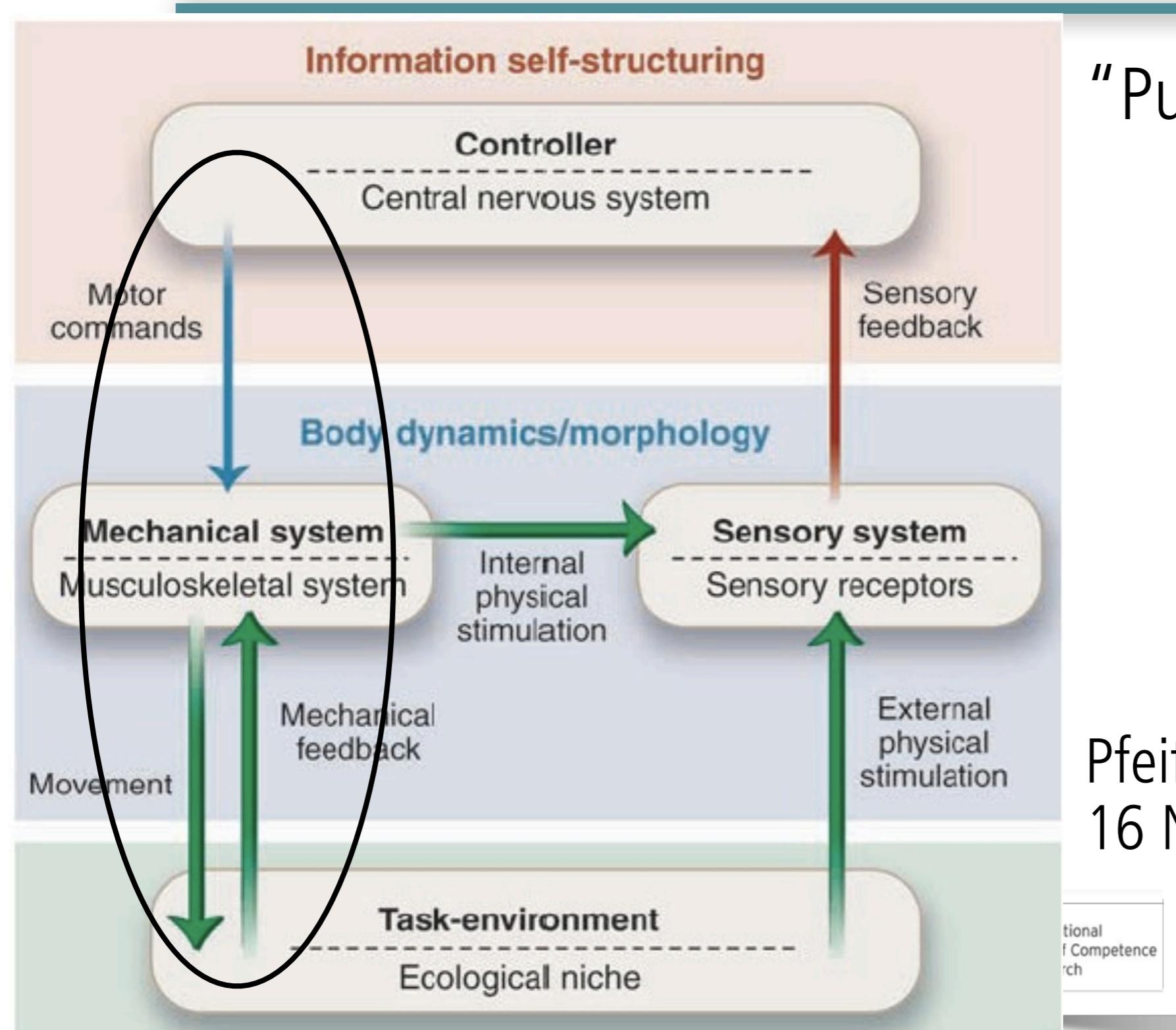
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The design of “Puppy” exploits the its own dynamics to achieve stable behavior.

Implications of embodiment Self-stabilization



"Puppy"

Pfeifer et al., Science,
16 Nov. 2007

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Circle left side of diagram --> it's the part responsible for self-stabilization.

Principle of “cheap design”



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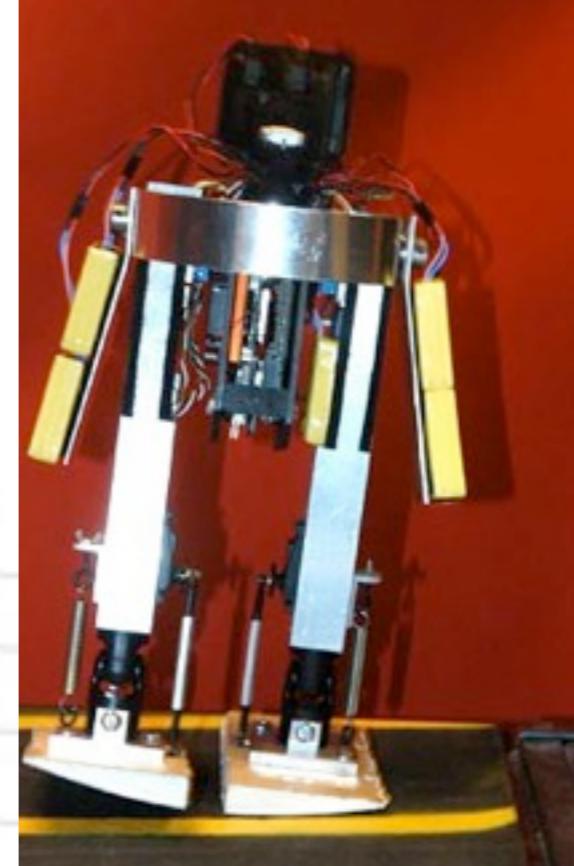


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- exploitation of ecological niche, interaction with environment
(recall the Swiss robots and what conditions must hold in the environment for them to function properly - e.g. right size and weight of cubes, boards around arena, position of IR sensors)
- parsimony (philosophy of science; Occam's razor)



Human walking



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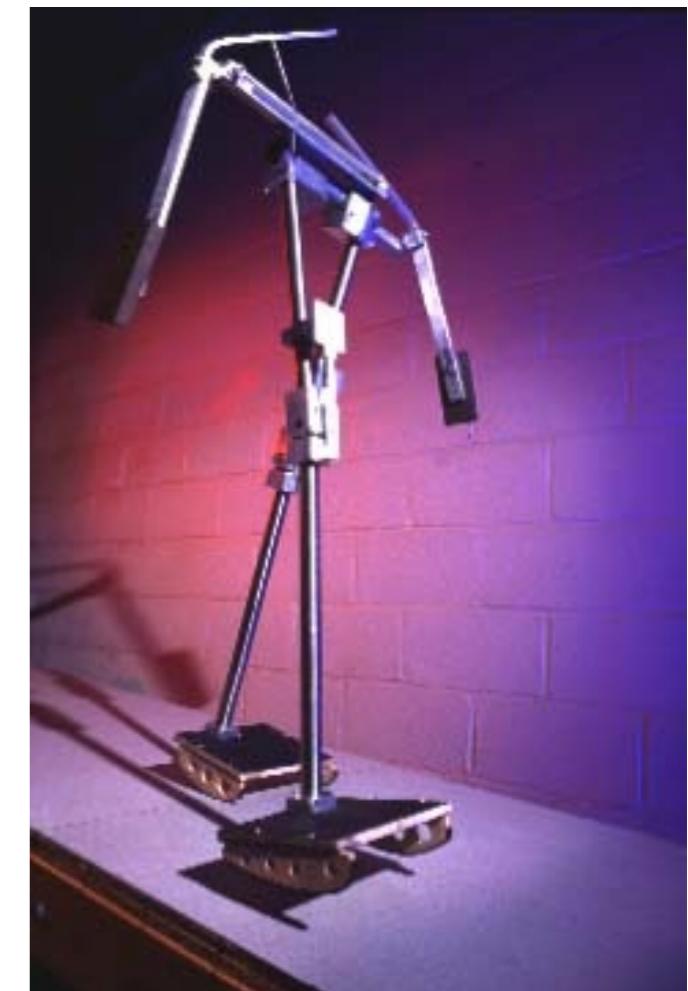
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This slide shows a number of humanoid robots, some of which have been specifically developed to study human walking, some to study robot walking, and some for PR and entertainment purposes.

Extreme case: The “Passive Dynamic Walker”

The “brainless” robot”: walking without control

Video “Passive Dynamic Walker”



Design and construction:
Ruina, Wisse, Collins: Cornell
University, Ithaca, New York



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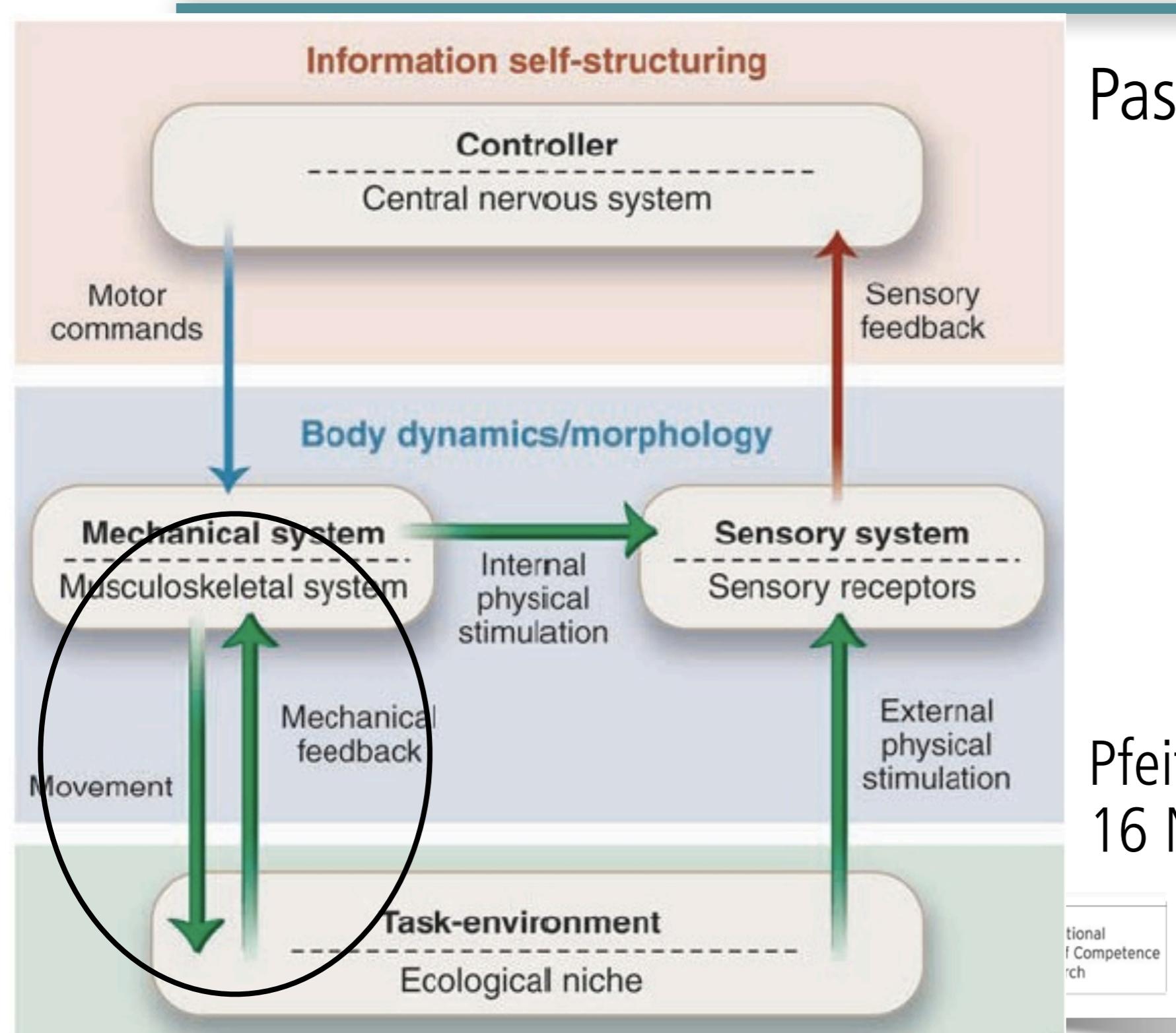
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Play video by Steve Collins

Implications of embodiment Self-stabilization



Passive Dynamic Walker

Pfeifer et al., Science,
16 Nov. 2007

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Circle left lower corner of diagram --> it's the part responsible for self-stabilization.

Reference: Pfeifer, R., Lungarella, M. and Iida, F. (2007). Self-organization, embodiment, and biologically inspired robotics. *Science*, 16 Nov. 2007, Vol. 318, 1088-1093.

Contrast: Full control

Video "Qrio"

Sony Qrio



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In Qrio all the joints are centrally controlled which requires a lot of computational effort. There is no exploitation of passive dynamics. (Qrio is a technological masterpiece, but designed in a framework of traditional control theory).

Redundancy principle



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- examples: natural language, brain, brake systems of airplanes (jets, wheels)
- standard notion: duplication of components
- design principle: subsystems based on different physical processes; partial overlap of functionality
- animal sensory systems, e.g. vision, touch, audio
- complementary to “cheap design”

Principle of “ecological balance”

balance in complexity

given task environment: match in complexity of sensory, motor, and neural system

balance / task distribution

brain (control), morphology, materials, and interaction with environment



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Principle of “ecological balance”

balance in complexity

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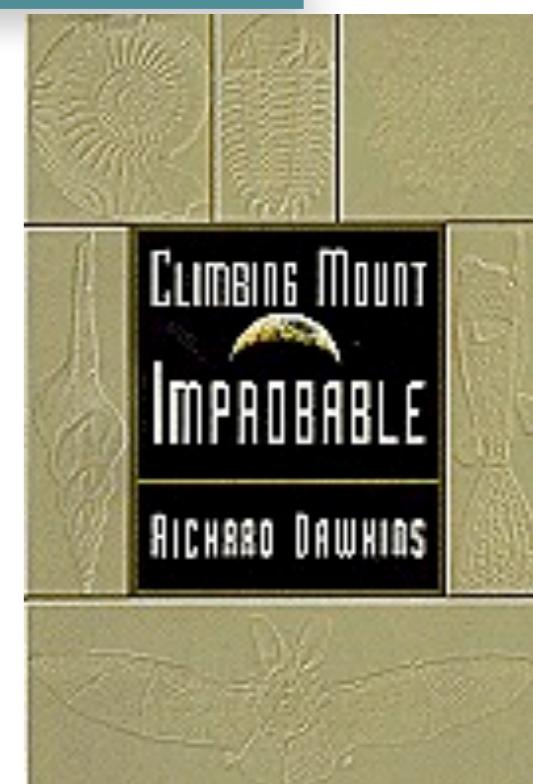
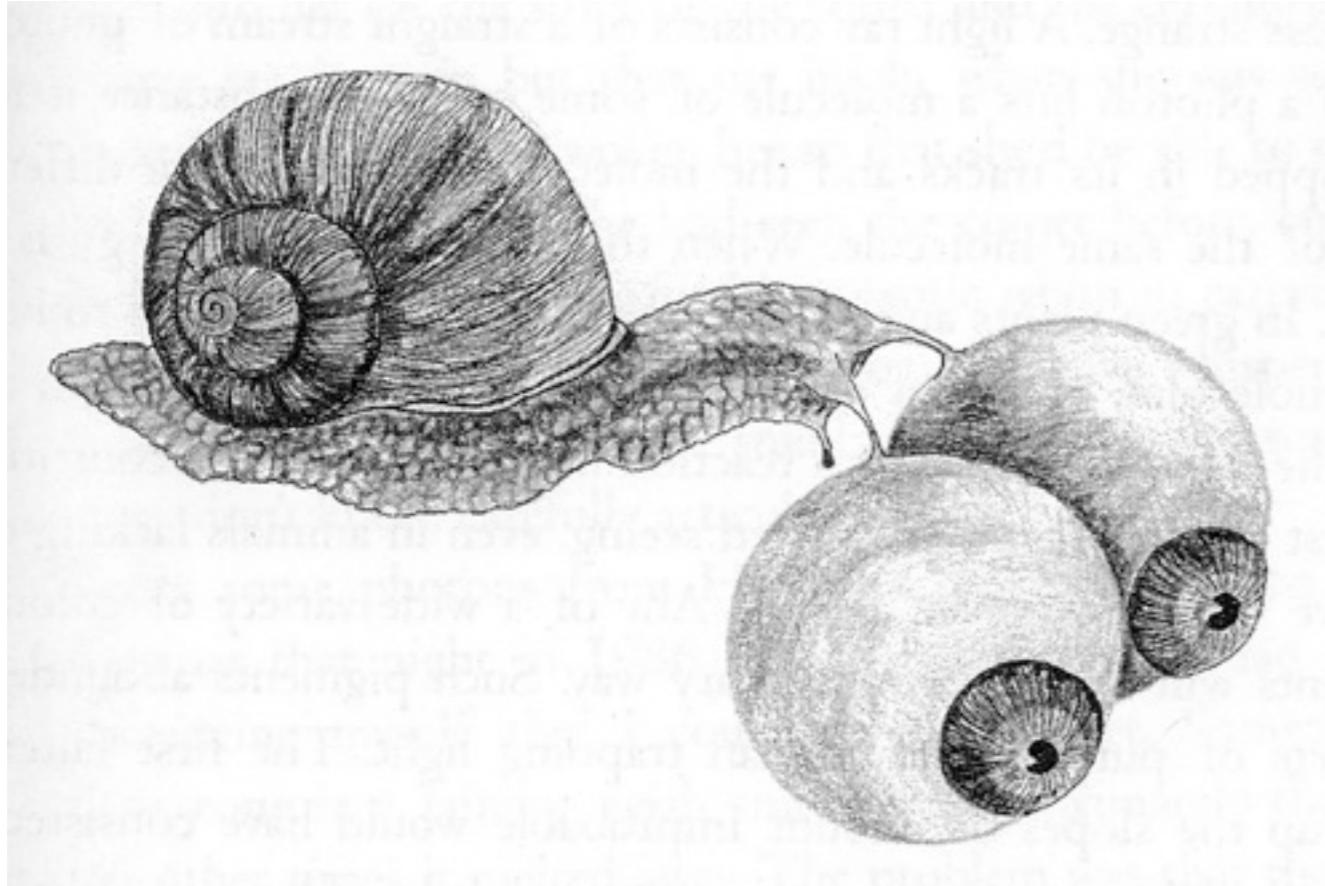


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An example of a non-balanced systems would be a Brantenberg 1 vehicle equipped with a human-sized brain. Think about how its behavior would change if it had such a huge brain instead of just one wire connecting the sensor to the motor.

Richard Dawkins's snail with giant eyes

ecologically unbalanced system



Author of:
“The selfish gene” and
“The blind watchmaker”



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What are such huge eyes good for if the snail cannot move quickly? It's only useless additional weight. Even if the snail had the brain (which it doesn't) to perceive approaching predators (such as birds) this information would be entirely useless.

“Brain builder”: Hugo de Garis

building a brain the size of the moon?

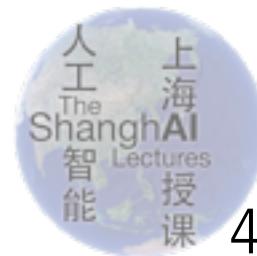
—> Xi'an for a short comment



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currently living in China, former director of the Artificial Brain Laboratory and Xiamen University.

Intelligent systems: properties and principles

“How the body …”, chapter 4

- **complete agents: embodied, situated, autonomous, self-sufficient**
- **real worlds vs. virtual worlds (see lecture 2)**
- **dynamical systems**
- **properties of complete agents**
- **agent design principles**



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Assignments for next week

- Read chapter 5 of “How the body ...”



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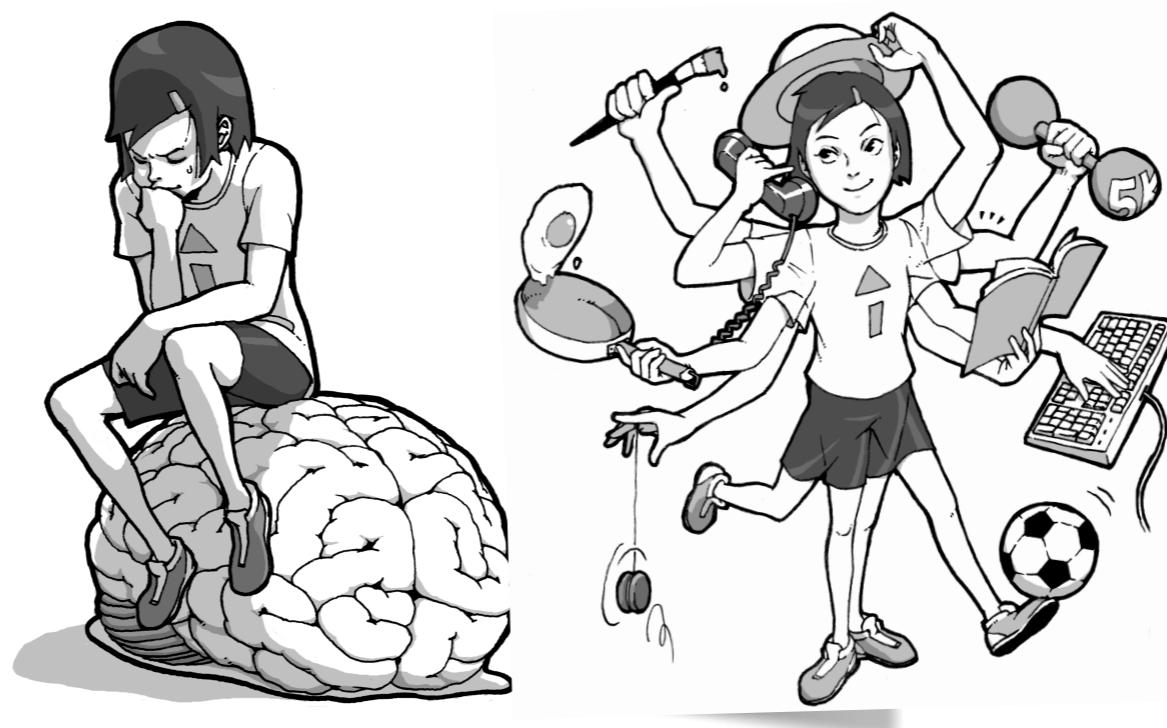
End of lecture 4

Thank you for your attention!

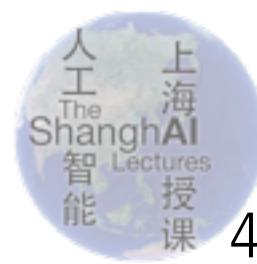
stay tuned for guest lecture by
Prof. Toshi Nakagaki



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Lecture 4: Guest speaker



from Hakodate Future University, Hokkaido, Japan

**Prof. Dr. Toshi Nagakaki, recipient of the Ig Nobel Prize (work together with Prof. Ryo Kobayashi and Prof. Akio Ishiguro)
“How does an amoeba tackle a maze”**

Today, 17.20 Japan local time, 10.20 CET



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Twenty-First 1st Annual Ig Nobel Prize ceremony happened on Thursday, September 29, 2011.

Watch video of the entire ceremony teaser below:

<http://improbable.com/ig/>



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End of lecture 4

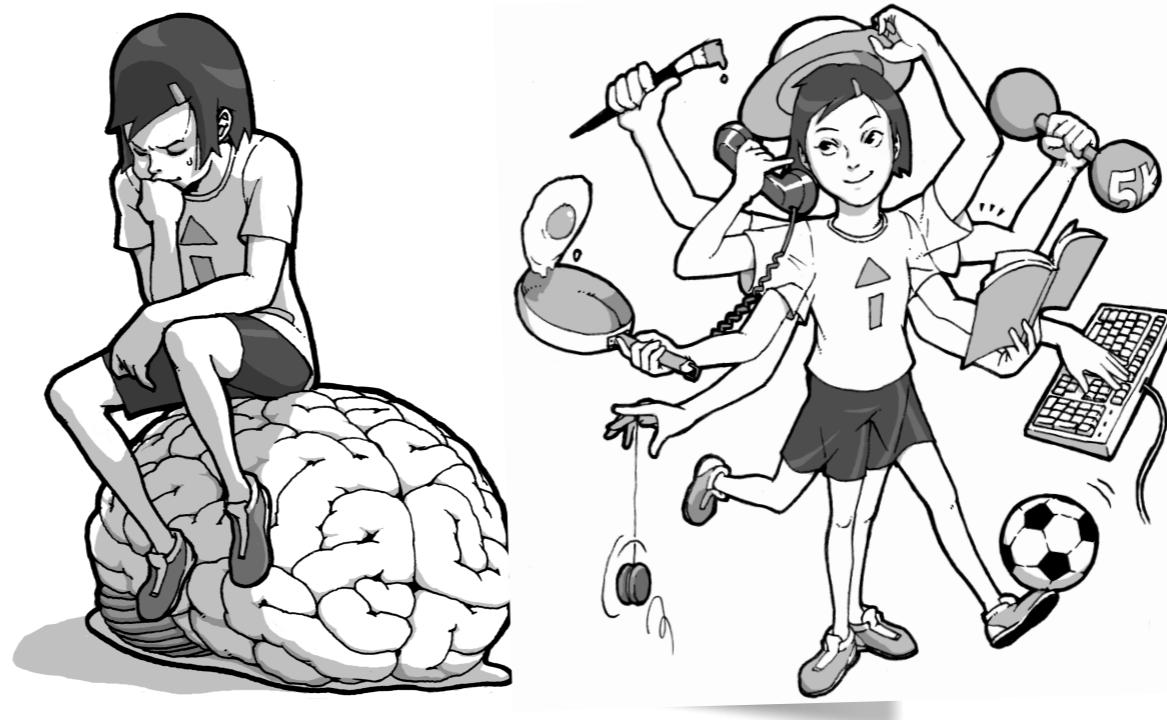
Thank you for your attention!

stay tuned for lecture 5

“Design principles for intelligent systems, Part II”



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