The ShanghAI Lectures

人工智能

上海授课

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

Rolf Pfeifer and Nathan Labhart
National Competence Center Research in Robotics (NCCR Robotics)
Artificial Intelligence Laboratory
University of Zurich

Today from Shanghai Jiao Tong University, Shanghai, China

欢迎您参与

“来自上海的人工智能系列讲座”

University of Zurich

robotics Swiss National Centre of Competence in Research

ai lab

Today's schedule

09.00 - 09.05 Introductory comments

09.05 - 09.15 Presentations from Xi'an

09.02 - 10.10 Design principles for intelligent systems

10.15 Break

10.20 - 10.50 Guest speaker: Prof. Dario Floreano, "Bio-inspired flying robots"

10.50 - 11.00 Guest speaker: Pascal Kaufmann, "The Roboy project"

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CHINA
RUSSIAN FEDERATION
KAZAKHSTAN
MONGOLIA
KYRGYZSTAN
Gobi Desert
Tarim Pendi
Kunlun Shan
Quingzang Gaoyuan (Plateau of Tibet)
Himalaya
INDIA
NEPAL
BHUTAN
BANGLADESH
MYANMAR
LAOS
THAILAND
VIETNAM
PHILIPPINES
TAIWAN
NORTH KOREA
SOUTH KOREA
JAPAN
PACIFIC OCEAN
Sea of Japan (East Sea)
Yellow Sea
South China Sea
Bay of Bengal
BEIJING
Shanghai
Hangzhou
Chengdu
Chongqing
Lhasa
Xi'an
Lanzhou
Xining
Kunming
Guangzhou (Canton)
Hong Kong
Macau
Haikou
Harbin
Shenyang
Dalian
Qingdao
Ürümqi
Kashi
Hotan
LEGEND
Country Boundary
Major Road
River
Seaport
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Airport
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上海交通大學 SHANGHAI JIAO TONG UNIVERSITY 电子信息与电气工程学院 School of Electronic, Information and Electrical Engineering

《上海人工智能系列讲座（The ShanghAI Lectures）

short intro by Prof. Weidong Chen

Short introduction by Prof. Weidong Chen

Autonomous Robot Group

School of Electronic Information and Electrical Engineering

Shanghai Jiao Tong University, China

Lecture 4: Guest speaker

from EPFL, Switzerland
Ecole Polytechnique Fédéral
de Lausanne

Prof. Dario Floreano, director, Intelligent Systems Lab, EPFL
Director, Swiss National Competence Center Robotics, Switzerland

"Bio-inspired flying robots"

Today, approx. 16.20 China local time, 10.20 CET

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Beautiful illustration of the synthetic methodology

Lecture 4: Guest speaker

AI Lab, University of Zurich
Switzerland

Pascal Kaufmann, neuroscientist

“The Roboy project”

Today, approx. 16.50 China local time, 10.50 CET

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Roboy is a fully tendon-driven small size (1.30m) humanoid developed at the Artificial Intelligence laboratory.
http://roboy.org/pages/en/roboy.php?lang=EN

Lecture 4

Design principles for intelligent systems: Part I

18 October 2012

University of Zurich

Swiss National Centre of Competence in Research

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

Recap

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- form of theory (philosophy of science): math. theory of dynamical systems (also metaphorically); design principles — synthetic science (joining engineering and science)
- Swiss robots: illustrating principle of “cheap design” — exploiting ecological niche
- “Puppy” as a complex dynamical system —> more today

Today's topics

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Complete agents

Masano Toda's
Fungus Eaters

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embodied
self-sufficient
autonomous
situated

Complete agents

Masano Toda's
Fungus Eaters

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The "Fungus Eater" is a creature – in our terminology, an autonomous agent – sent to a distant planet to collect uranium ore. The more ore it collects, the more reward it will get. If feeds on a certain type of fungus that grows on this planet. The "Fungus Eater" has a fungus store, means of locomotion (e.g., legs or wheels), and means for decision making (a brain), and for collection (e.g., arms). Any kind of activity, including thinking, requires energy, if the level of fungus in its fungus store drops to zero, the Fungus Eater dies. The Fungus Eater is also equipped with sensors, one for vision and one for detecting uranium ore (e.g., a Geiger counter). (Understanding intelligence, p. 84).

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: next slide

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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We will use the terms dynamical systems, chaos,
nonlinear dynamics, and complex systems synonymously (for the purpose of our discussion)
- phase space: local audience at JiaoTong University (joint angles of the quadruped robot "Puppy")
- point in phase space: characterization of state of system
- use differential equations to describe how they change
- path of point through phase space: trajectory
- non-linear system: principle of superposition does not hold. Example: play two favorite songs simultaneously
- sensitivity to initial conditions: difficulty of weather forecast
- attractor state: system will automatically move there if it is within the basin of attraction (region in phase space)
- different types of attractors: point, periodic, quasi-periodic, chaotic

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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

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).

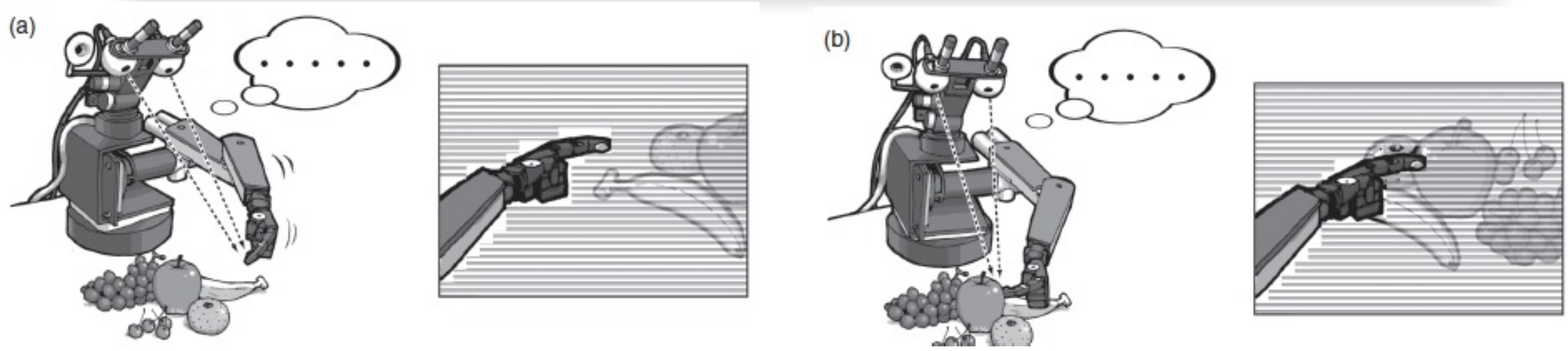
Complete-agent principle

- **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**

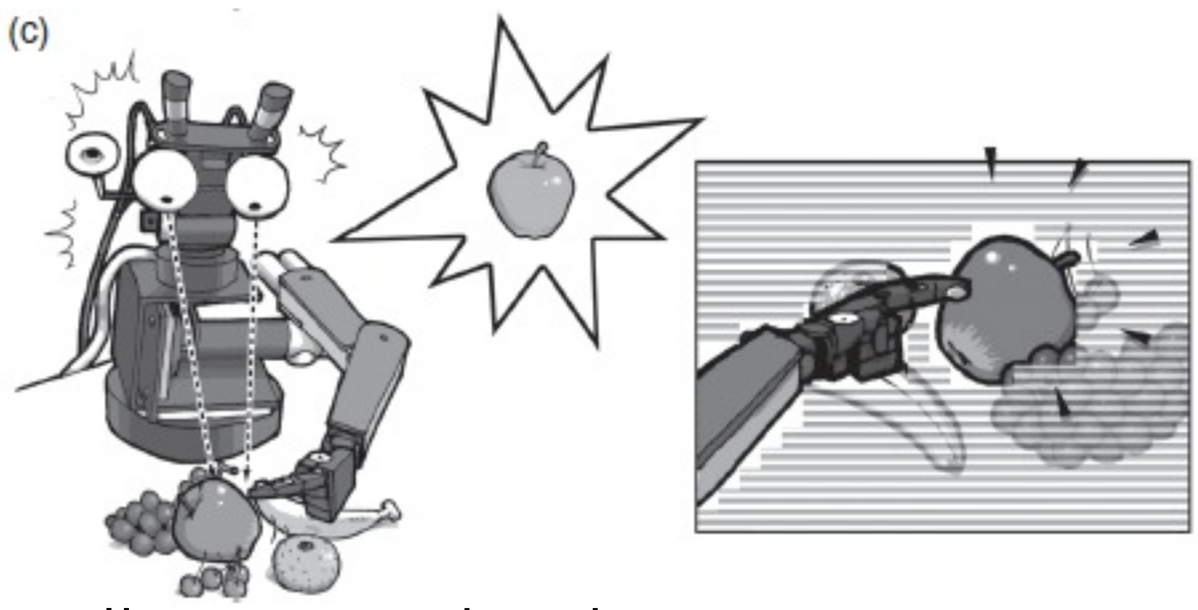
→ can be exploited!

Story: computer vision student, very clever.
What about solving the “partial occlusion problem”? (i.e. recognizing objects from a picture when they are partially occluded and cannot be completely seen).
If the robot can move around, the need to solve this problem is strongly reduced.

Recognizing an object in a cluttered environment



manipulation of environment can facilitate perception



Experiments: **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

- short recap
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- illustration of design principles
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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**

Often, the coupling occurs through the interaction with the environment.

Recall: The "embodied turn" Rodney Brooks, MIT

The subsumption architecture the "behavior-based" approach

classical, cognitivistic

sensors → perception - modeling - planning - acting → actuators

sense-model-plan-act
sense-think-act

"behavior-based", subsumption

sensors

→ explore →
→ collect object →
→ avoid obstacle →
→ move foreward →

actuators

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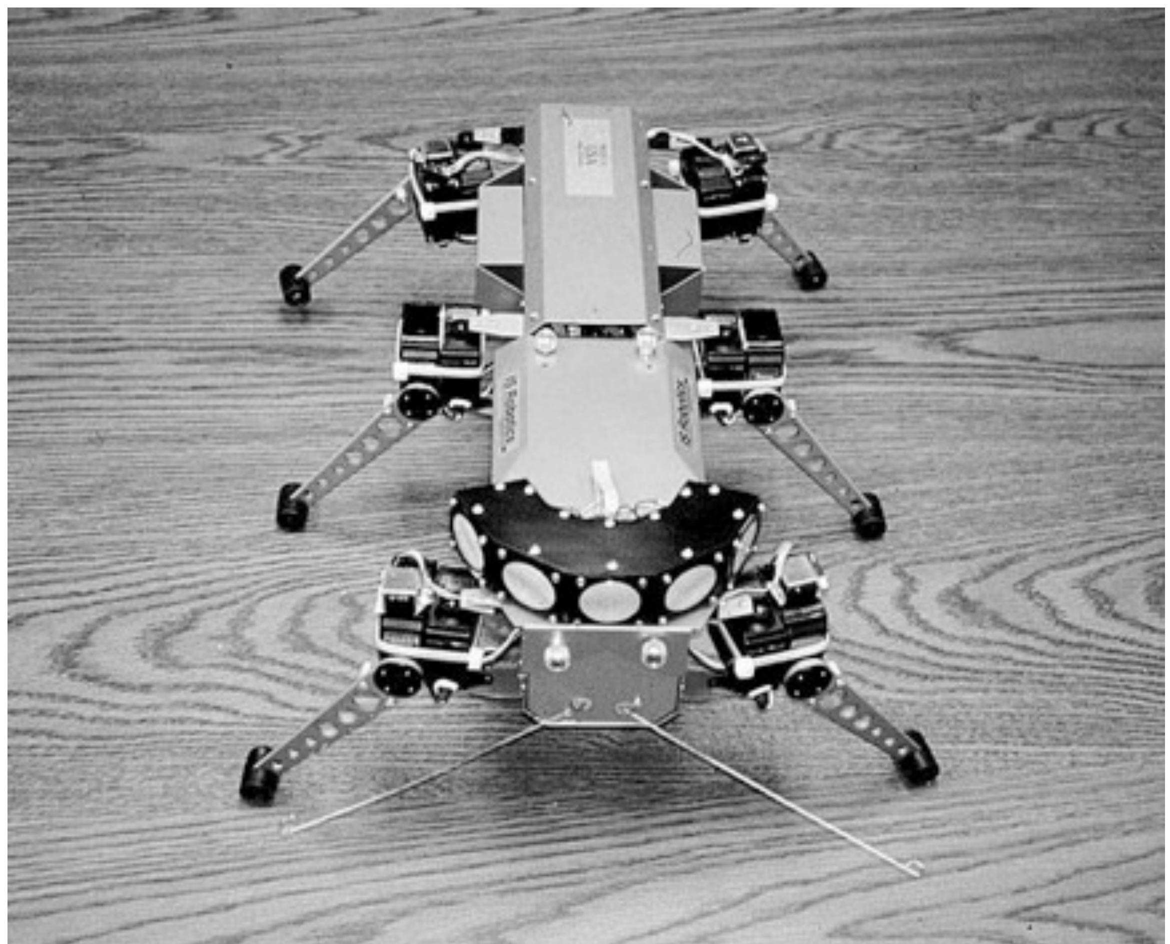
The subsumption architecture was originally proposed by Rodney Brooks as an alternative to the classical symbol-based approach, which starts from the assumption that control is hierarchical and centralized. 1986: "A robust layered control system for a mobile robot." IEEE Journal of Robotics and Automation,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

Mimicking insect walking

- **subsumption architecture well-suited**

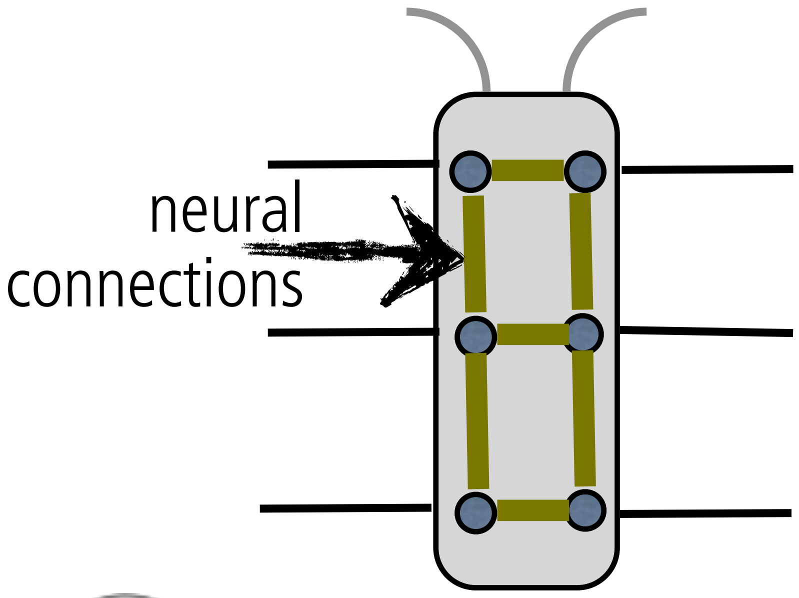
six-legged robot
"Ghenghis"



Insect walking

Holk Cruse, German biologist

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

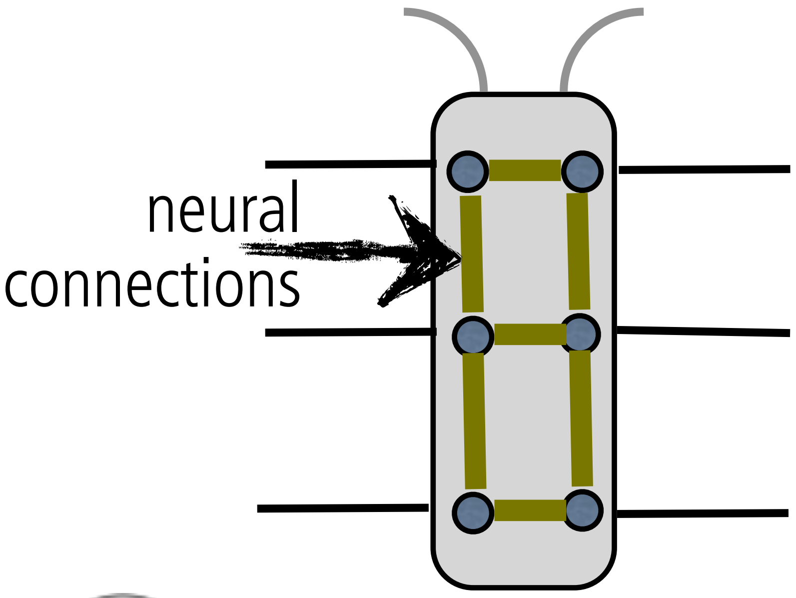


It has been known for quite some time that there is no central area in the brain of the insect controlling the coordination of the legs in walking. But then, how is coordination possible?

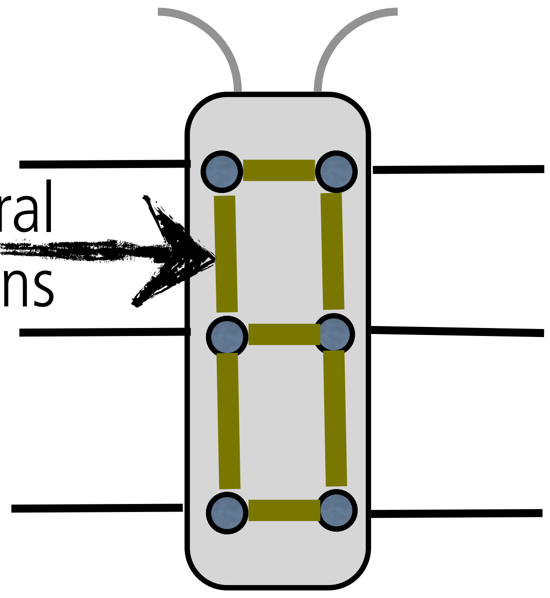
Insect walking

Holk Cruse, German biologist

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



Insect walking



Holk Cruse, German biologist

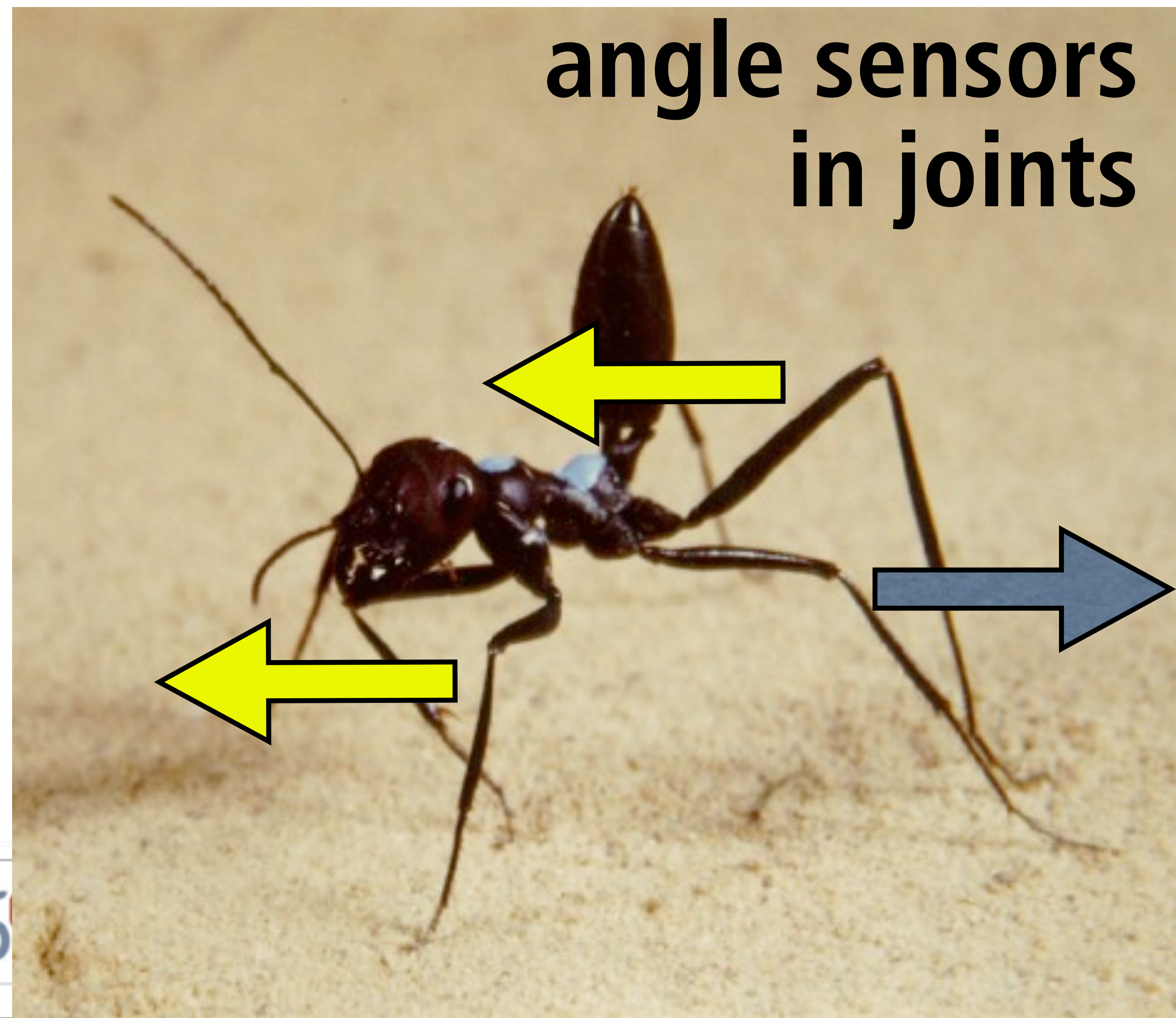
- **no central control for leg-coordination**
- **only communication between neighboring legs**
- **global communication: through interaction with environment**

Communication through interaction with environment

- **exploitation of interaction with environment**

→ **simpler neural circuits**

"parallel, loosely coupled processes"



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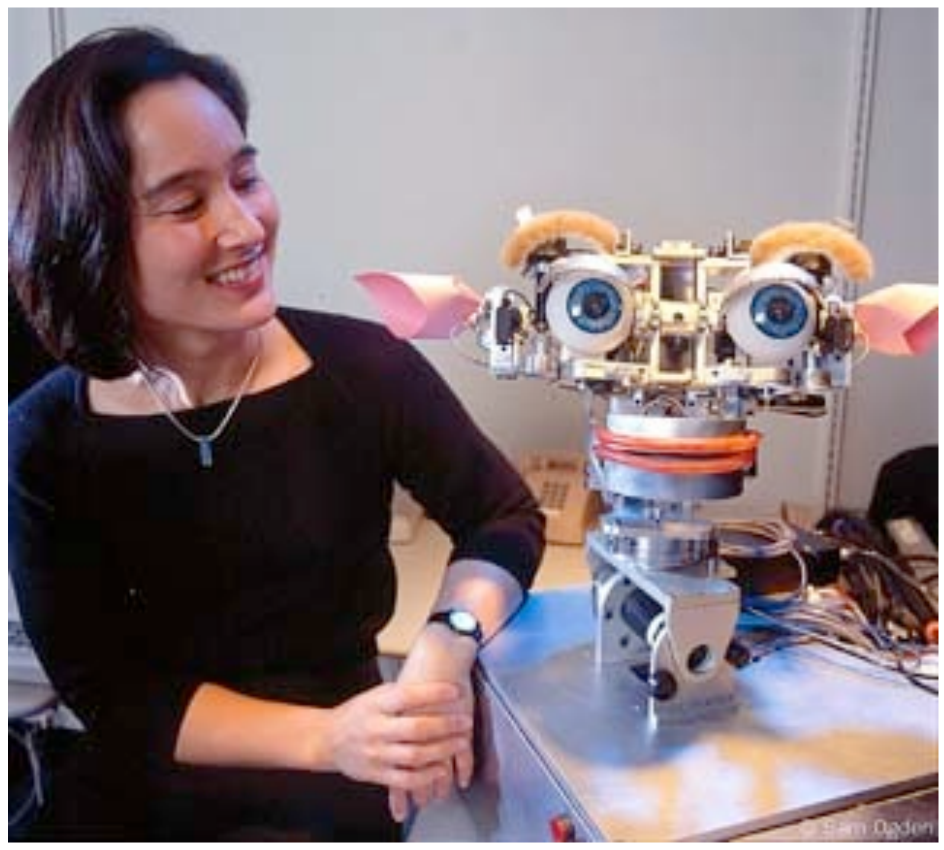
In fact, there IS global communication but rather than through specific neural connections, it is through the interaction with the environment: because insects are embodied systems, if it pushes back with one leg, the joints of the other legs standing on the ground will be moved as well. All it needs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

Subsumption: Engineering or cognitive science?

``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 the 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).

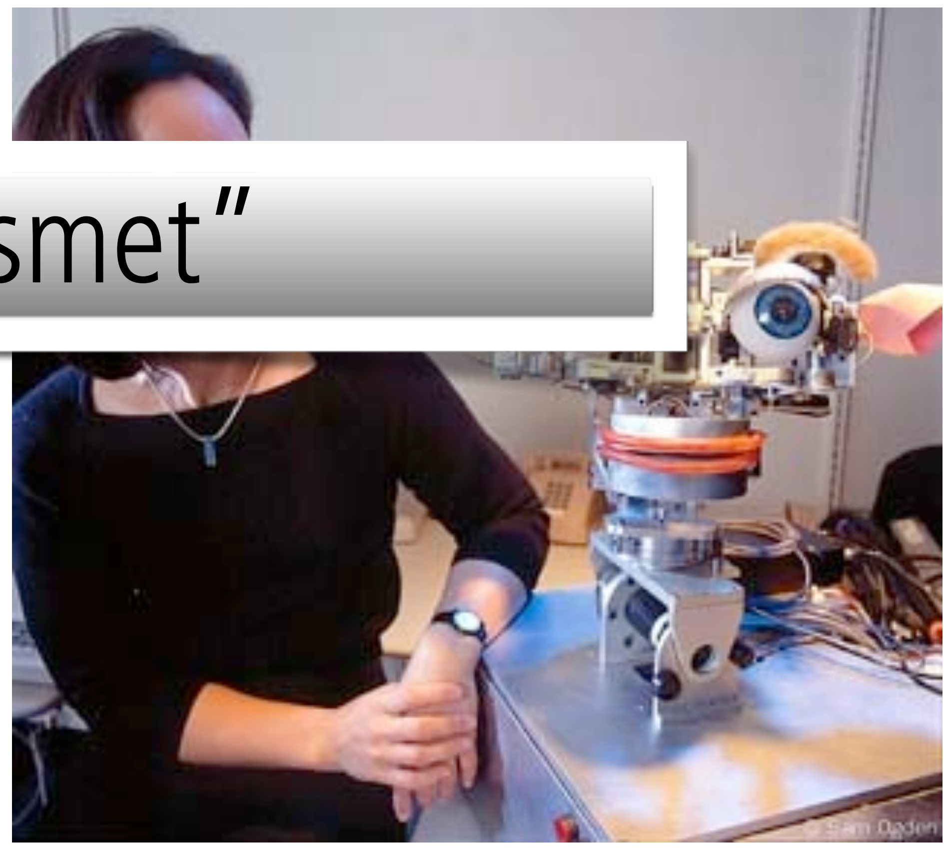
Kismet: The social interaction robot



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

Kismet: The social interaction robot

Video "Kismet"

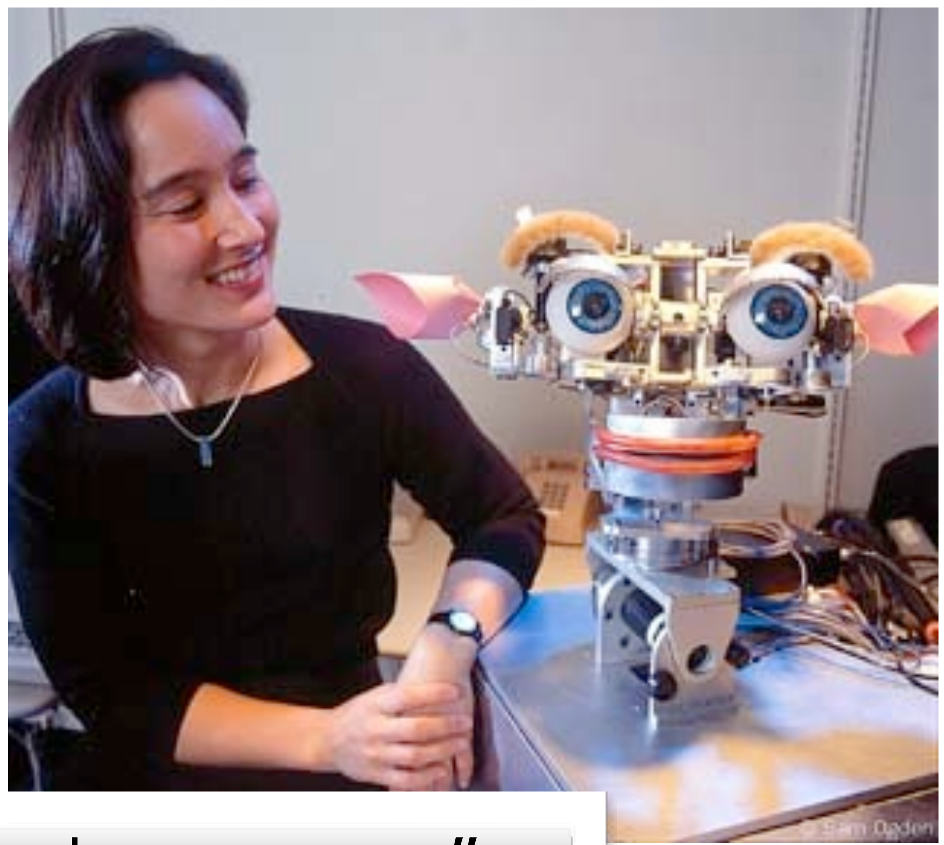


Cynthia Breazeal, MIT Media lab (prev. MIT AI Lab)

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**



principle of "parallel, loosely coupled processes"

, MIT Media lab (prev. MIT AI Lab)

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Kismet: The social interaction robot

Reflexes:
- turn towards loud noise
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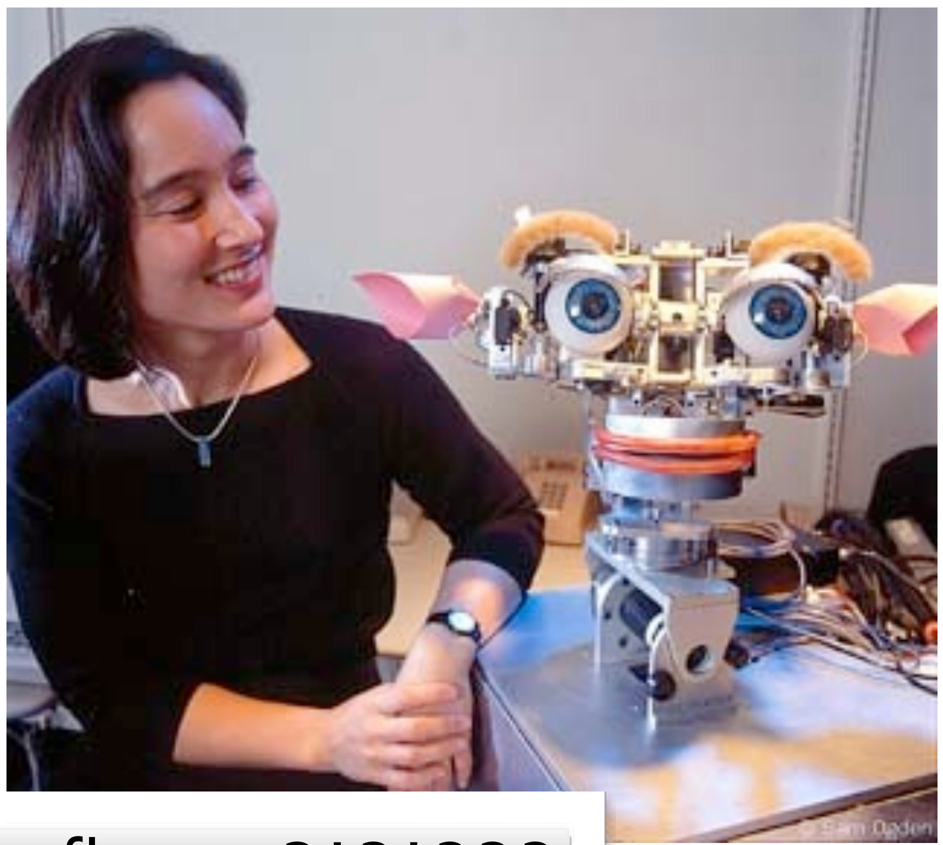

social competence: a collection of reflexes ?!?!???

, MIT Media lab (prev. MIT AI Lab)

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Rolf Pfeifer: "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."

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.

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."

volunteer for brief presentation on the "Brooks-Kirsh" debate - or generally, scalability of subsumption (from Univ. of Tasmania, 1 Nov. 2012)

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Sometimes, this is called the "scalability" issue, in other words, does the approach scale from insects to humans?

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- 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

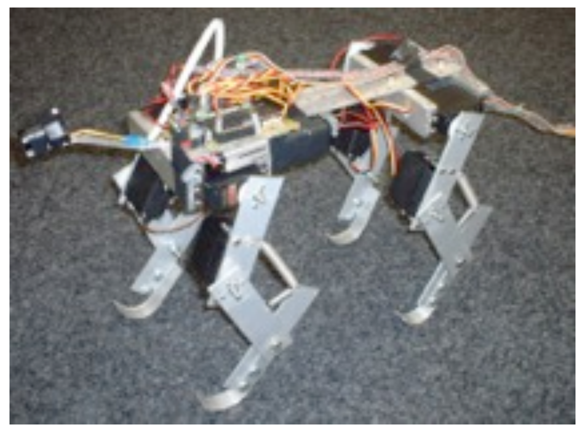
Case study: “Puppy” as a complex dynamical system

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

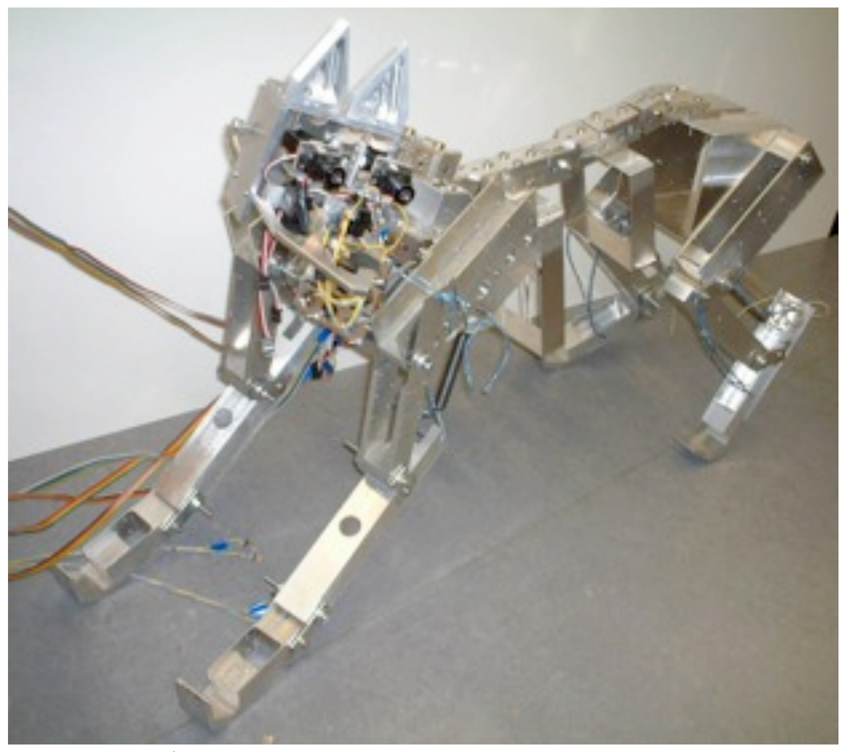
→ morphological computation

Recall: “Puppy’s” simple control

rapid locomotion in biological systems



recall last week’s
lecture: emergence of behavior

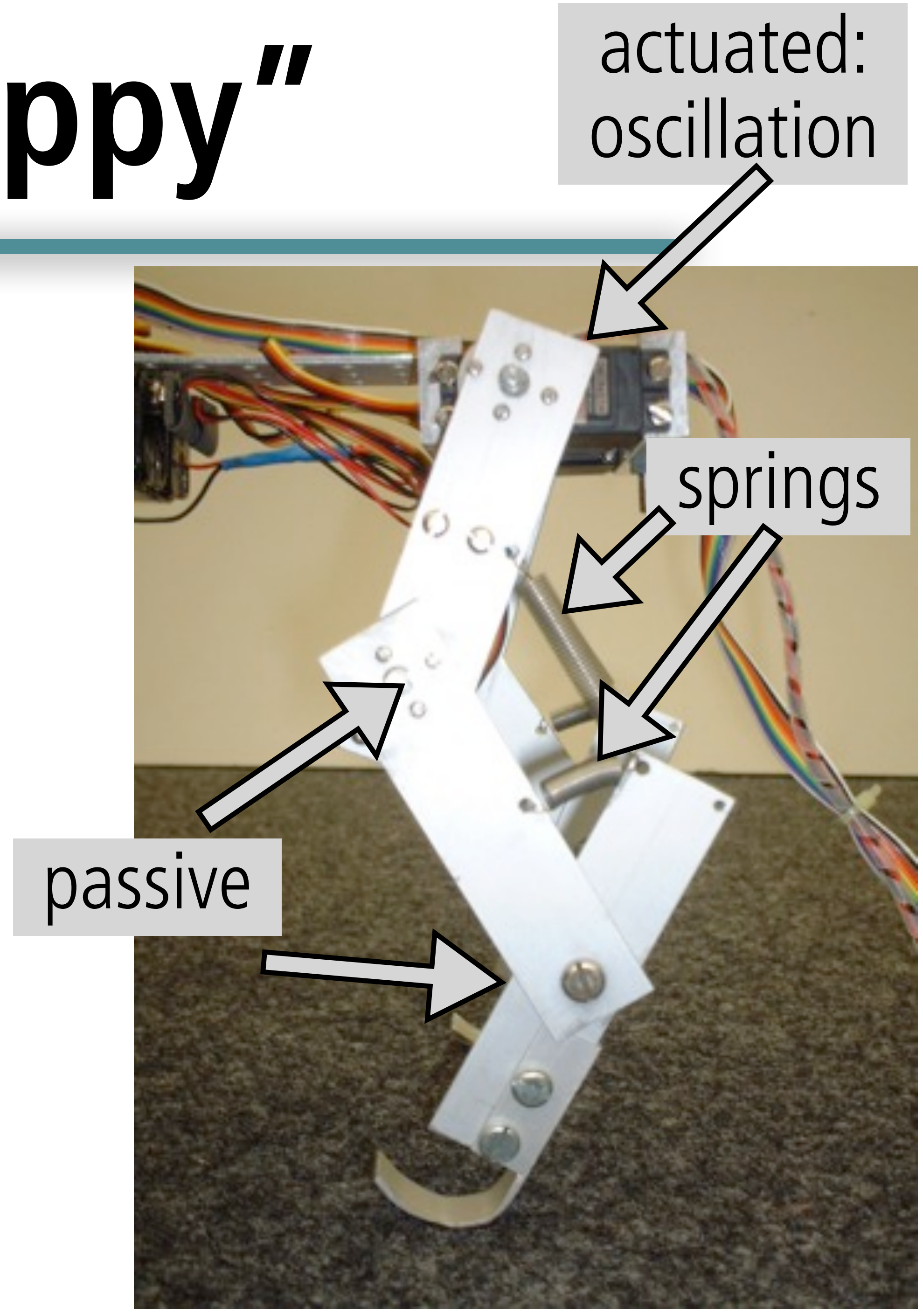


Design and construction:
Fumiya Iida, AI Lab, UZH and ETH-Z

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"

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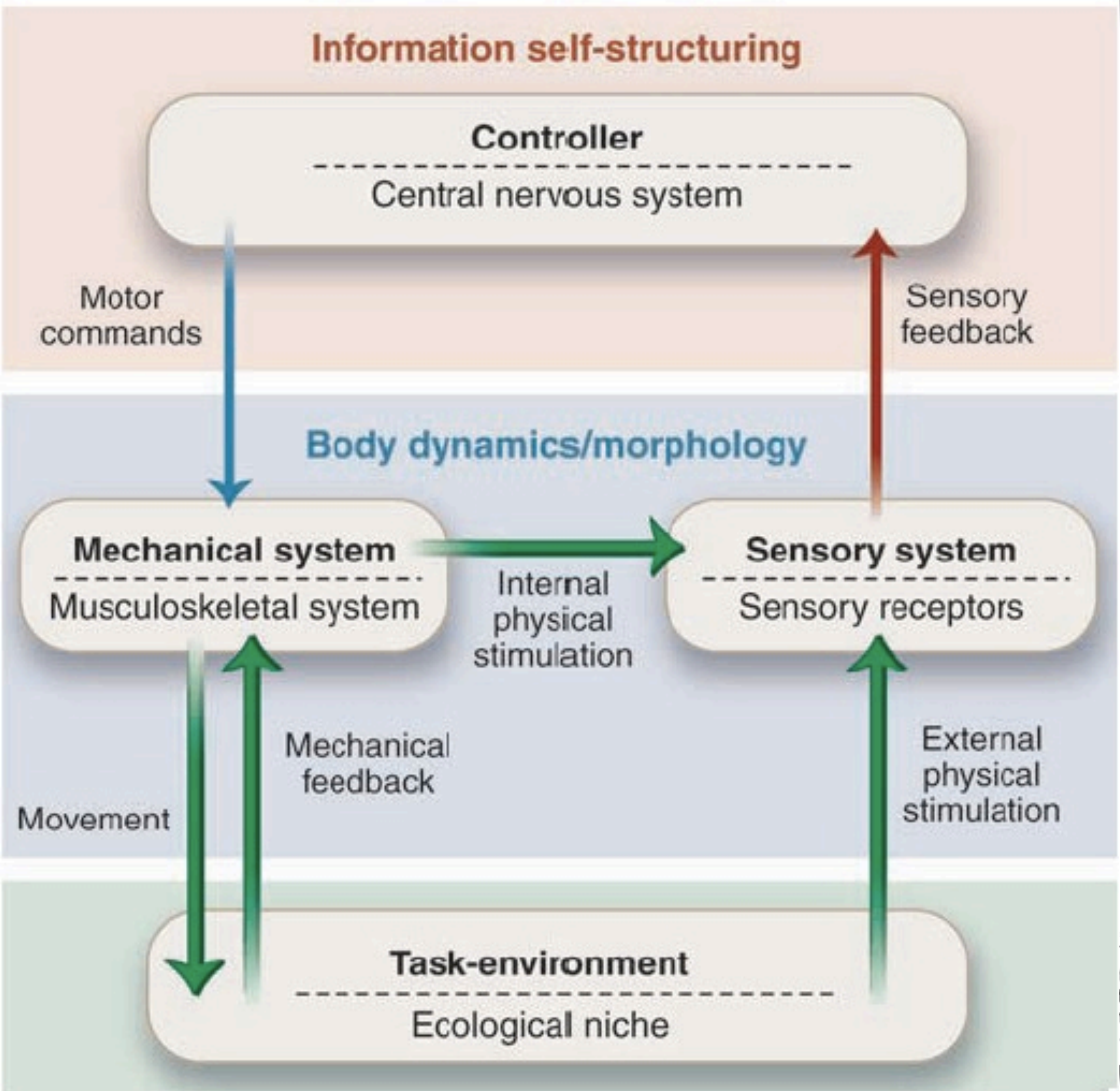
The behavior is very irregular, but as long as "Puppy" is within a basin of attraction, it will maintain its gait pattern. Gate patterns can be viewed as discrete entities within a continuous phase space. Because of their discrete nature, some researchers talk about "proto-symbols".

Implications of embodiment
Self-stabilization



"Puppy"

which part of diagram relevant? —> Zurich

Pfeifer et al.,Science, 16 Nov. 2007

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

Principle of "cheap design"

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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)

walking

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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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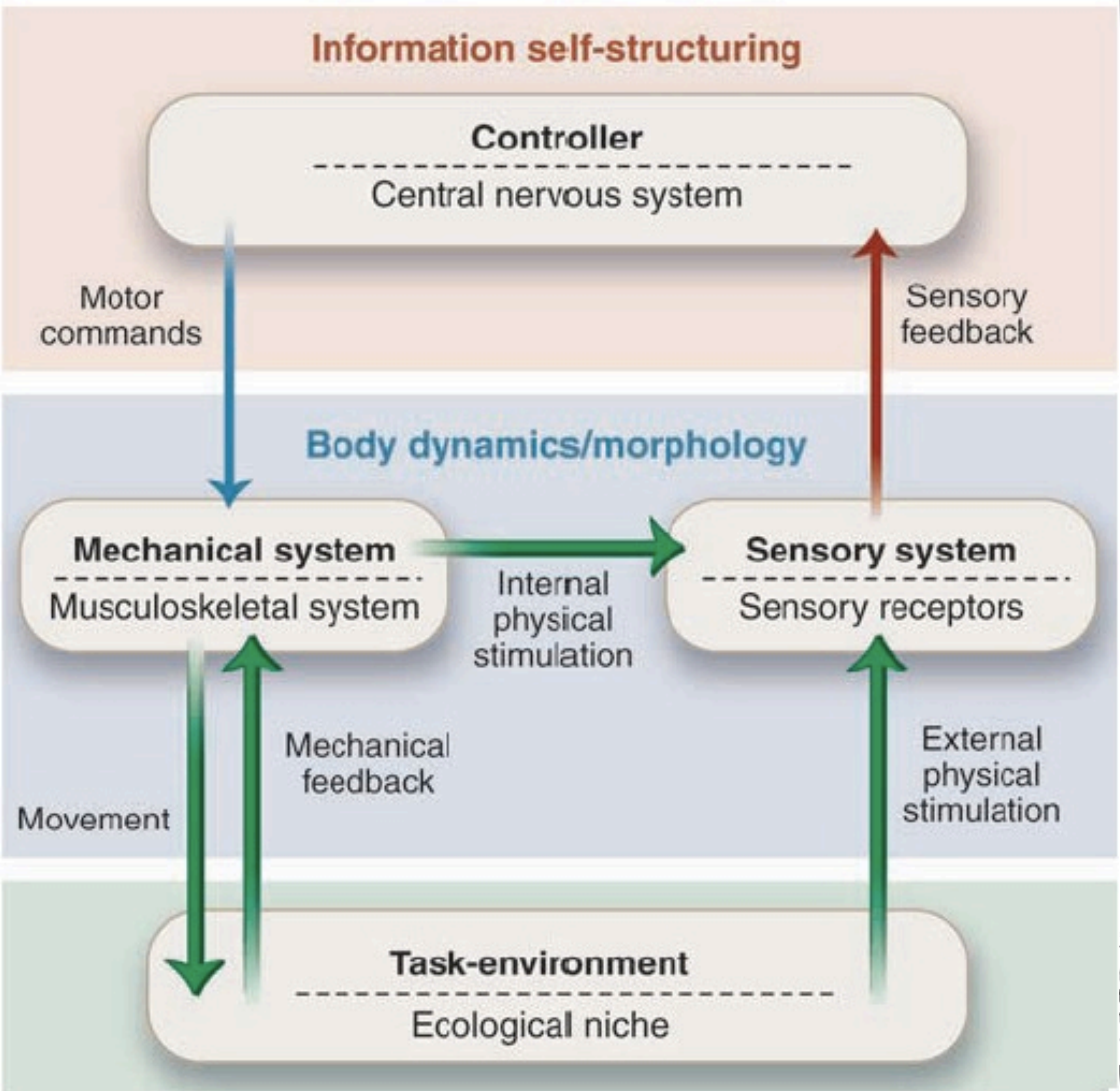
Play video by Steve Collins

Implications of embodiment
Self-stabilization



Passive Dynamic Walker

which part of diagram relevant? —> Shanghai

Pfeifer et al.,Science, 16 Nov. 2007

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

Short question

memory for walking?

The Cornell Ranger

design and construction:
Andy Ruina
Corr

Video "Cornell Ranger"

exploitation of passive dynamics

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taking the exploitation of passive dynamics to the extreme: The Cornell Ranger

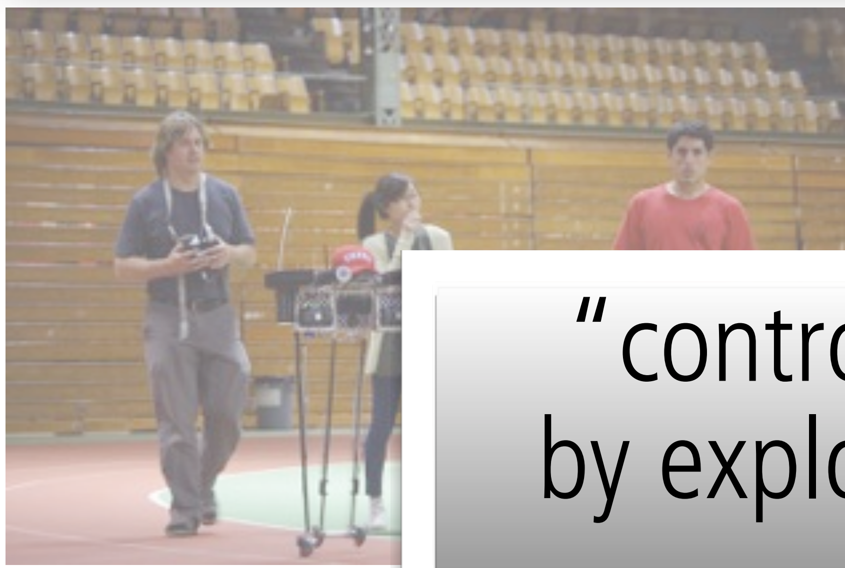
The Cornell Ranger

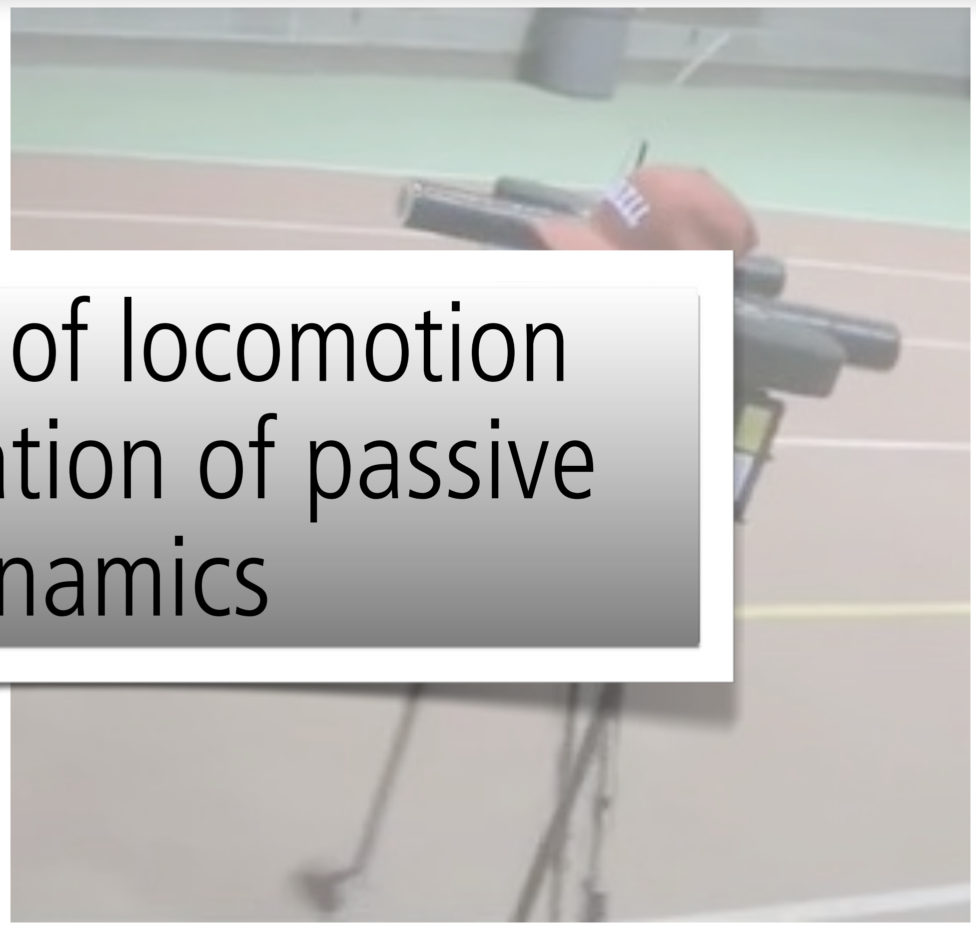
conception et construction:
Andy Ruina
Cornell University

65km with one battery charge!

taking the exploitation of passive dynamics to the extreme: The Cornell Ranger

The Cornell Ranger



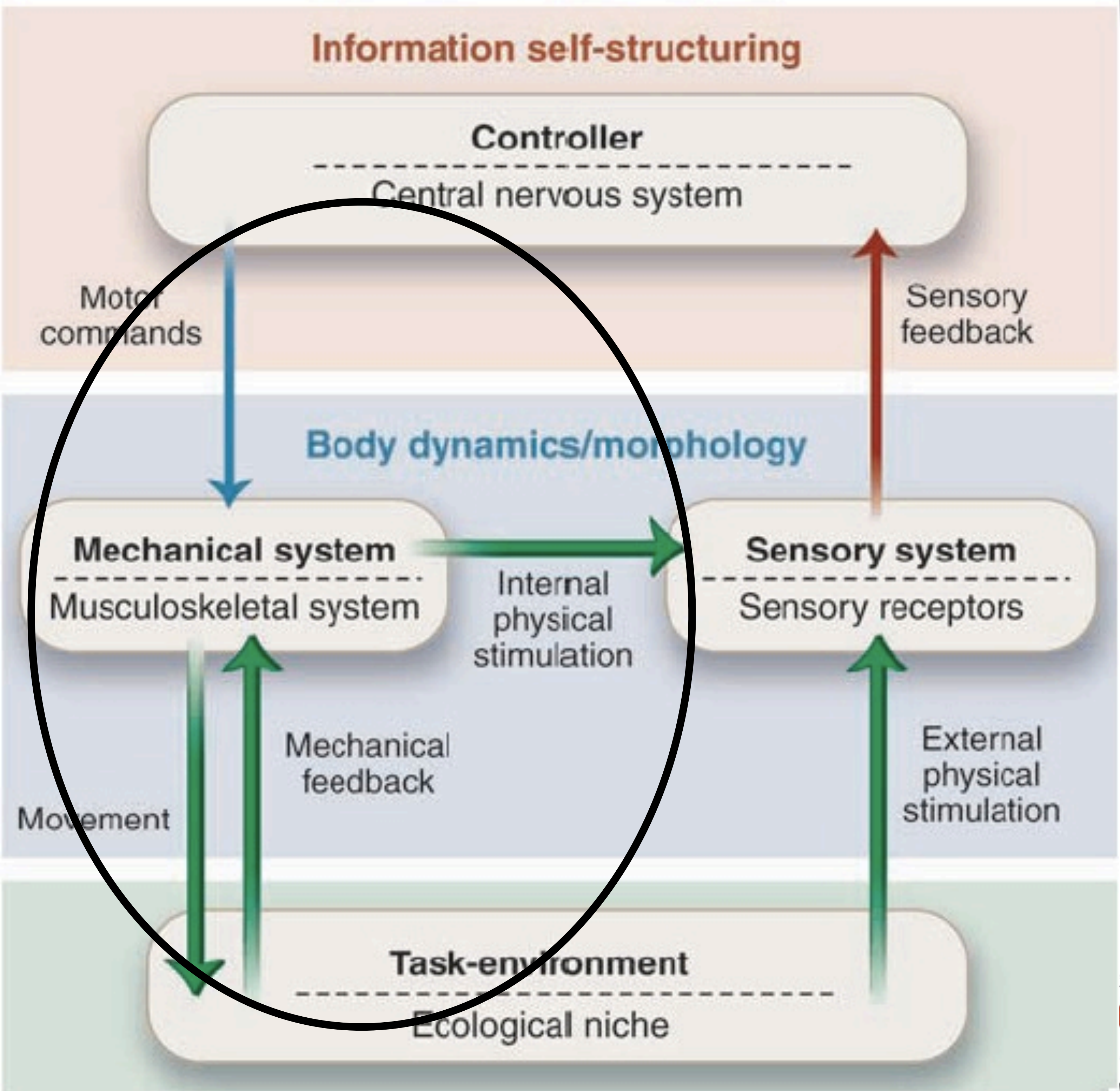


"control" of locomotion by exploitation of passive dynamics

conception et construction:
Andy Ruina
Cornell University

65km with one battery charge!

Self-stabilization in Cornell Ranger



Pfeifer et al.,Science, 2007

There is only a tiny bit of sensing (the contact sensors on the feet); it's all that's required to make the Ranger walk on flat ground.

Contrast: Full control

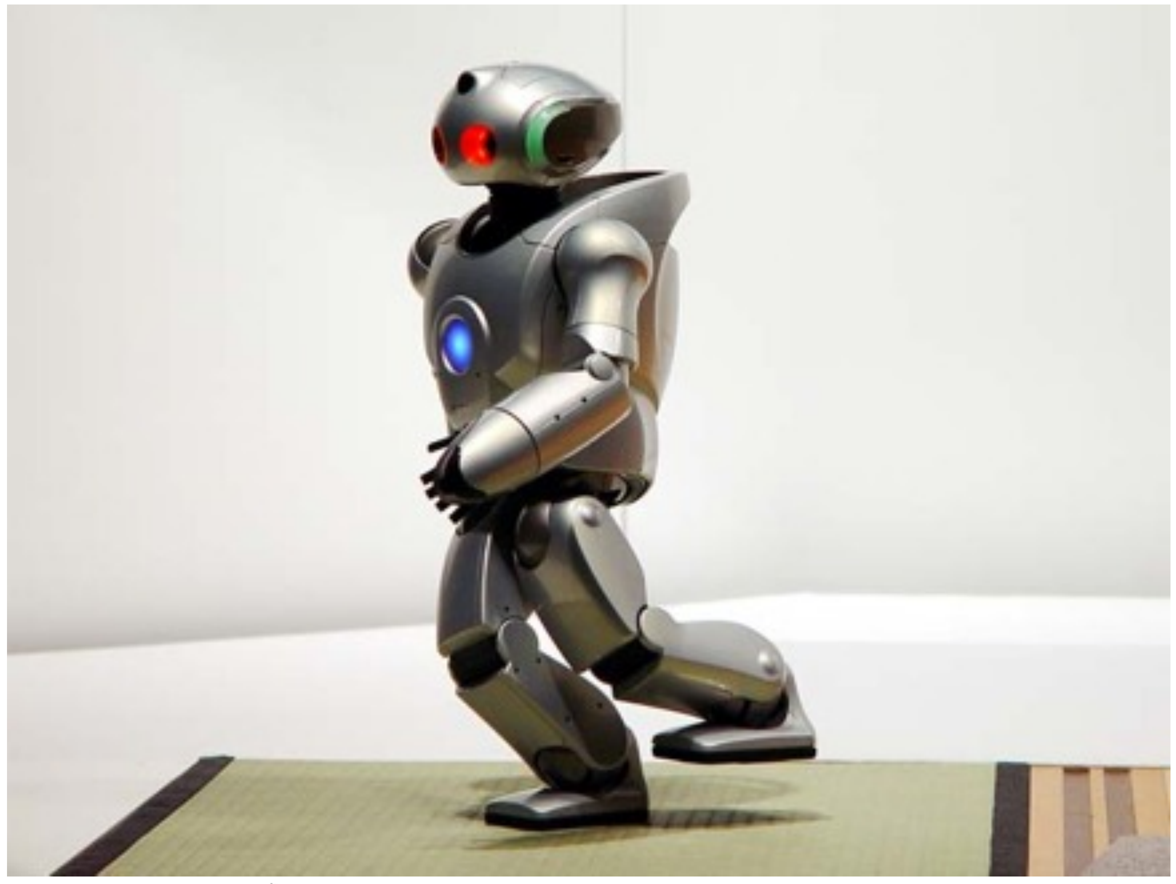
Honda Asimo

Sony Qrio

Contrast: Full control

Video "Qrio"

Sony Qrio



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Redundancy principle

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- examples: natural language, brain, brake systems of airplanes (jets, wheels, parachutes)
- 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

Principle of "ecological balance"

Braitenberg Veh. 1 with human-size brain
—> HIT Lab, Australia

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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The ShanghAI Lectures 人工智能 上海授课

Principle of "ecological balance"

balance in complexity

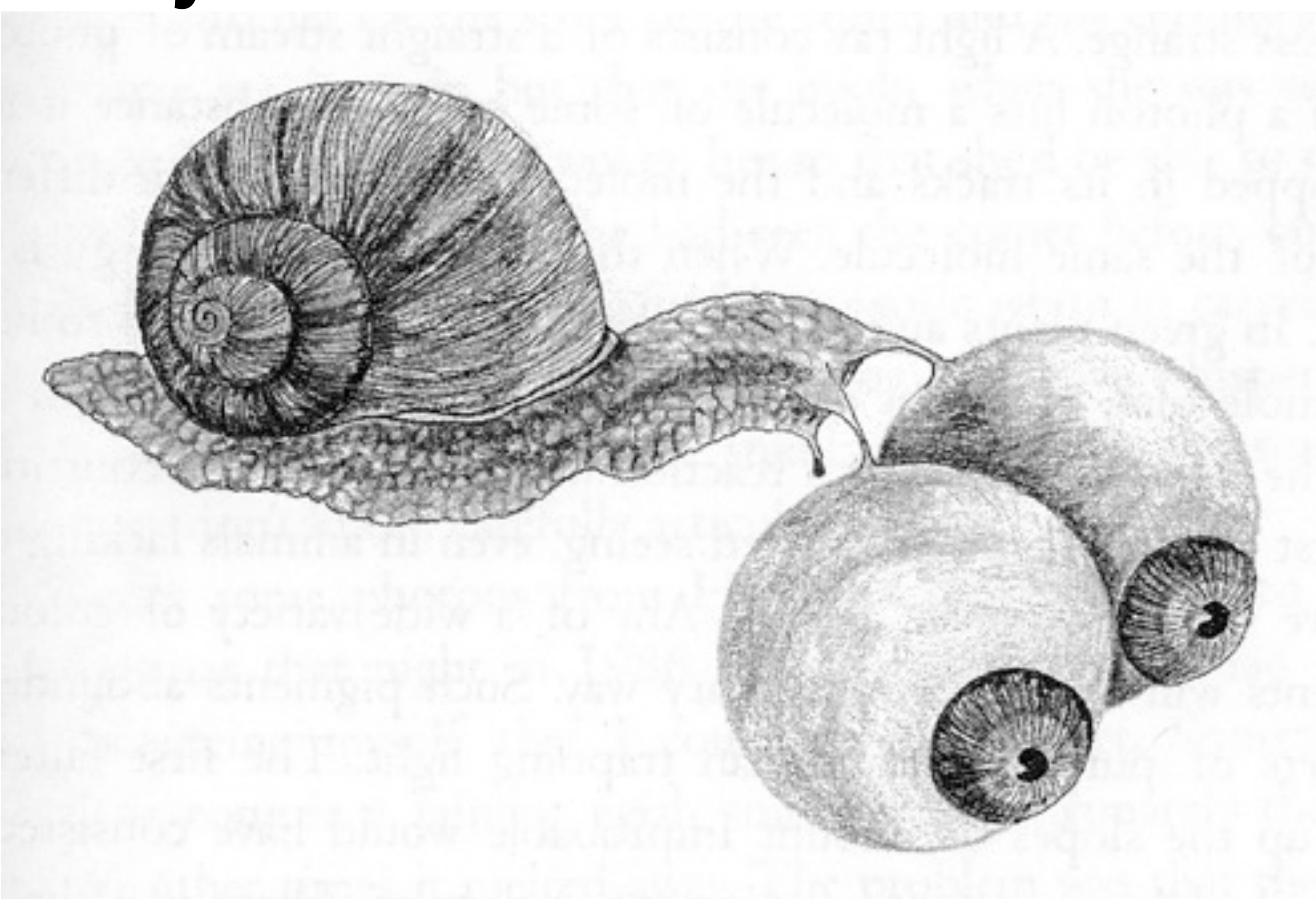
given task environment: match in complexity of sensory, motor, and neural system

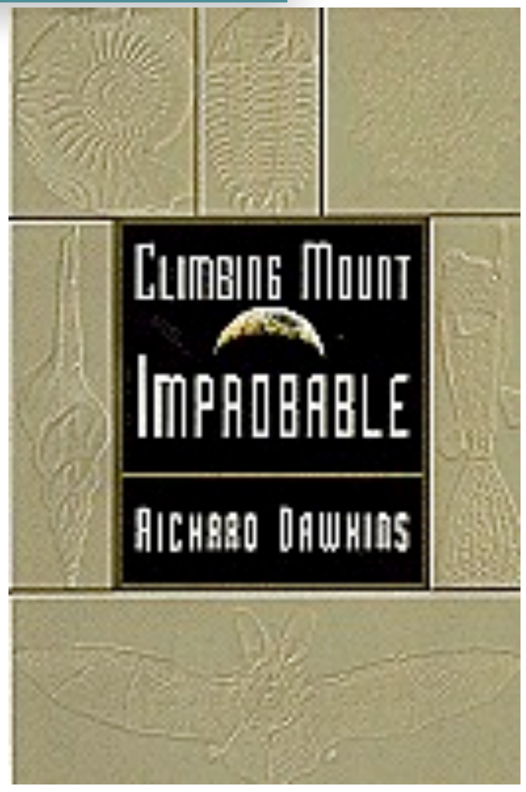
balance / task distribution

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

Richard Dawkins's snail with giant eyes

ecologically unbalanced system





Author of:
"The selfish gene" and
"The blind watchmaker"

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?

—> NYU, Abu Dhabi for a short comment

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currently living in China, former director of the Artificial Brain Laboratory, previously at 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**

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. Dario Floreano


University of Zurich

Lecture 4: Guest speaker

from EPFL, Switzerland
Ecole Polytechnique Fédéral
de Lausanne

Prof. Dario Floreano, director, Intelligent Systems Lab, EPFL
Director, Swiss National Competence Center Robotics, Switzerland

"Bio-inspired flying robots"

Today, approx. 16.20 China local time, 10.20 CET

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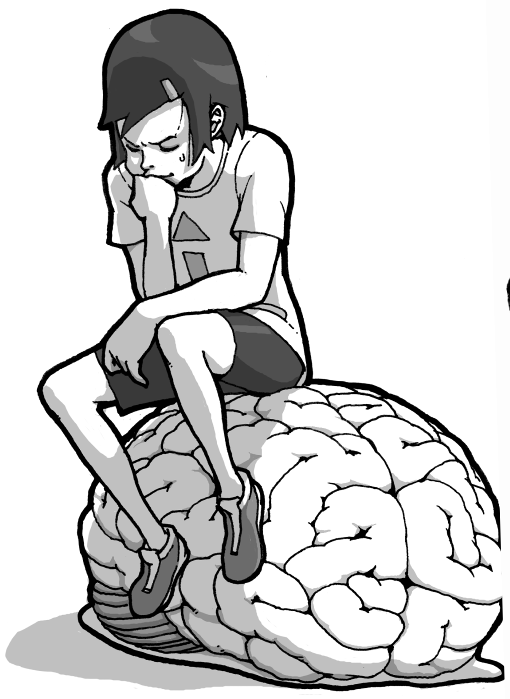
End of lecture 4

Thank you for your attention!

stay tuned for lecture 5

"Design principles for intelligent systems, Part II"



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