Morphology, morphosis and materials: research opportunities

The four messages of embodiment

Locomorph Summer School
University of Southern Denmark
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LOCOMORPH

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NCCR National Competence Center Robotics, Switzerland

University of Zurich

robotics Swiss National Centre of Competence in Research

ai lab

Thanks to ...

Hajime Asama
Rudolf Bannasch
Josh Bongard
Simon Bovet
Rodney Brooks
Weidong Chen
Steve Collins
Holk Cruse
Paolo Dario
Raja Dravid
Rodney Douglas
Peter Eggenberger
Andreas Engel
Martin Fischer
Dario Floreano
Toshio Fukuda
Robert Full
Philippe Gaussier
Gabriel Gomez
Karl Grammer
Verena Hafner
Fumio Hara
Alejandro Hernandez
Owen Holland
Koh Hosoda
Fumiya Iida
Auke Ijspeert
Takashi Ikegami
Masayuki Inaba
Akio Ishiguro
Oussama Kathib
Alois Knoll
Maarja Kruusma
Yasuo Kuniyoshi
Cecilia Laschi
Jean-Paul Laumond
Lukas Lichtensteiger
Hod Lipson
Max Lungarella
Ren Luo
Barbara Mazzolai
Giorgio Metta
Jean-Arcady Meyer
Vincent Muller
Shuhei Miyashita
Toshi Nakagaki
Norman Packard
Alex Pitti
Mike Rinderknecht
Roy Ritzmann
Andy Ruina
Giulio Sandini
André Seyfarth
Olaf Sporns
Luc Steels
Kasper Stoy
Russ Tedrake
Esthen Thelen
Barry Trimmer
Sethu Vijakyakumar
Oskar von Stryk
Ruediger Wehner
Martijn Wisse
Hiroshi Yokoi
Wenwei Yu
Marc Ziegler
Tom Ziemke

University of Zurich

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… for their ideas

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Contents

Desired: robust, adaptive behavior in real world (the "usual")

LOCOMORPH

- self-sufficient, situated, autonomous
- sophisticated sensory-motor skills (walking, running over uneven terrain, climbing, soccer, next level factory automation, dexterous soft manipulation, etc.)
- smooth ("soft") social interaction and cooperation

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LOCOMORPH

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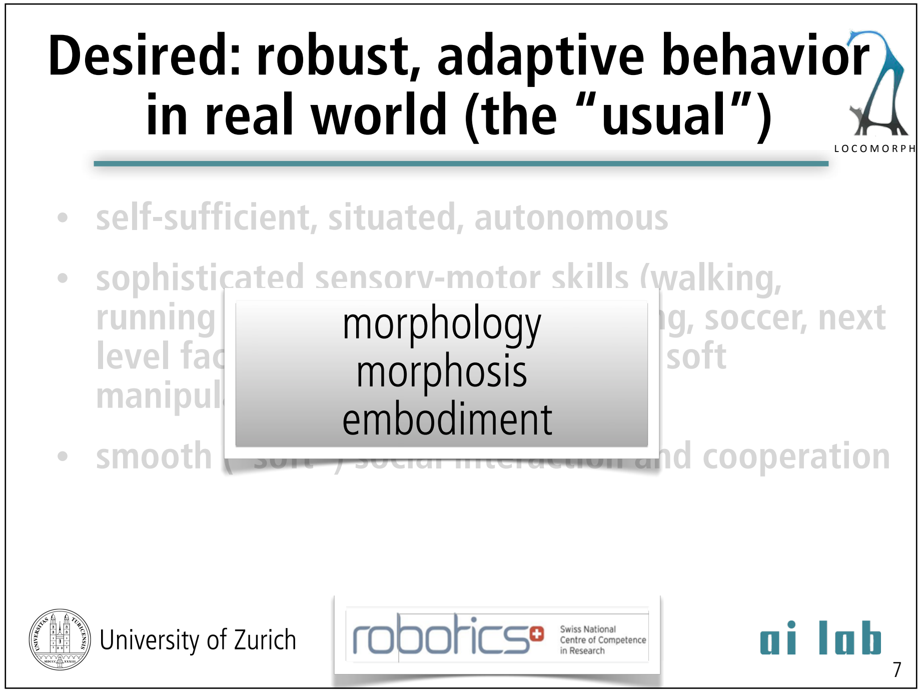
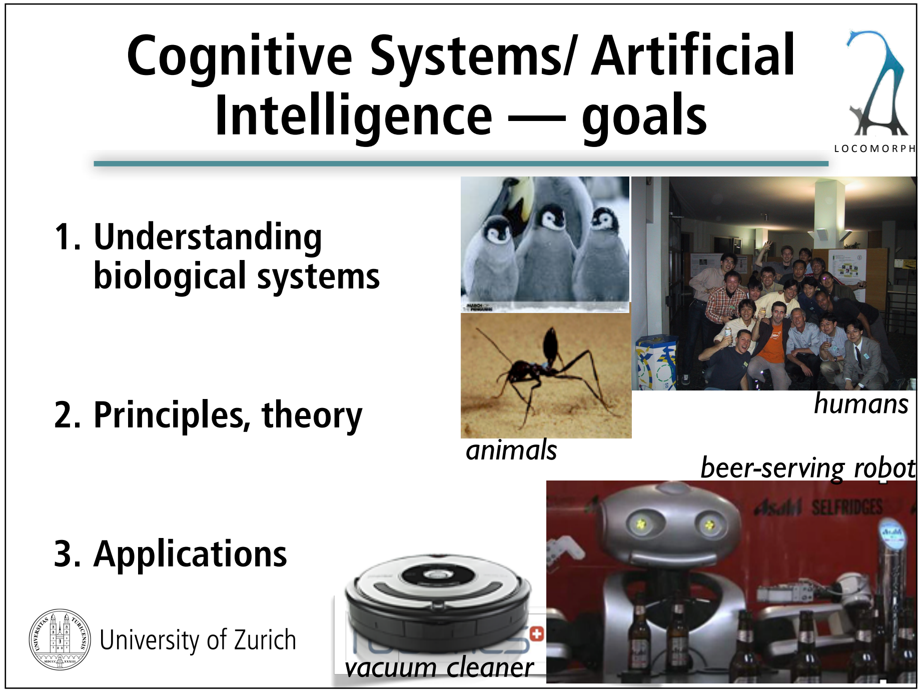
how to get there?



morphology
morphosis
embodiment
"soft robotics"



Background of AI

Within AI considerable changes in last 60 years

high-level cognition (abstract problem solving, chess, theorem proving, etc.)

more recently: movement, locomotion - what is the connection between the two?

--> quote by Lewis Wolpert

Relation to cognition/ intelligence?

"Why do plants not have brains?"

Relation to cognition/ intelligence?

"Why do plants not have brains? The answer is actually quite simple: they don't have to move."
Lewis Wolpert, UK

—> evolutionary selectionist pressure
on brain development
complete organism

selectionist pressure on development of brain: complete organism that has to interact with and survive in a real-world environment
thus, whatever we call "cognition" or "intelligence" today, has emerged from this interaction which is always mediated by the body

Cognitive Systems/ Artificial Intelligence — goals

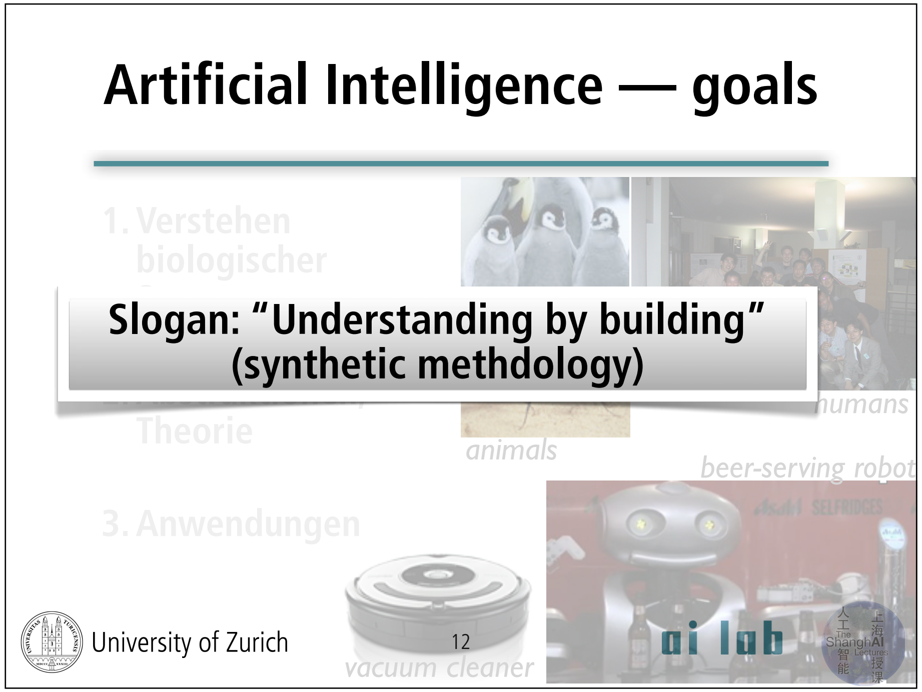
1. **Understanding biological systems**
2. **Principles, theory**
3. **Applications**


animals


humans

beer-serving robot

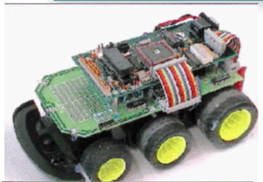

vacuum cleaner

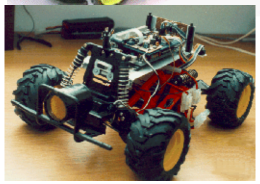


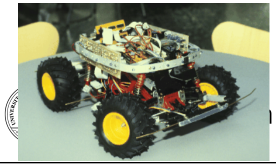
Because of the interest in embodiment, the systems to build are robots (or simulations thereof)

The synthetic methodology enables us to conduct novel types of experiments that cannot be done in biology (or would be very hard to do).

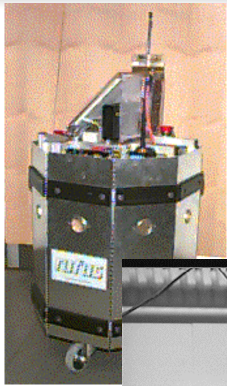
Zurich AI Lab robots


Didabot

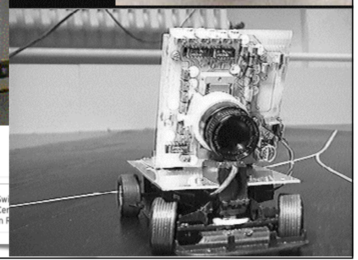

Famez


Sita

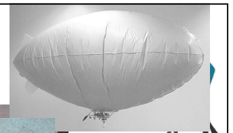
Rufus T.
Firefly

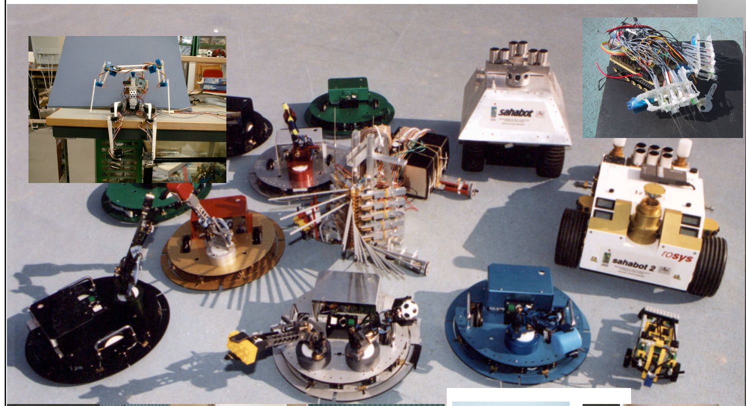


Ms. Gloria
Teasdale

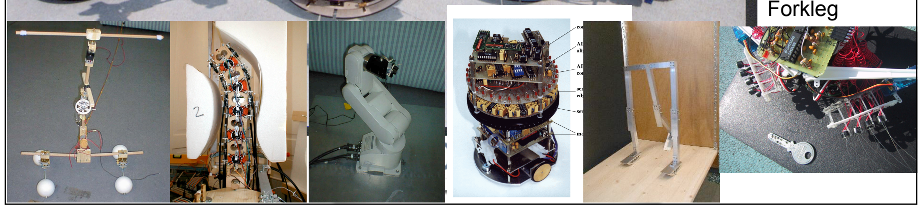

Morpho

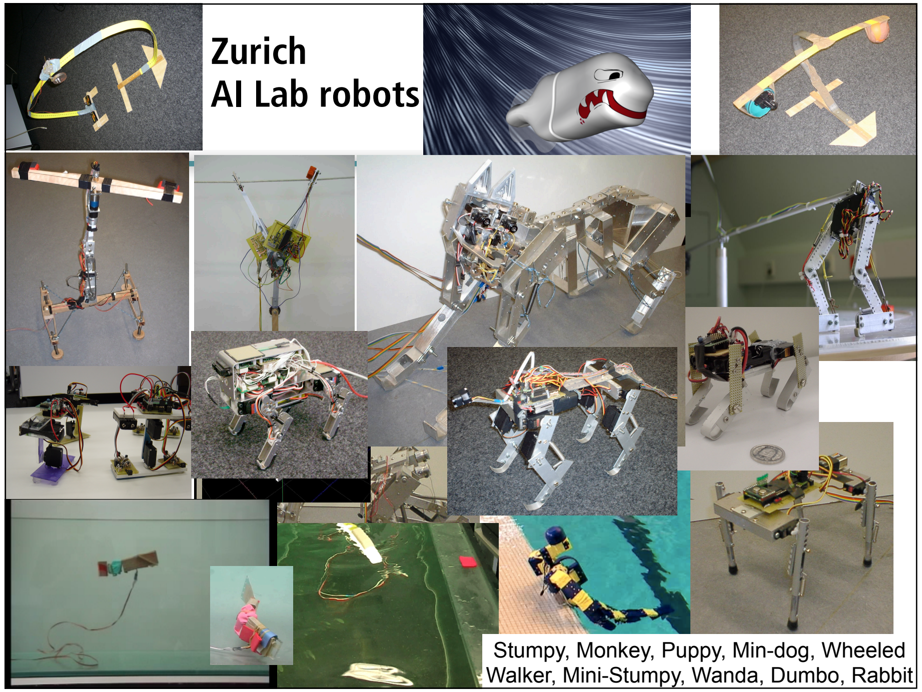
Zurich AI Lab robots



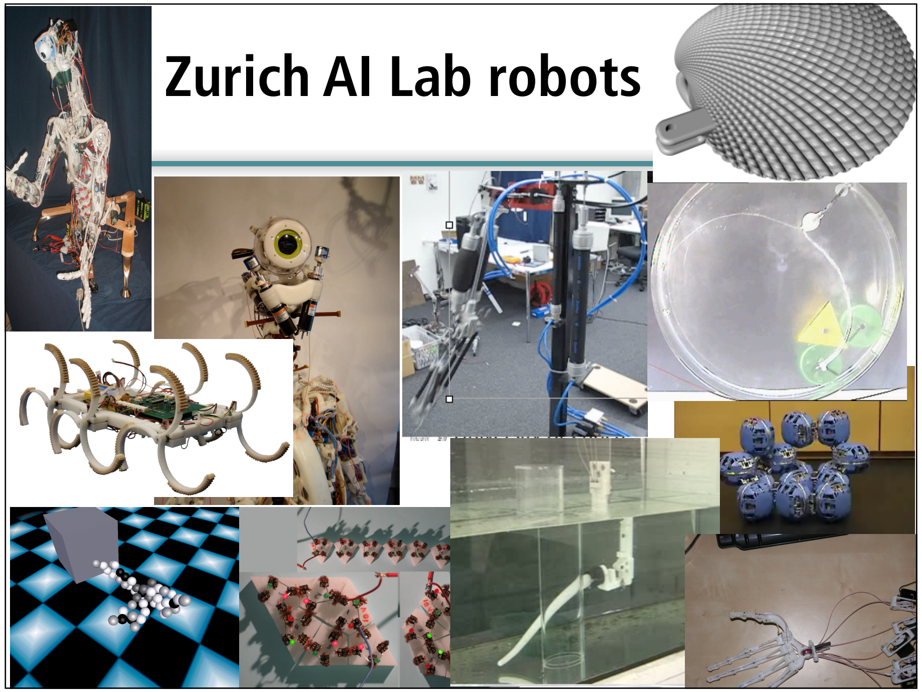


- Amouse
- SahabotI/II
- Melissa
- Tripp
- Samurai
- Analogrob
- Dexterolator
- Stumpy
- Eyebot
- Mindstorms
- Kheperas
- Mitsubishi
- Forkleg

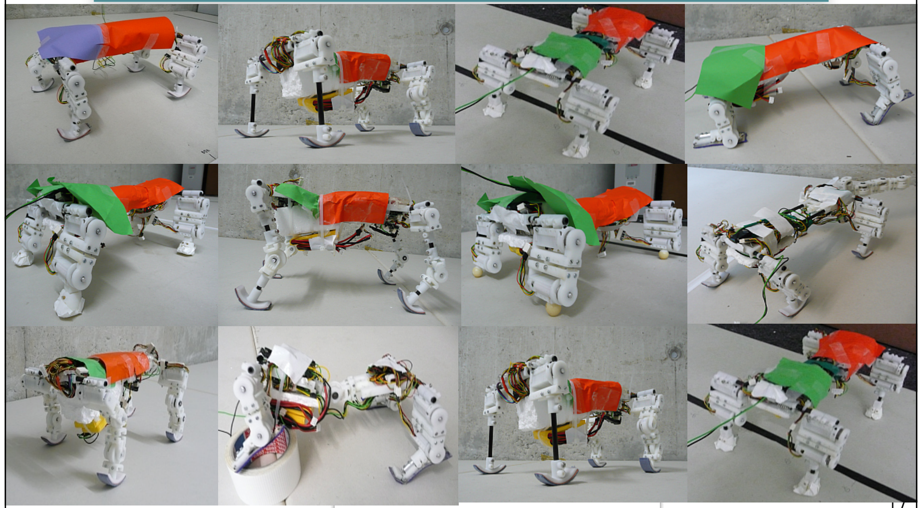



Zurich
AI Lab robots
Stumpy, Monkey, Puppy, Min-dog, Wheeled
Walker, Mini-Stumpy, Wanda, Dumbo, Rabbit

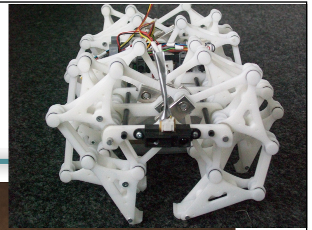
Zurich AI Lab robots

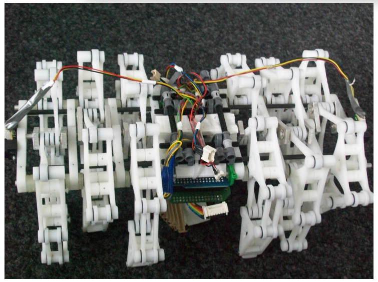


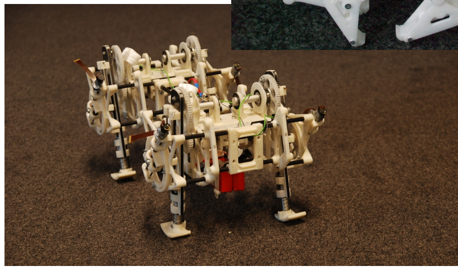
AI Lab Robots
(exploration of morphology)

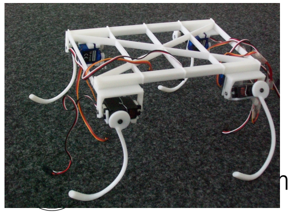


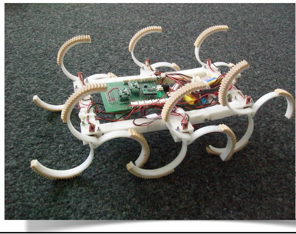
Zurich AI Lab
Robots (Locomorph)

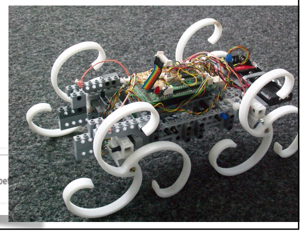


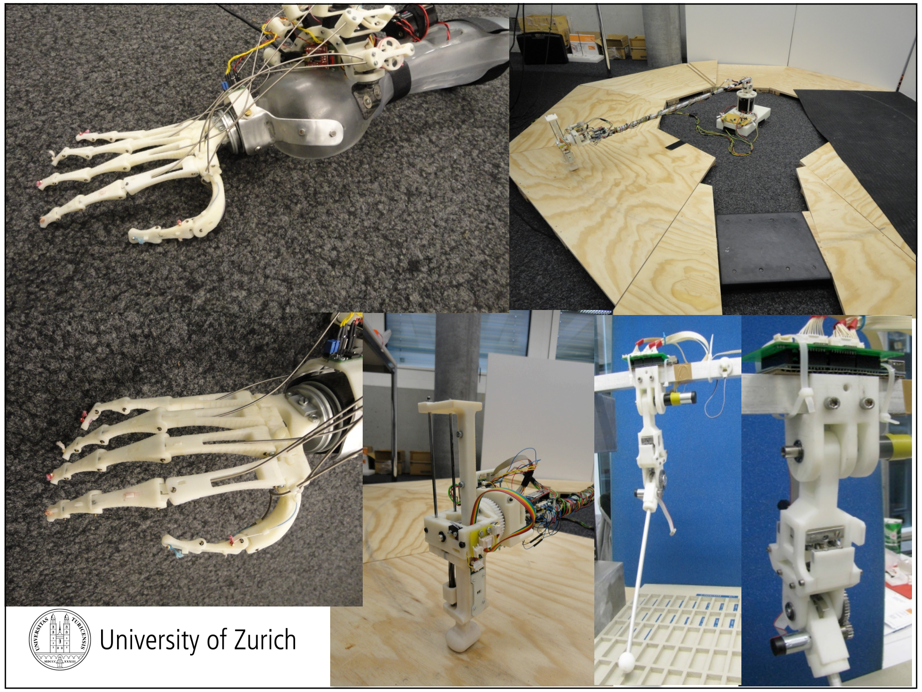












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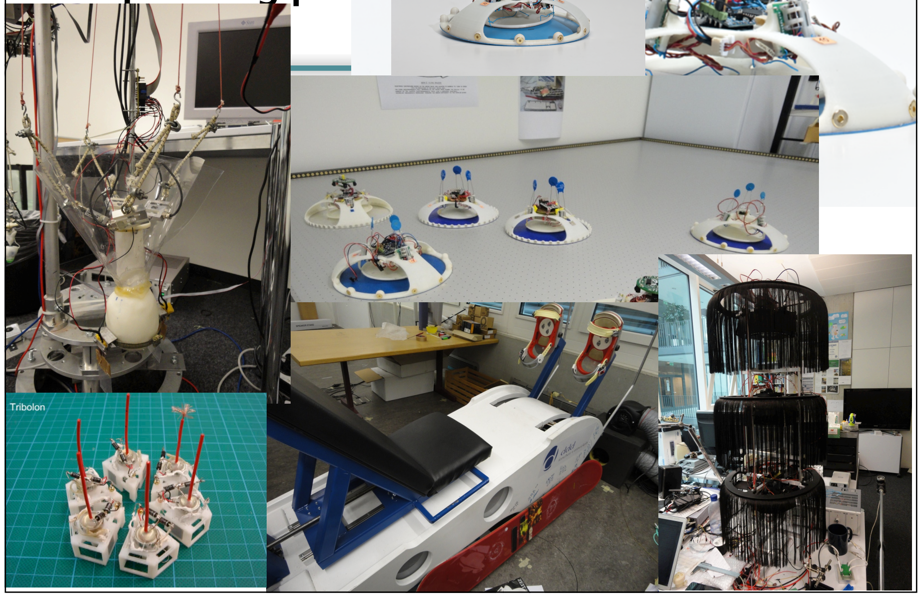
floating; hair-bot; adaptive leg press



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Contents

- introduction
- the idea of the Locomorph project: morphology, ...orphosis, and materials
- the four messages o...
- exploiting morpholog...
- understanding the "design space"
- summary and conclusions

Helmut's introduction

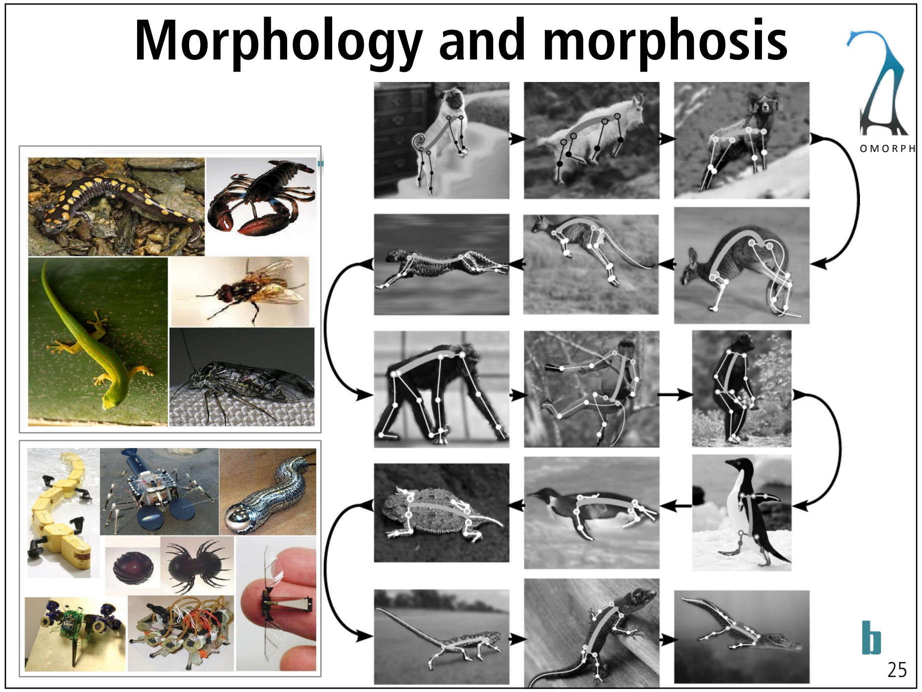
Robost Robotic Locomotion and Movements through Morphology and Morphosis

LOCOMORPH

Objective:

Locomorph's main objective is to apply the concepts of morphology and morphosis to achieve efficient and robust robotic locomotion and movements, in particular, with increased self-stabilization, energy efficiency, maneuverability, and adaptivity to unknown environment.

Based on the two main concepts of the project, morphology and morphosis, the objective .. is to develop robots with novel morphology for efficient and robust locomotion.
Using insights from the experimental results from biology, which studies morphosis strategies in nature, we will then investigate how to enable robots which can voluntarily morph according to different tasks and environments. If we believe that clever morphology is one of the key factors of successful legged locomotion, then it would be even better if robots can switch among a number of optimal morphologies depending on where they are and what they have to do. We are not talking here about morphing from liquid metal to a terminator, but we will explore a number of different types of morphosis, for example altering the length of various limbs, stiffness in each joint, overall torso shape, use of tail, and switching from quadrupedal to bipedal gaits.



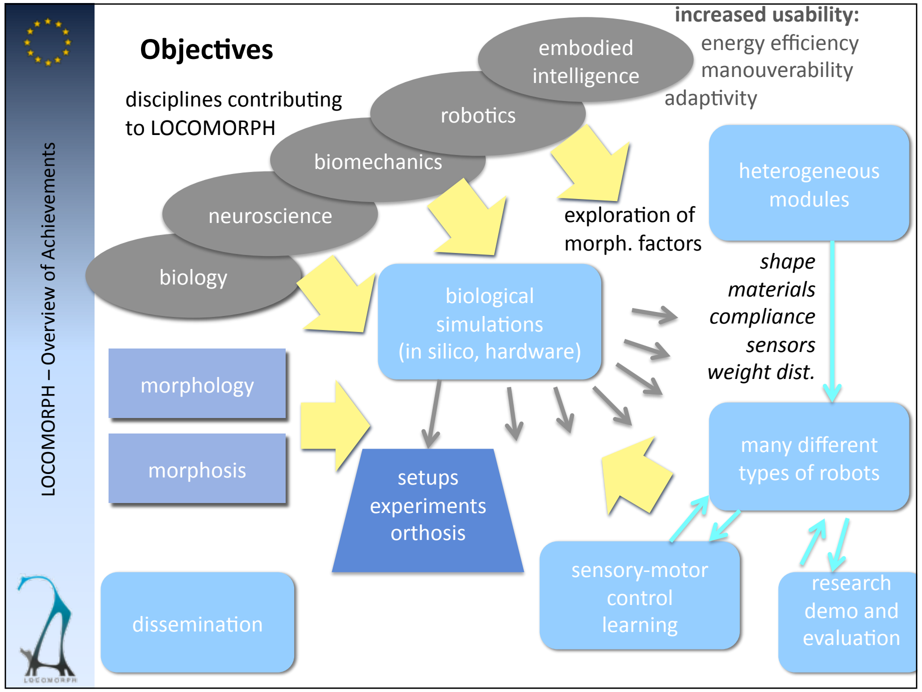
Schematic representation of morphosis (voluntary change in morphology).

Expected results

- increased self-stabilization, efficiency, maneuverability, and adaptivity in unknown environments: by exploiting mechanical structure, materials, sensor and actuator characteristics
- experimental results and advances in biology and biomechanics, and neuromechanical strategies in morphing animals
- robots capable of morphing during runtime
- robot control strategies for coping with voluntary and involuntary morphosis, based on strategies in nature
- robust robots: capable of adapting to change and recovering from injury (e.g. limb loss) through morphological change and appropriate control strategy

Expected impact

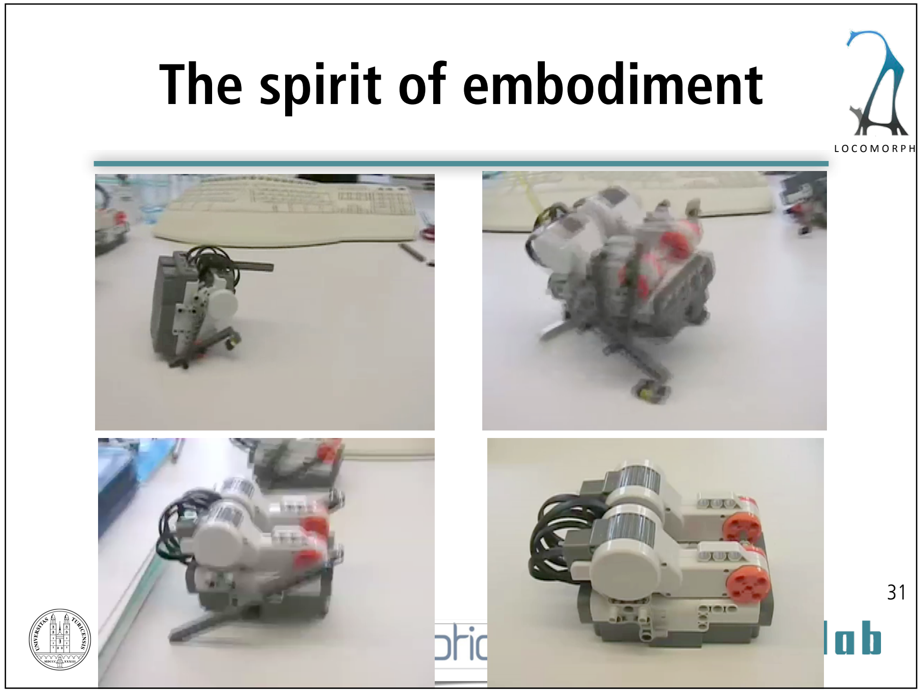
- operation of robots in novel environments
- reduced cost through infrastructure for fast construction from modular components
- extension of usability through morphing
- novel ways of thinking about robots in general
- new image of humans and the world around us



LOCOMORPH – Overview of Achievements
Objectives
disciplines contributing to LOCOMORPH
increased usability:
energy efficiency
manouverability
adaptivity
embodied intelligence
robotics
biomechanics
neuroscience
biology
exploration of morph. factors
heterogeneous modules
biological simulations (in silico, hardware)
shape
materials
compliance
sensors
weight dist.
morphology
morphosis
setups experiments orthosis
many different types of robots
sensory-motor control learning
research demo and evaluation
dissemination

Contents

Getting into the spirit of embodiment

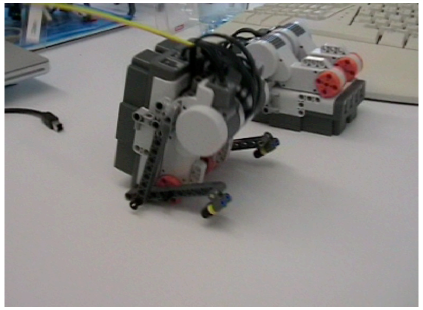


Three Lego Mindstorms “creatures”, all with the same control, i.e. constantly turning wheels

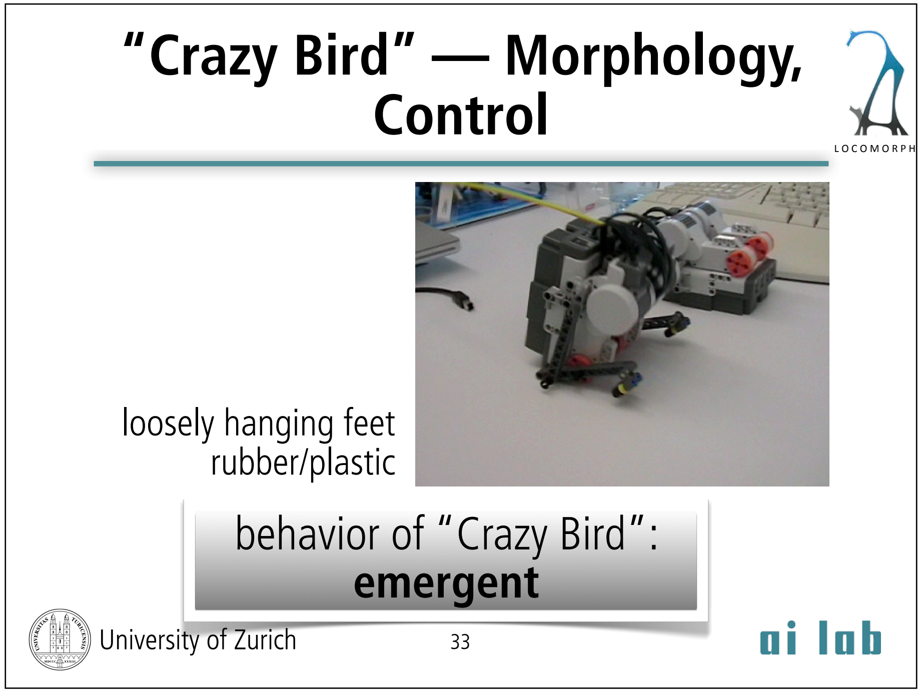
"Crazy Bird" — Morphology, Control

LOCOMORPH

loosely hanging feet
rubber/plastic



random component: loosely hanging feet
turning around it's own axis: difference in friction between rubber and plastic

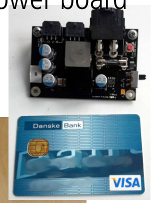


random component: loosely hanging feet
turning around it's own axis: difference in friction between rubber and plastic

Next time around: Experiments with "Locokit" (Jørgen Larsen)

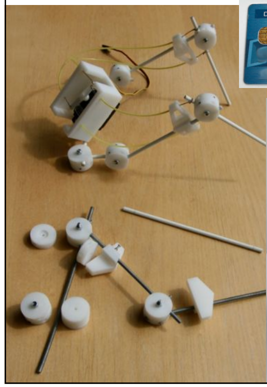
LOCOMORPH

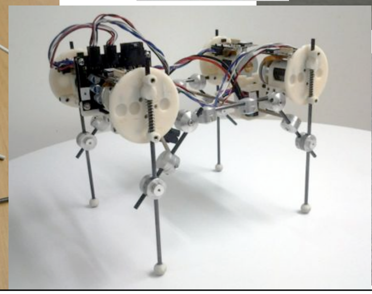
power board



processor board

components



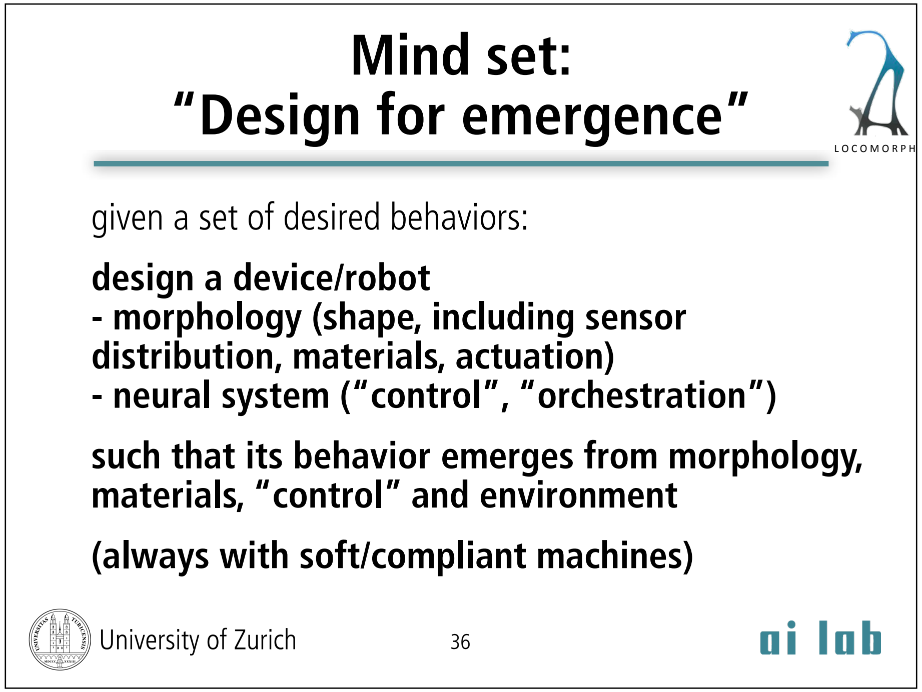


Message 1: Physical embedding

Studying brain (or control) not sufficient: Understanding of

- embedding of brain into organism
- organism's morphological and material properties
- environment

required



Message: as soon as there are soft, compliant materials --> one can only design for emergence; it is not possible otherwise because what's written in the program will never correspond to the situation in the real world (e.g. passively deformable tissue).

Let me be clear

The brain is important!

Let me be clear

The brain is important!

but not the whole story ...

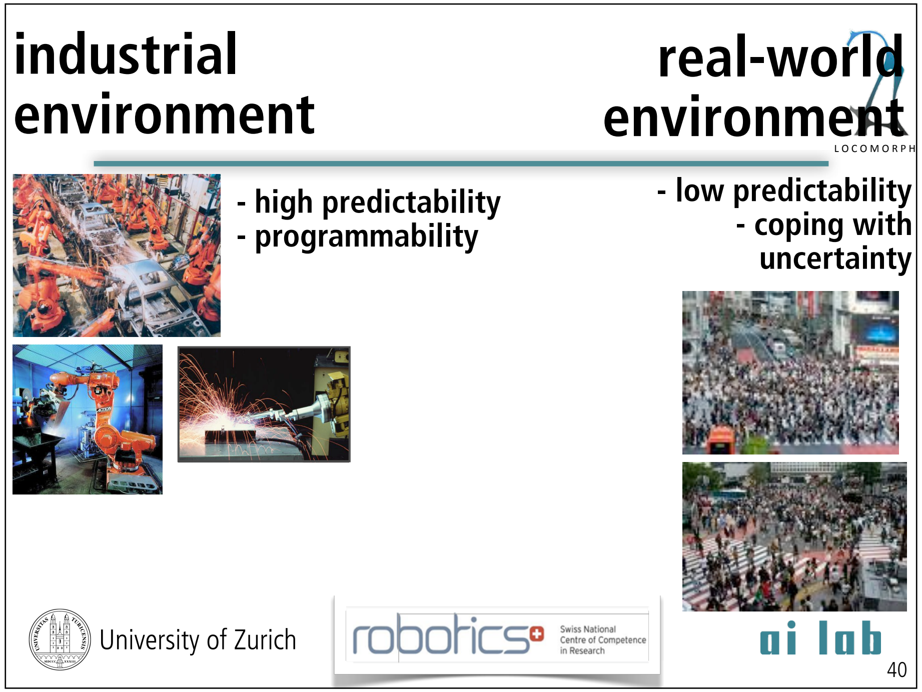
Message 2: Real/ Artificial-constructed worlds

Understanding the differences between

- artificial/constructed worlds (e.g. industrial)

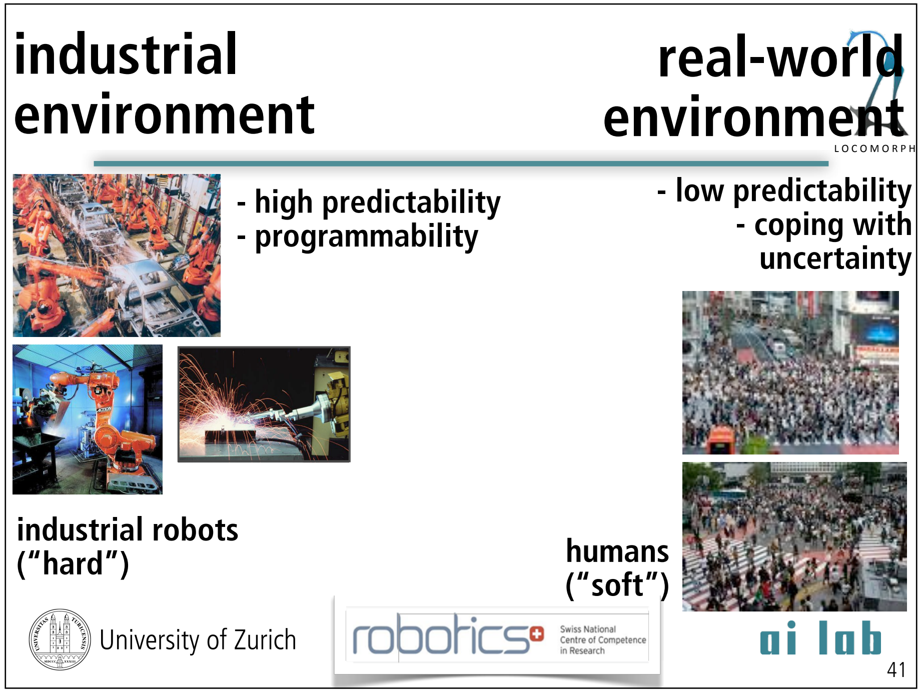
- real worlds (e.g. downtown area, school, home, soccer field)

—> different requirements for robots



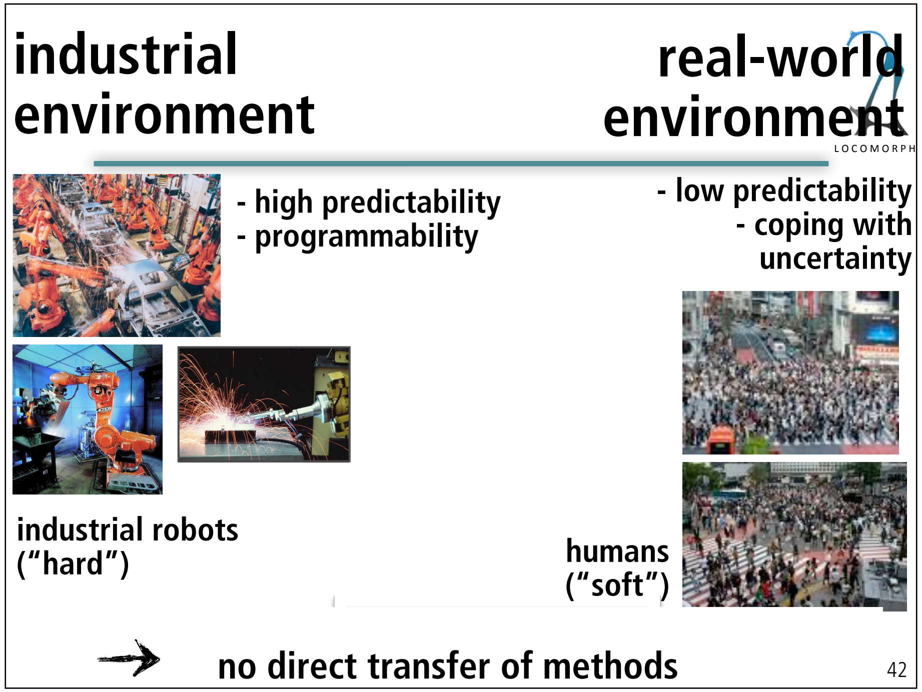
electrical motors, metal, plastic

humans: skin, tissue, passively deformable, etc.



electrical motors, metal, plastic
controlled environment

humans: skin, tissue, passively deformable, etc.
rapidly changing environment, "uncontrolled"

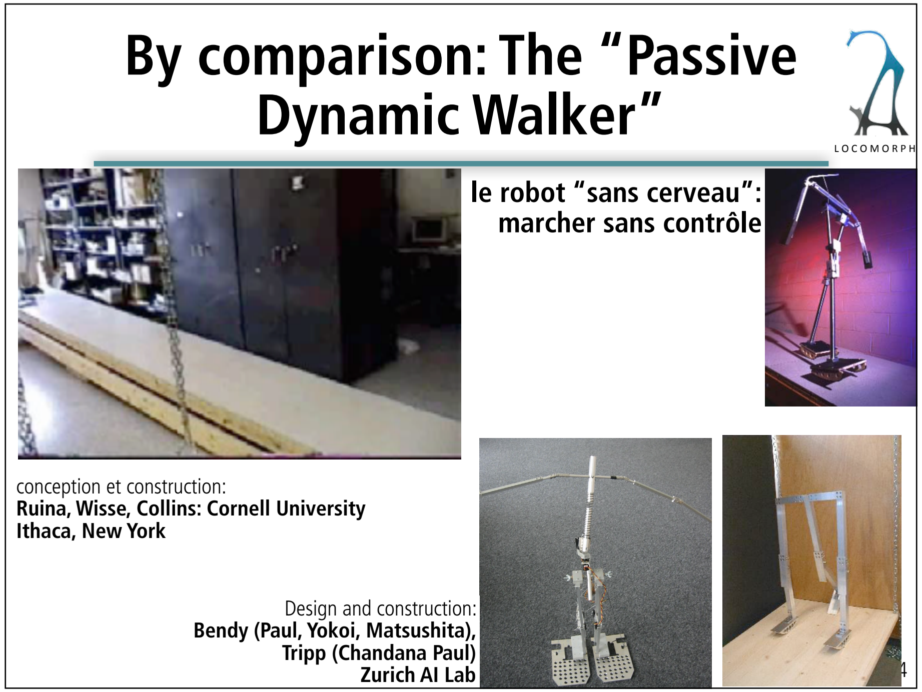


electrical motors, metal, plastic
controlled environment

humans: skin, tissue, passively deformable, etc.
rapidly changing environment, "uncontrolled"

Transfer of methods?

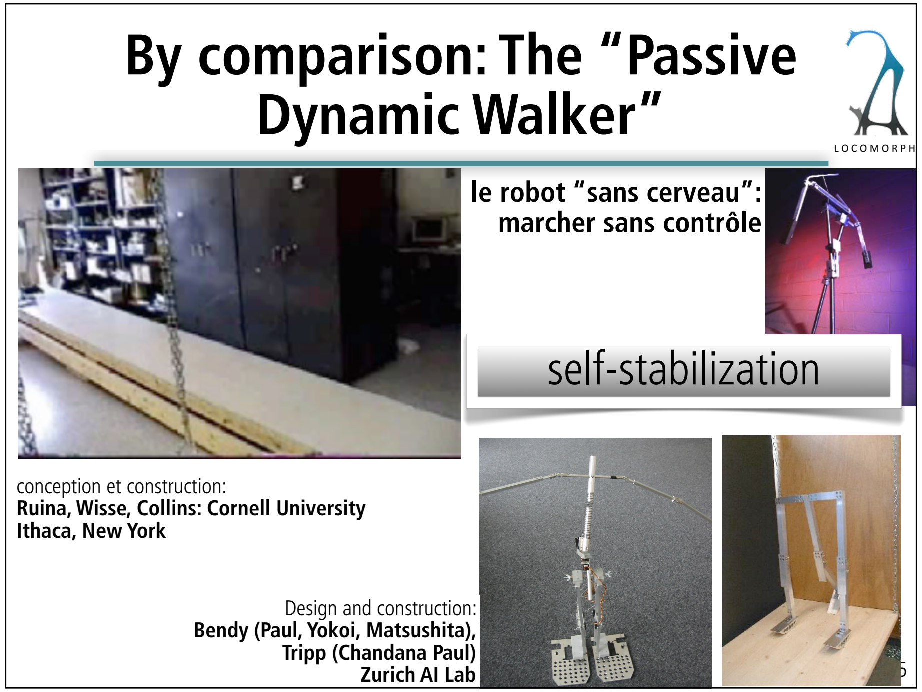
Sony Qrio:
high stiffness
centralized control
conputationally intensive



Inclined plane: plan (m.) incliné

Application à la marche humaine: movement pendulaire de la jambe - pour la plupart passif. Pendent la phase “movement avant”: peu de tension, phase contact: tension haute.
l’articulation du genou n’est pas côntrolée directement: trajectoire est le résultat d’un processus d’auto-organisation

cheville: Fussgelenk



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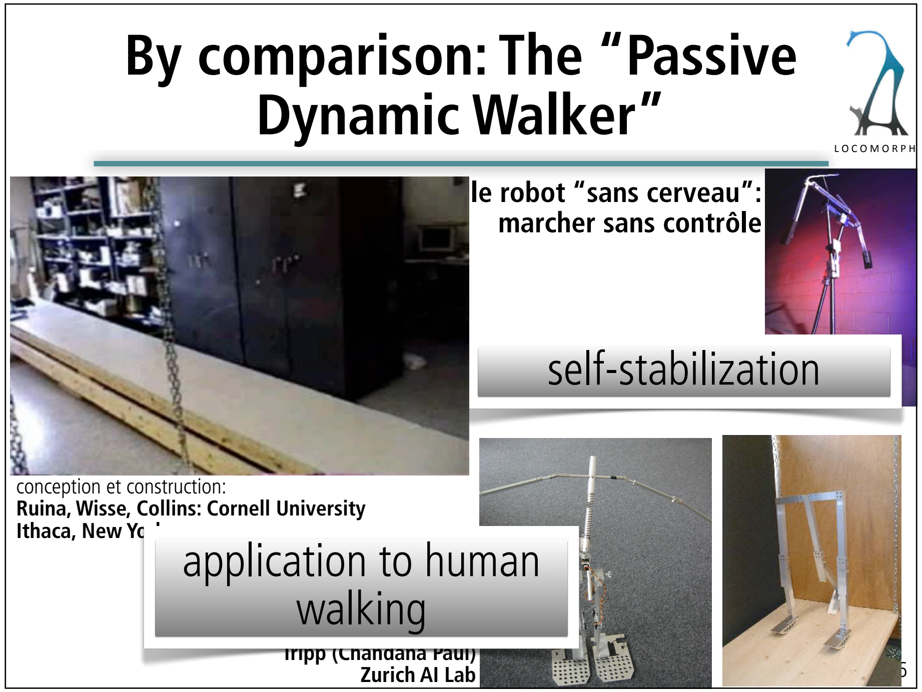

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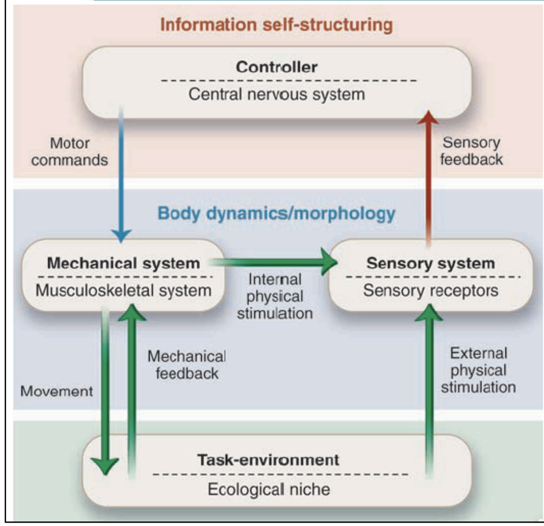
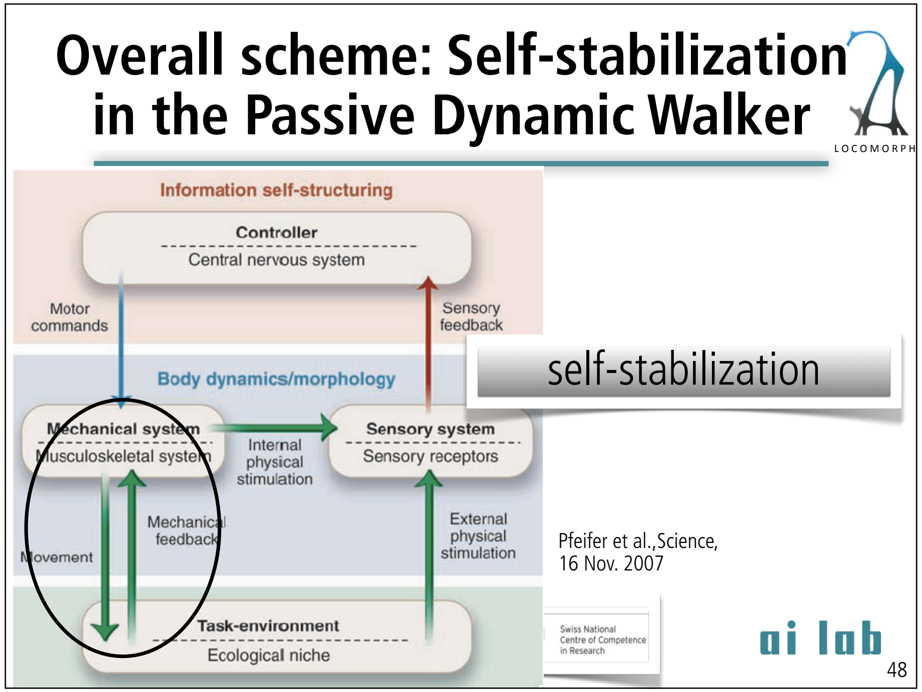
cheville: Fussgelenk

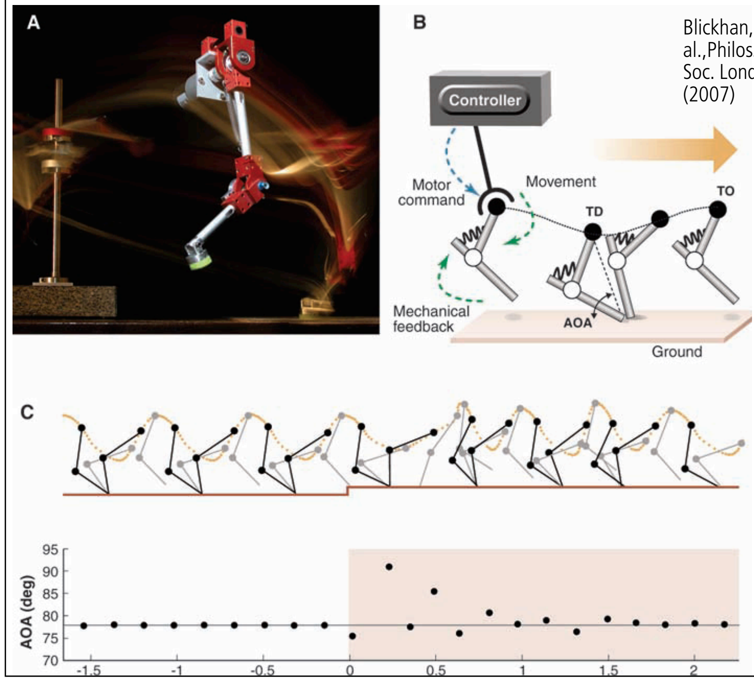
Overall scheme: Self-stabilization in the Passive Dynamic Walker



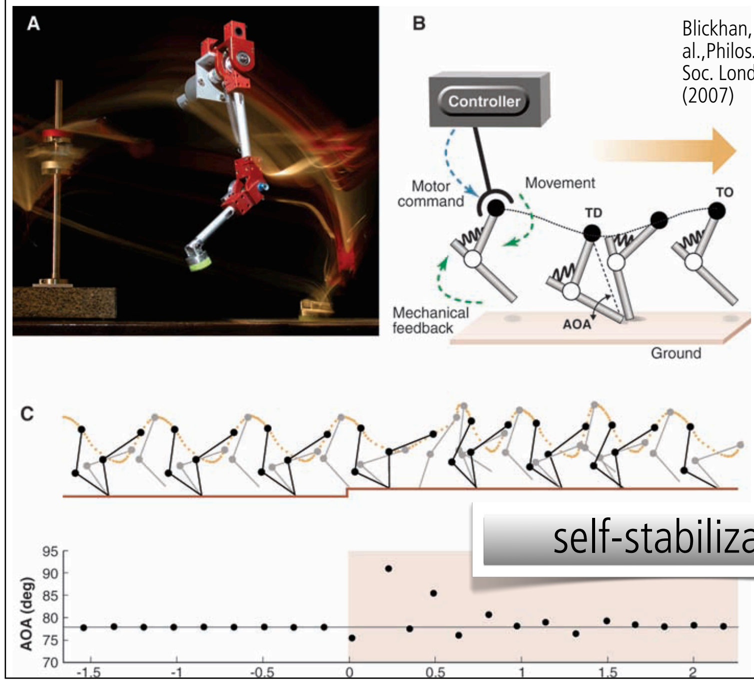
Pfeifer et al.,Science, 16 Nov. 2007



The fact that the passive dynamic walker has no sensors for the mechanical feedback does not imply that it's not there!



Blickhan, Seyfarth et al.,Philos. Trans. Act. R. Soc. London, 365, p. 199 (2007)



Blickhan, Seyfarth et al.,Philos. Trans. Act. R. Soc. London, 365, p. 199 (2007)

self-stabilization

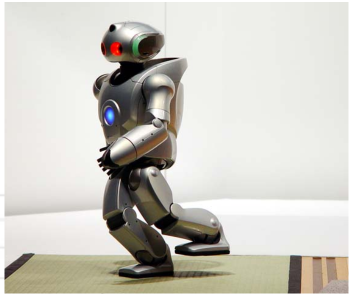
Short question

memory for walking?

Contrast: Full control

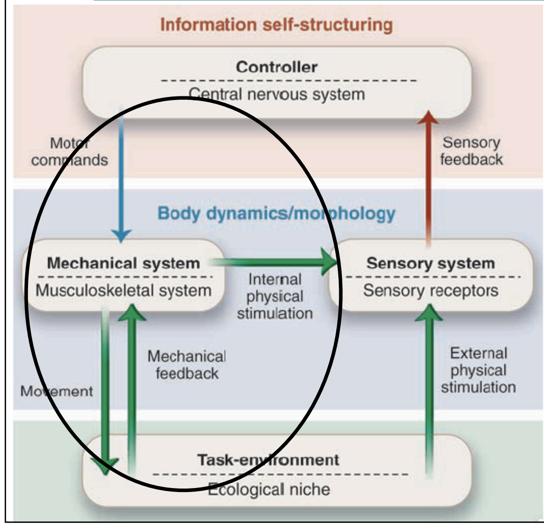
Honda Asimo

Sony Qrio



Reflex: contact sensor on feet; when contact occurs —> move other leg forward (with pneumatic actuators)

Overall scheme
Self-stabilization in Denise



Pfeifer et al.,Science, 16 Nov. 2007

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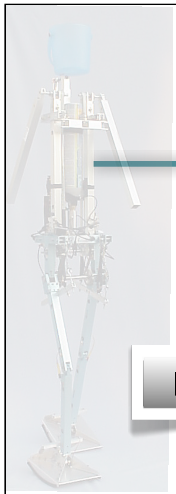
There is only a tiny bit of sensing (the contact sensors on the feet); it’s all that’s required to make Denise walk on flat ground.

Extending the ecological niche: Denise



memory for walking?

Design and construction:
Martijn Wisse, Delft University

self-stabilization

The Cornell Ranger

conception et construction:
Andy Ruina
Cornell University

exploitation of passive dynamics

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

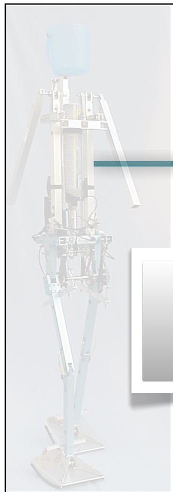
The Cornell Ranger

conception et construction:
Andy Ruina
Cornell University

65km with one battery charge!

taking the exploitation of passive dynamics to the extreme: The Cornell Ranger
“Robots on Tour”: Trying for a new world record

Passive Dynamic Walker, Denise, Cornell Walker



“control” of locomotion by exploitation of passive dynamics

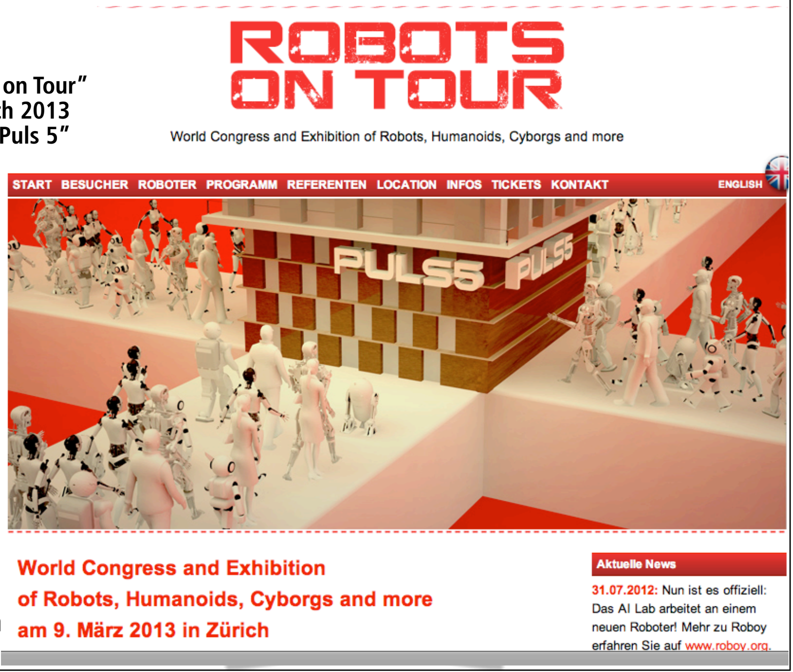
research opportunity

Design and construction:
Martijn Wisse, Delft University

self-stabilization

Visit:

“Robots on Tour”
8/9 March 2013
Zurich, “Puls 5”



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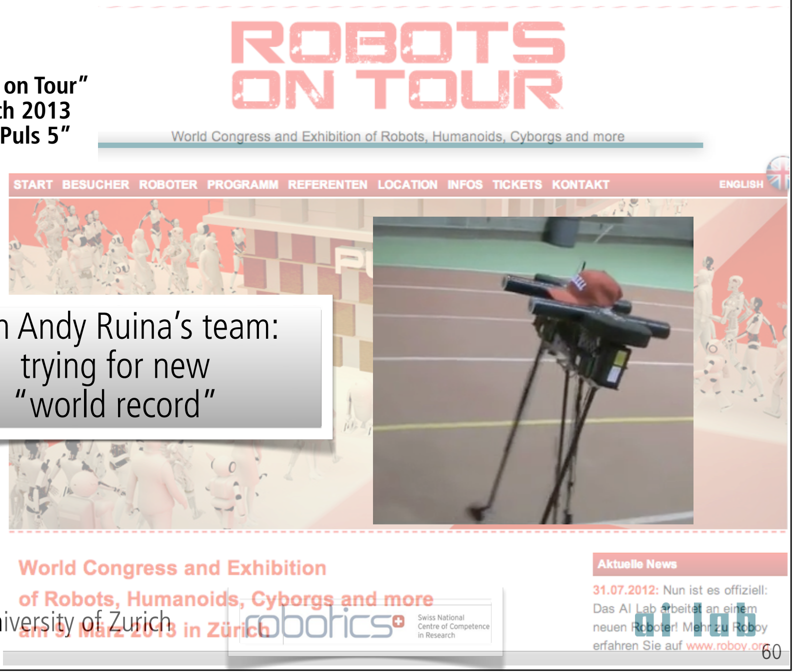


with Andy Ruina's team:
trying for new
"world record"

Message 3: Task distribution

Task distribution between brain (control), body (morphology, materials), and environment

Message 3: Task distribution

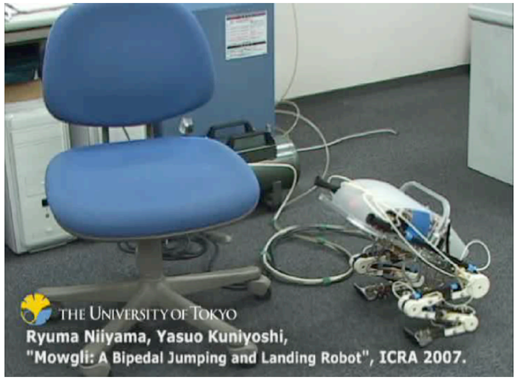
LOCOMORPH

Task distribution between brain (control), body (morphology, materials), and environment

no clear separation between control and hardware (“soft/compliant robotics”)

morphological computation

The "robot frog" driven by pneumatic actuators (UTokyo)



Design and construction:
Ryuma Niiyama and Yasuo Kuniyoshi University of Tokyo

pneumatic actuators:
compliant materials

University of Zurich

The damped oscillatory movement after impact is not controlled but the result of the morphological and material characteristics (pneumatic actuators).

Message 3: Task distribution (elaboration)

Task distribution between brain (control), body (morphology, materials), and environment

no clear separation between control and hardware ("soft robotics")

re-thinking of "control" ("orchestration")

Message 3: Task distribution (elaboration)

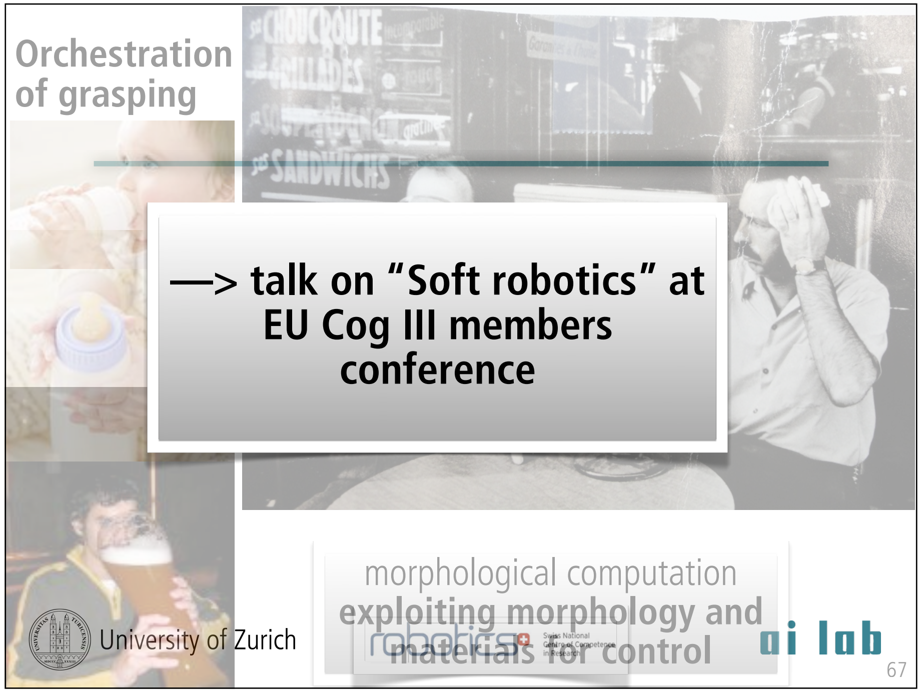
LOCOMORPH

- Task distribution betwee... in (control), body (morphology, materia... environment
- no clear separation between control a... hardware ("soft robotics")

research opportunity

re-thinking of "control" ("orchestration")

Grasping hard object with thimbles on all fingers: extremely challenging
“The power of materials”: passive adaptation of materials to object shape (soft tissue flattening out, thereby increasing contact surface) – fingers wrapping around object via force control.
Exploitation of deformability of materials (including morpholog of hand)



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Exploitation of deformability of materials (including morpholog of hand)

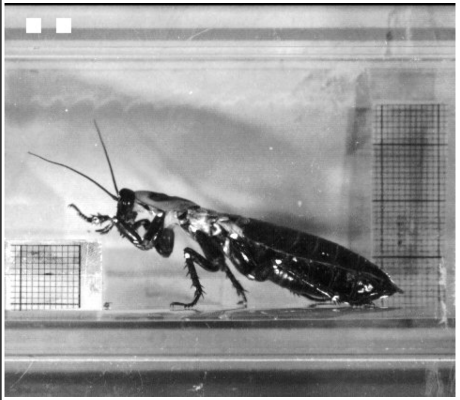
Contents

- introduction
- the idea of the Locomorph project: morphology, morphosis, and materials
- the four messages of embodiment
- **exploiting morphology change**
- **understanding the "design space"**
- **summary and conclusions**

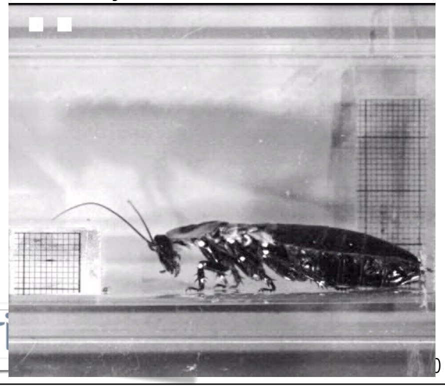
Case study: adaptation through morphology change

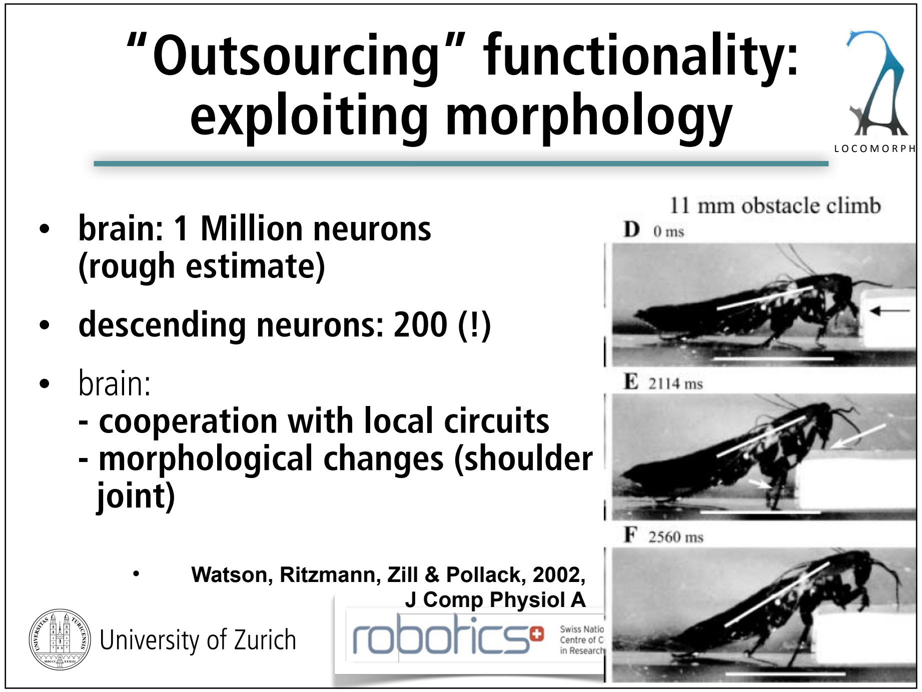
Roy Ritzman's cockroaches climbing over obstacles

Exploiting morphological change for adaptation: managing complex bodies

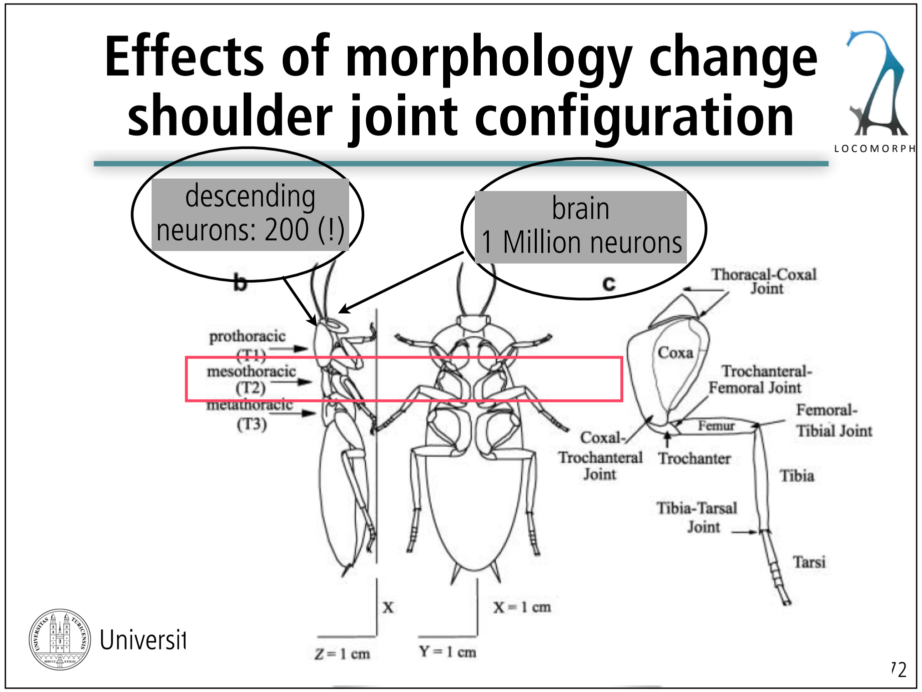


pictures and ideas:
courtesy Roy Ritzmann
Case Western Reserve
University





The following considerations are highly speculative but they make, hopefully, a good story about morphological computation.



rather than recalculating the joint trajectories: changing the mechanical configuration of the mesothoracic shoulder joint (morphological - global - parameter)

Climbing over obstacles

- CPG on flat ground
- get hight estimate from antenna
- change configuration of shoulder joint
- CPG continue to function as before (don’t “know” about climbing)
- brain-body cooperation

because the mechanical configuration of the shoulder joint is changed, even though the local CPGs continue doing the same thing, the effect on behavior will be different

Climbing over obstacles

LOCOMORPH

- CPG on flat ground
- get hight estimate from an
-
- re (don
  know" about climbing)
- brain-body cooperation

research opportunity

exploiting morphology/change for control

Exploiting morphological change for control

LOCOMORPH

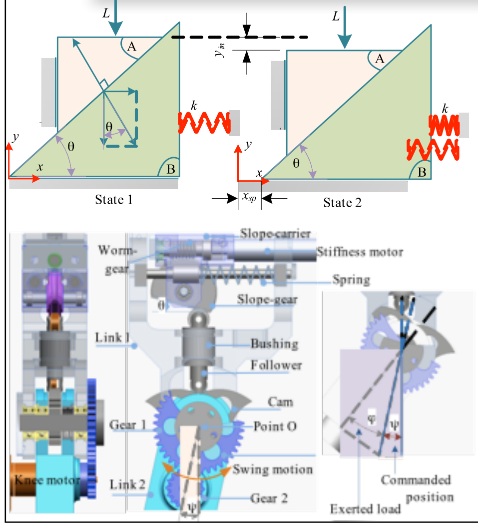
- change of shoulder configuration to move over obstacles (cockroaches)
- dynamical change of muscle stiffness / actuator compliance (depending on walking phase) (human / robot walking —> Hung: variable compliance actuator)
- change length of limb to adapt to different terrains (locomorph robots; Farrukh)
- freezing DOFs to increase learning speed (human development, ECCE Robot, Roboy, Kenshiro)

Changeable stiffness: The Mestran actuator

design and construction:
Vu Quy Hung, AI Lab, UZH

ai lab

Changeable stiffness Mestran actuator: Conceptual model



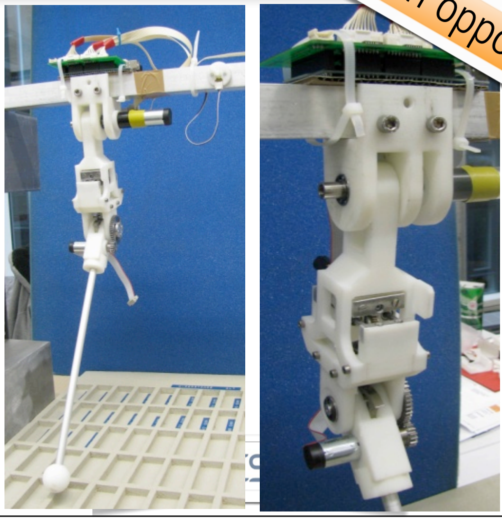
$$L = \frac{k x_{sp}}{\tan\theta} = \frac{k}{(\tan\theta)^2} y_{in}$$

L: pressing force
θ : slope (transmission) angle
x_{sp}: spring deflection
y_{in}: displacement
k: stiffness

design and construction:
Vu Quy Hung, AI Lab, UZH

Changeable stiffness: The Mestran a tor

research opportunity



design and construction:
Vu Quy Hung, AI Lab, UZH

ai lab

Changing joint compliance for adaptive behavior

LOCOMORPH

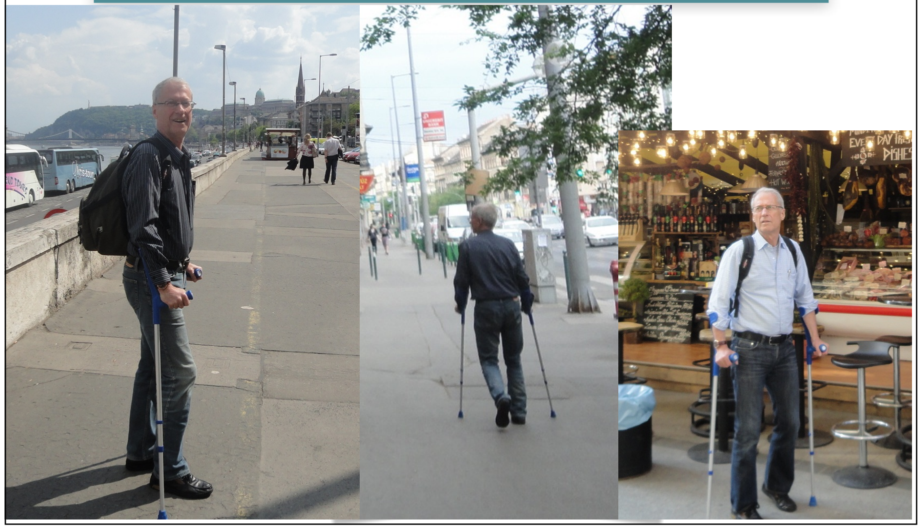
design and construction:
Vu Quy Hung, AI Lab, UZH

Adapting to morphological change

- **voluntary/involuntary morphological change**
- voluntary:
  - four legs —> two legs (and vice versa - Peter Arts)
  - freeing/freezing DOFs
  - stiffening/loosening of muscles
- involuntary:
  - growing organism
  - torn ligament —> Rolf (suffering, but adapting)
  - lost limb (see also Josh Bongard et al.; Starfish)
  - amputation

Adaptation to involuntary morphological change

LOCOMORPH



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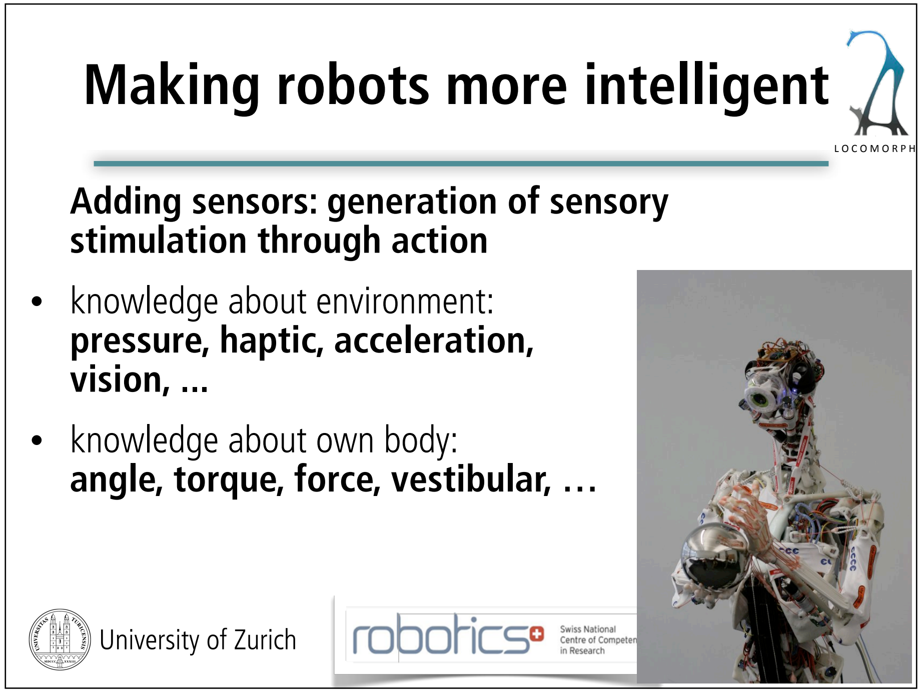
  - lost limb
  - amputation

research opportunity

Freezing and freeing DOFs



Adding sensors to make robots more intelligent is the obvious thing to do. What's important here is that each action has a consequence in terms of sensory stimulation (see also John Dewey's quote, below). And this is one of the fundamental differences to a computer which, in essence, "waits" for input, i.e. for someone to push a key or click a mouse button. Also: extremely impoverished sensory system.

Message 4: Physical dynamics and information structure

LOCOMORPH

Induction of patterns of sensory stimulation through physical interaction with environment
—>

raw material for information processing of brain (control)
—>

induction of correlations (information structure)

Essence

- **self-structuring of sensory data through — physical — interaction with world**
- **physical process, not computational**

pre-requisite for learning

—> predictions / expectations

Inspiration:
John Dewey, 1896 (!)
Merleau-Ponty, 1963
Bajcsy, 1963; Aloimonos, 1990; Ballard, 1991
Sporns, Edelman, and co-workers
Thelen and Smith (developmental studies)

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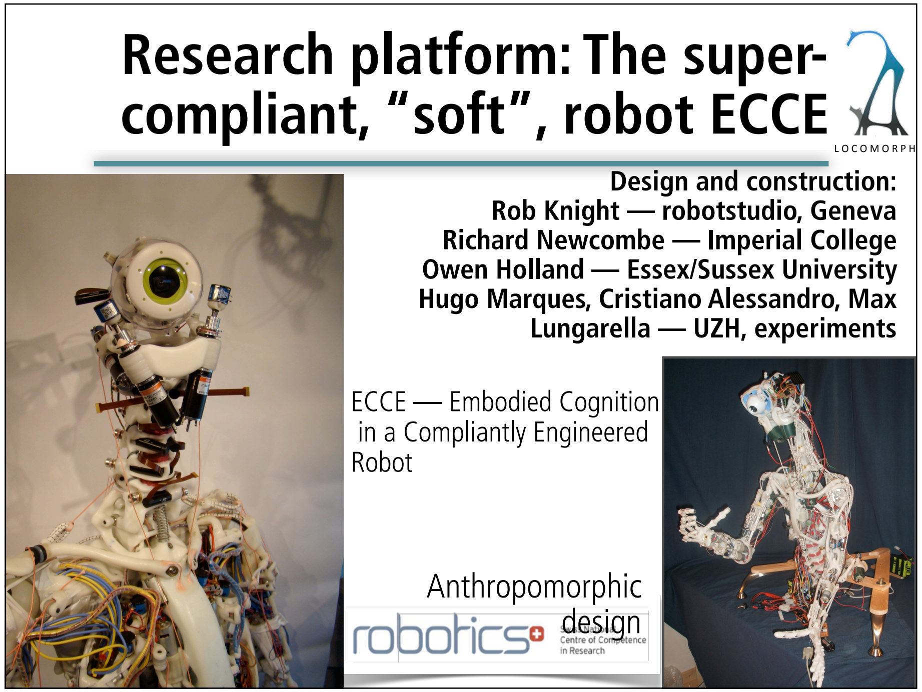
Sporns, Edelman, and co-workers
Thelen and Smith (developmental studies)

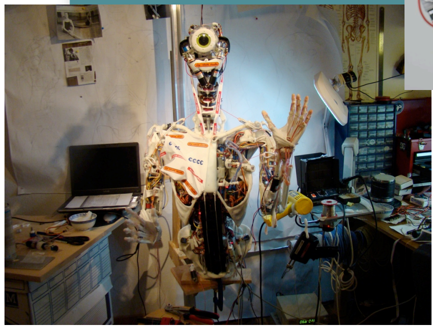
lab

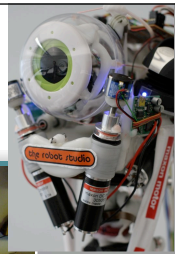
Compliance, "softness": the next steps

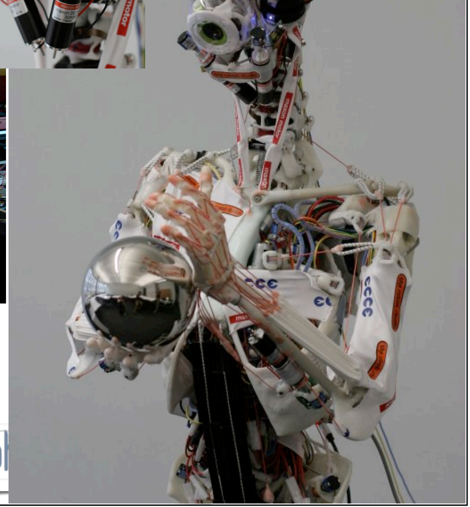


ECCE is a fully tendon-driven robot with tendons that incorporate a soft element.

The super-compliant "soft" robot ECCE

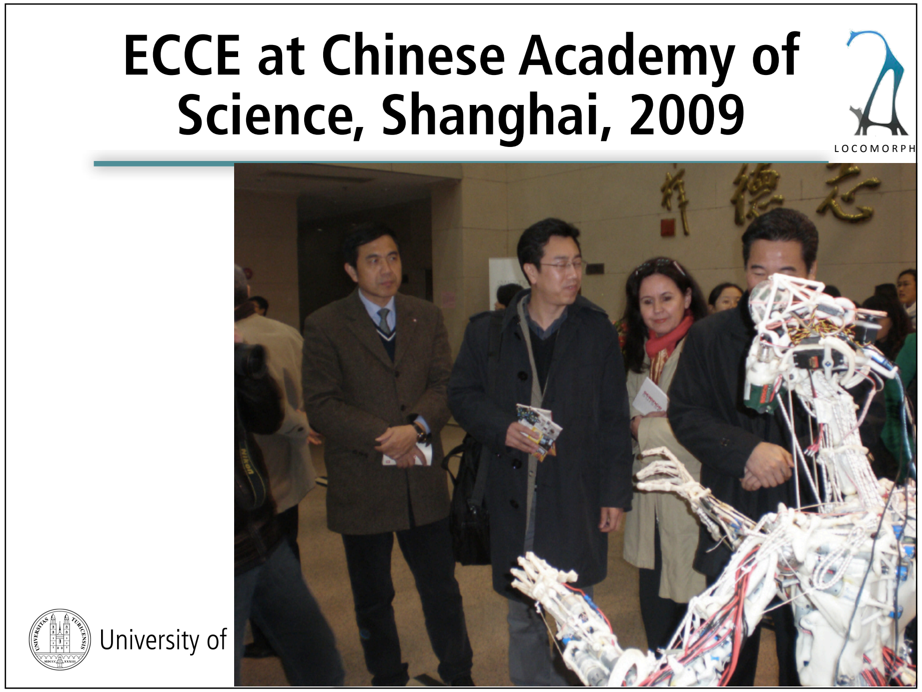






fully tendon-driven

University of Zurich



2nd from left: Prof. Weidong Chen, Shanghai Jiao Tong University

Not everybody seems to be happy about ECCE

Hannover Fair, ICT Brussels, Science Fair St. Agrève, France

University of Zurich

Doris Leuthard shaking hands with ECCE

ECCE in Singapore, 2011
UBS and Nanyang Politecnic

ai lab

Techfest 2011, IIT Bombay

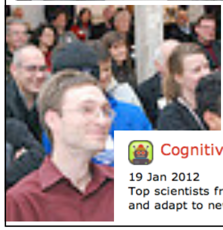
LOCOMORPH

Embodied Intelligence
Switzerland

University of

ECCE in San Francisco
Swissnex 2012

LOCOMORPH



Hod Lipson, Rolf Pfeifer, Pascal Kaufmann
Swissnex San Francisco

Cognitive Robotics and Artificial Intelligence

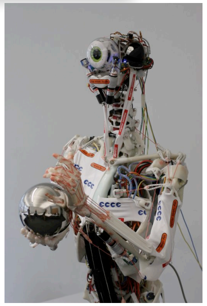
19 Jan 2012
Top scientists from Switzerland and the US discuss developments in robotics. Find out if robots can self-reflect, self-improve, and adapt to new circumstances, and if robots of the future could one day possess the same cognitive characteristics as humans.

The super-compliant, "soft", robot ECCE

ECCE ROBOT

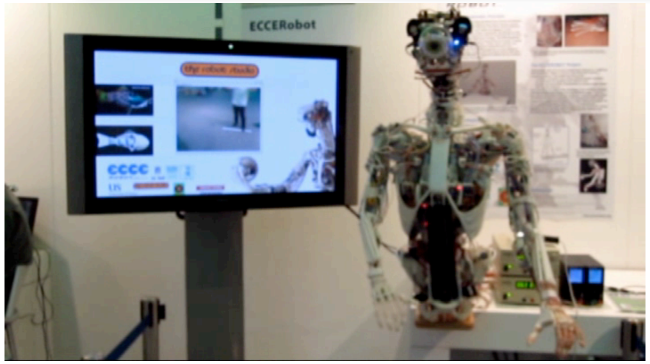
Embodied Cognition in a Compliantly Engineered Robot

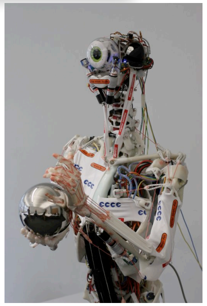
Technische Universität München
Robotics and Embedded Systems



Anthropomorphic design

The super-compliant "soft" robot ECCE





Anthropomorphic design

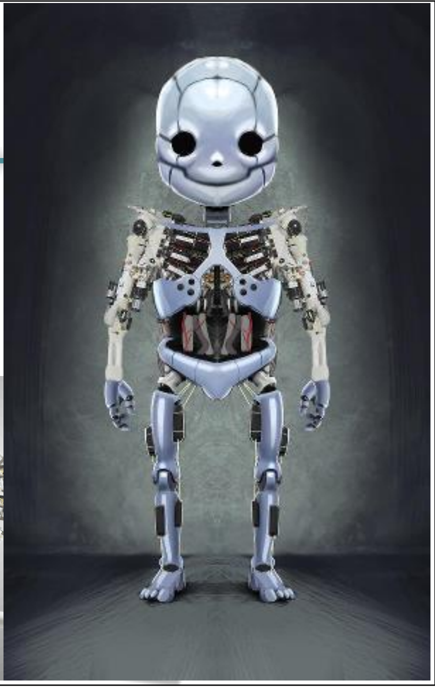
fully tendon-driven

cf. also: Inaba's Kojiro

New platform: Roboy

(under - rapid - development: target date February 2013)

- fully tendon-driven
- anthropomimetic
- size: 1.20m
- embodied "brain"
- Q&A facility
- manufacturable
- crowd funded



Visit:

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8/9 March 2013
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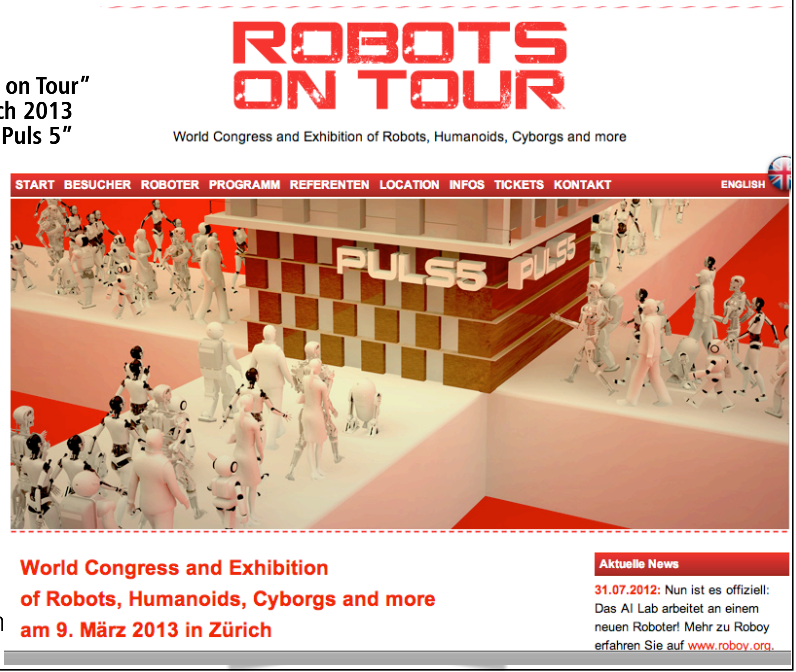

Un

Bernstein's problem

- **highly complex system; large number of redundant DOFs in compliant systems**
- **how to control/orchestrate?**

(Nikolai Bernstein, Russian physiologist, 1896-1966)

Bernstein's problem

LOCOMORPH

- highly complex system; large number of redundant DOFs in compliant system
- how to control/orchestrate?

→ complexity barrier

(Nikolai Bernstein, Russian physiologist, 1896-1966)

Bernstein's problem

LOCOMORPH

- **highly complex system: ... number of redundant DOFs in compl... ...em**
- **how to control/orchestrate?**

research opportunity

→ complexity barrier

(Nikolai Bernstein, Russian physiologist, 1896-1966)

Approaches

- learning/development (robot learning its own dynamics through "motor babbling")
- robot can sense the effect of its own actions (Message 4 of embodiment)
- freezing/freeing DOFs
- exploiting biomechanical constraints

Contents

Recall: Message 3
"Task distribution"

Task distribution between brain (control), body (morphology, materials), and environment

no clear separation between control and hardware ("soft/compliant robotics")

re-thinking of "control"
("orchestration")

Principle: Induction of information structure through interaction with world

patterns of sensory stimulation:
dependence on
- morphology
- materials
- action
- environment

Principle: Induction of information structure through interaction with world

patterns of sensory stimulation:
dependence on
- morphology
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"sensory-motor contingencies"

Expansion of design space: trading spaces and trade-offs

- morphologies (physical structure, distribution of sensors, actuators)

- many materials, functionalities

- changeable characteristics (e.g. stiffness, length, shape, sensor distribution)

- trade-offs: morphology/materials - flexibility (but changeable properties)

- must understand “trading space”: morphology - computation/control

- “orchestration of movement” (partly contained in morphology and materials)

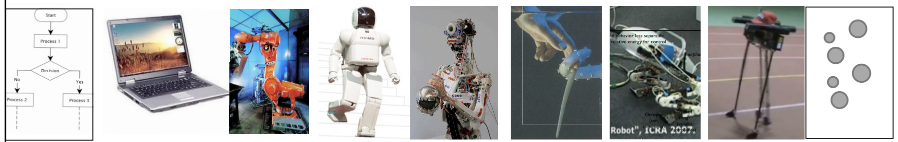
Morphology and computation: "trading spaces"

increasing dominance of morphology and materials
decreasing dominance of control

control and behavior less separable

informational computation — morphological computation

control dominant — *morphology and materials dominant*



pure algorithm | computer (running algorithm) | industrial robot (centralized control | Asimo (and similar robots) | ECCE (compliant, tendon-driven) | Octopus (soft, continuous) | "Robot Frog" (variable compliance) | Cornell Ranger (exploiting morphology) | cells molecules "Tribolons"

Morphology and computation: "trading spaces"

increasing dominance of morph... and materials
decreasing dominan...

control and behavior less ...

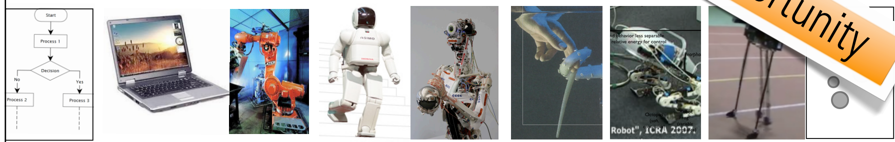
research opportunity

informational computation

control dominant

morphological computation

morpho... dominant



pure algorithm	computer (running algorithm)	industrial robot (centralized control	Asimo (and similar robots)	ECCE (compliant, tendon-driven)	Octopus (soft, continuous)	"Robot Frog" (variable compliance)	Cornell Ranger (exploiting morphology)	cells molecules "Tribolons"

Contents

The four messages of embodiment

Message 1: Physical embedding
Understanding brain not enough; morphology materials; embedding

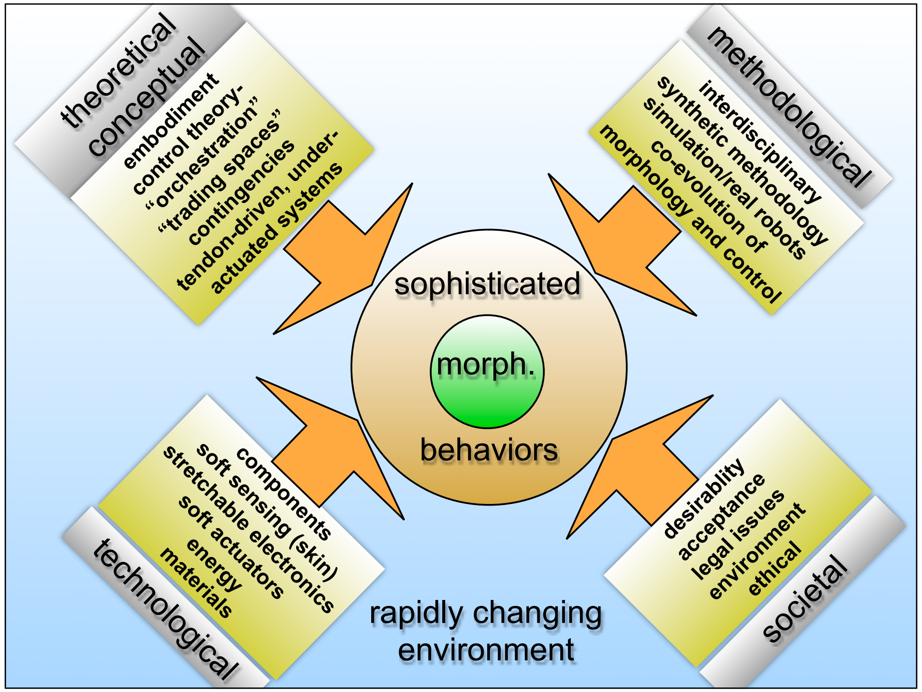
Message 2: Real/Artificial worlds
Fundamental differences industrial and real-world environments

Message 3: Task distribution
Cooperation - brain, body, environment

Message 4: Physical dynamics and information structure
Induction of information structure; dependence on morphology and control

Research opportunities: Classification

- theoretical/conceptual
- methodological
- technological
- societal


theoretical
conceptual
embodiment
control theory-
"orchestration"
"trading spaces"
contingencies
tendon-driven, under-
actuated systems
methodological
interdisciplinary
synthetic methodology
simulation/real robots
co-evolution of
morphology and control
sophisticated
morph.
behaviors
technological
components
soft sensing (skin)
stretchable electronics
soft actuators
energy
materials
societal
desirability
acceptance
legal issues
environment
ethical
rapidly changing
environment

Overview: Challenges

MODELING	SENSING	ACTUATION	CONTROL/ ORCHESTRAT-ION	MANUFACTU-RING	ENERGY	MATERIALS	APPLICATIONS	COMMUNITIES
physical simulation	deformable structures	artificial muscles	acquisition of control	design tools, methodology	metabolism	functional mat. changeable properties	manipulation for assembly/ surgery	material science, soft-matter physics
theory, compliance hard to model	growing structures	variable compliance actuactors	model-free	assembly, growth	storage	skin-line	entertainment	neuroscience
system identification	space and time resolution	power density	decentralized	self-assembly multi-layer deposition		growing/ healing self-repair	therapy, human assistance	biomechanics and bio-engineering
implementat-ion	large-scale distributed	embedding technology	morphological computation	building blocks		composite	understanding life	manufacturing process engineering
	embedding technologies		underactuated/ overactuated systems	organic materials?			mobility	ALife/AI
	other sensor modalities (e.g. whiskers)		human/robot interaction, emotion			smart programmable materials		comp. science electrical engineering

Like to know more?

Like to know more?

follow the Locomorph research

http://locomorph.eu/

University of Zurich

robotics Swiss National Centre of Competence in Research

ai lab

visit us in Zurich

ai lab

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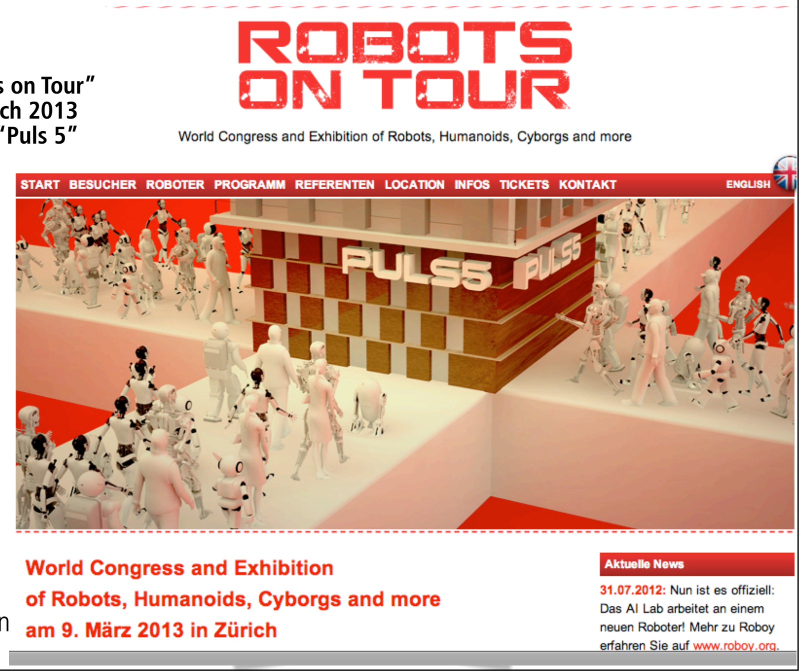

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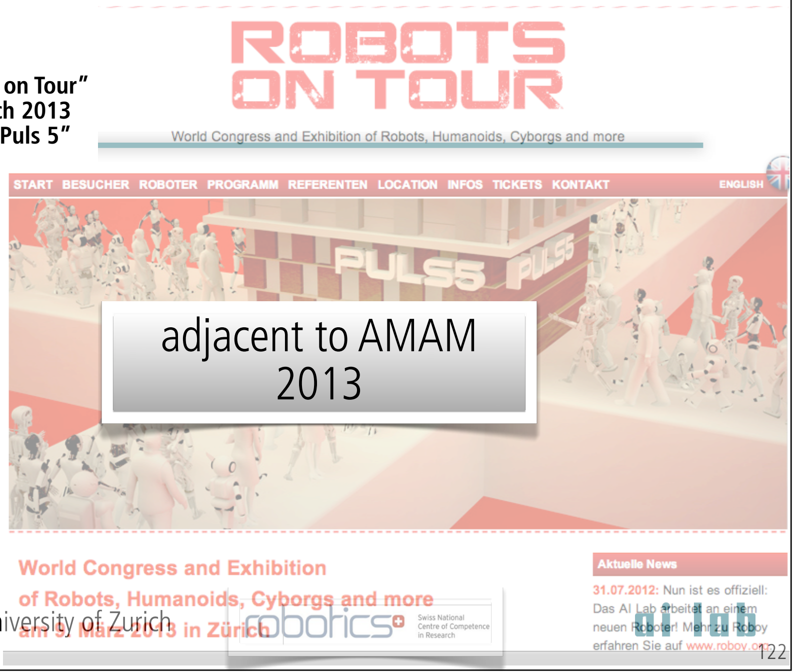

adjacent to AMAM 2013

robotics

Swiss National Centre of Competence in Research

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Intelligent robots for improving the quality of life

Version Française

The National Centre of Competence in Research (NCCR) Robotics is a nation-wide center, launched by the Swiss National Science Foundation, with the common objective of developing new, human-oriented robotic technology for improving our quality of life.

This center gathers leading robotic experts in Switzerland from cutting-edge research institutions: EPFL as the home institution, ETH Zurich, University of Zurich and Dalle Molle Institute for Artificial Intelligence. Launched on 1 December 2010, the NCCR Robotics will run for up to twelve years.

The NCCR Robotics brings together Swiss robotic research and aims to generate long-term benefits to society as a whole. Through this website, we would like to establish two-way communication about robotics in Switzerland and abroad with researchers, students, teachers, industries, and the general public.

Home institution

Partners

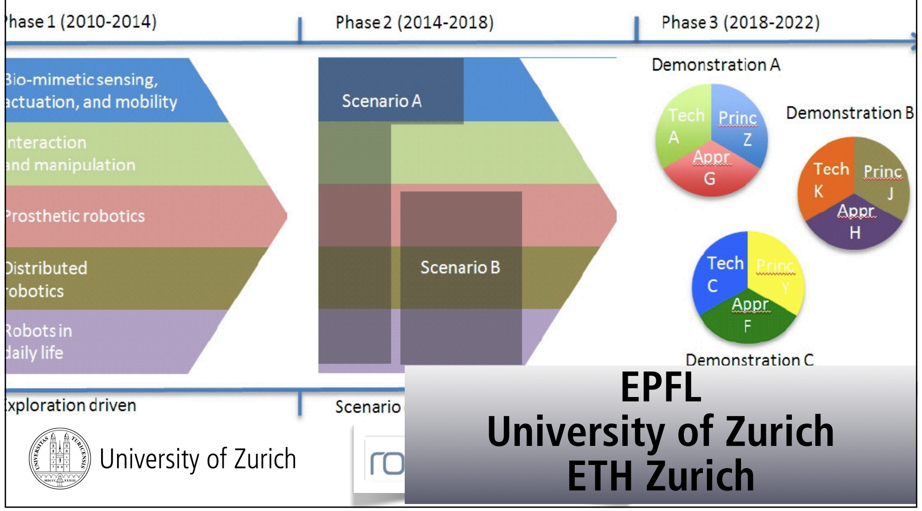
Highlights

Robots in Daily life -
NCCR Robotics 1st Symposium
16 June 2011, ETH Zurich
Registration is now closed. We will re-open the registration again if any seats become available.

Europe shortlisted Robotics Flagship
Project *Robot Companions for Citizens* has been chosen among six other *grand challenges* by European Commission in Budapest. This project aims at developing *sentient machines* whose applications include helping elderly people or rescuing people in natural disasters.

Summer School - Dynamic Walking and Running with Robots
11-15 July 2011, ETH Zurich

NCCR: started Dec 2010 for 12 years



or: Read THE book

Read THE book

what book?!??

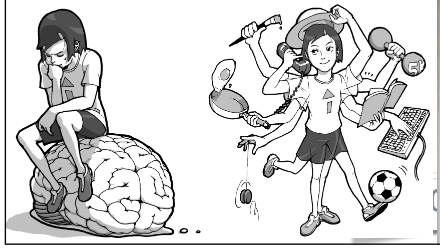
Read

Rolf Pfeifer and Josh Bongard

How the body shapes the way we think — a new view of intelligence

MIT Press, 2007

Illustrations by Shun Iwasawa

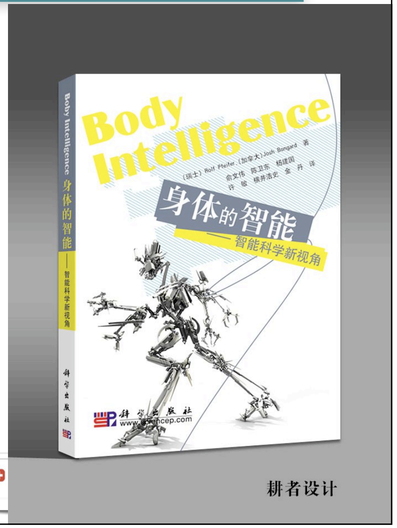


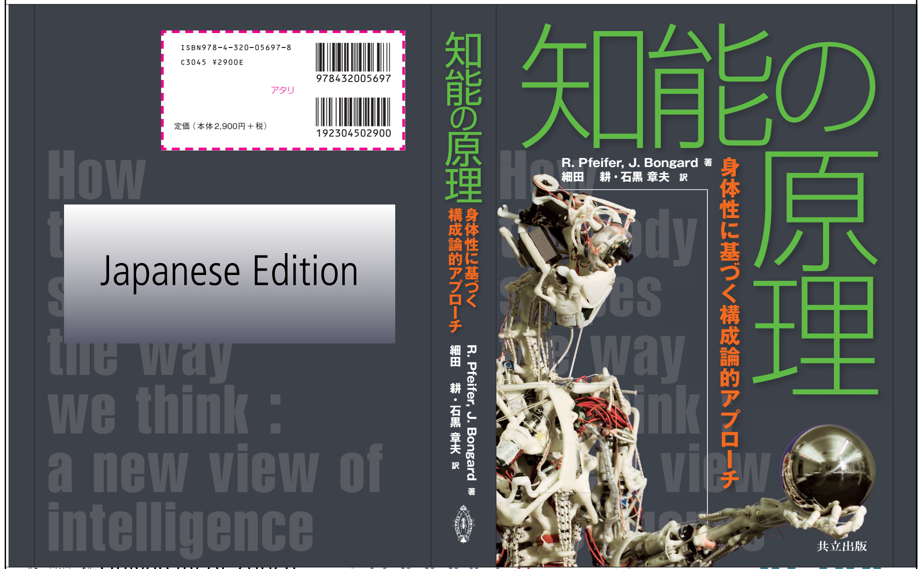
popular science style

Chinese translation

Translated by
Weidong Chen
Shanghai Jiao Tong University
and
Wenwei Yu
Chiba University, Japan

Foreword by
Lin Chen
Chinese Academy of Science
Beijing

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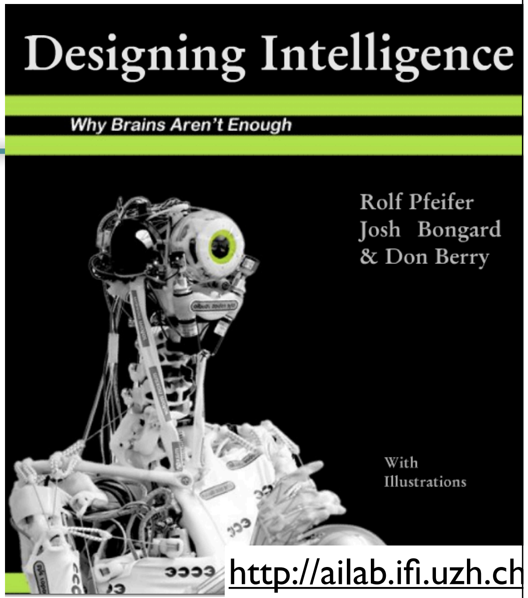
知能の原理
身体性に基づく構成論的アプローチ
R. Pfeifer, J. Bongard 著
細田 耕・石黒 章夫 訳
共立出版

Short e-book version

Designing Intelligence

Why Brains Aren't Enough

Rolf Pfeifer
Josh Bongard
Don Berry



http://ailab.ifi.uzh.ch

Can be downloaded from here:
http://www.grin.com/e-book/165548/designing-intelligence#inside

ai lab

New book in French

La révolution de l'intelligence encorporée

(The revolution of embodied intelligence)

Alexandre Pitti and Rolf Pfeifer

Paris, France: Les Éditions Xanadu

(to appear: October 2012)

or join
The ShanghAI Lectures

人工智能 The ShanghAI Lectures 上海授课

- **global lecture series on natural and artificial intelligence**
- **video conference with 20 universities**
- **3D virtual collaborative environments for classwork with over 40 universities**
- **intercultural cooperation on interdisciplinary topic**

The ShanghAI Lectures, Sept to Dec 2012
(from the University of Zurich, Salford University, UK, ShanghAI JiaoTong University)

Started at Shanghai Jiao Tong University, October 2009

with the generous support of

HASLERSTIFTUNG

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Participating sites 2009–2011

University of Zurich[UZH]

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The Zurich AI Lab

Funding

- University of Zurich, Switzerland

- Swiss FNS:
  - From locomotion to cognition
  - Dynamical coupling in motor-sensory function substitution
  - From morphology to functionality
  - Swiss National Competence Center Robotics (started Dec 2010)

- EU-FET:
  - Locomorph
  - Octopus
  - iCub (finished)

- EU-Cognitive Systems:
  - ECCERobot
  - Amarsi
  - EU-Cog II/III
  - Extended Sensory-Motor Contingencies

- Private funding/others:
  - CIAN (Club of Intelligent Angels)
  - Maxon Motor
  - Festo
  - Hasler Foundation
  - Switch

“Better robots — better life!”

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Thank you for your attention!