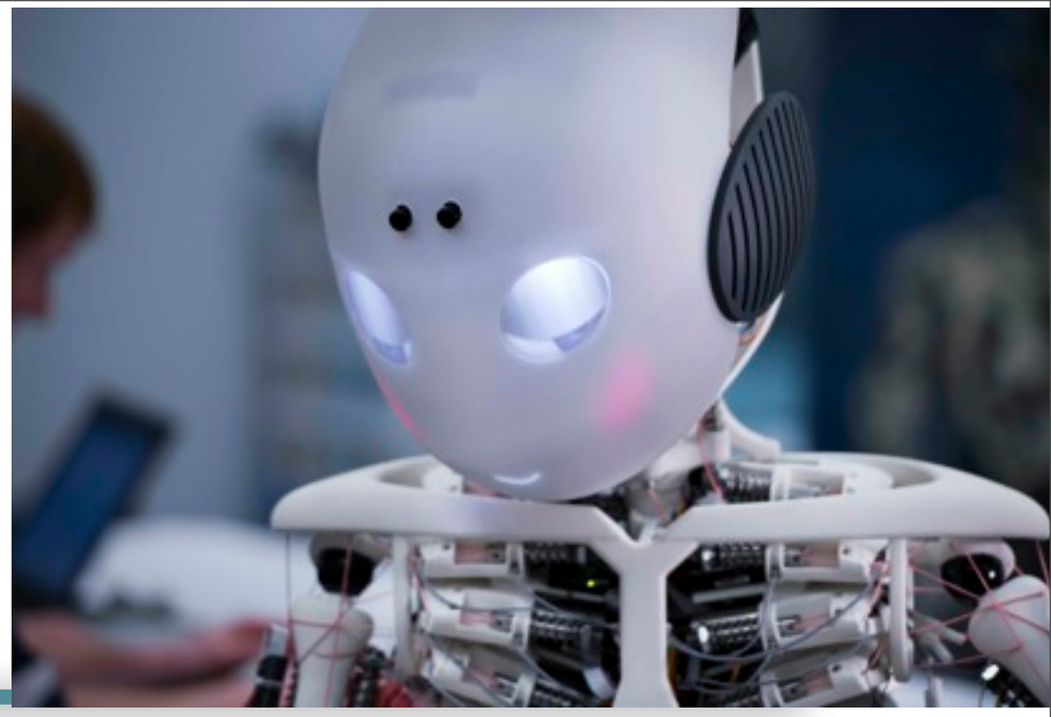
“Soft Robotics” - the next generation of intelligent machines



“A perspective from artificial intelligence”

RobotSoft Plenary Meeting
SSSA, Pisa, Italy

31 March 2014

Rolf Pfeifer, Artificial Intelligence Laboratory
Department of informatics, University of Zurich, Switzerland
NCCR National Competence Center Robotics, Switzerland

The Economist March 29th - April 4th

University of Zurich[UZH]

Thanks to ...

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Weidong Chen
Steve Collins
Holk Cruse
Paolo Dario
Rüdiger Dillmann
Raja Dravid
Rodney Douglas
Peter Eggenberger
Andreas Engel
Martin Fischer
Dario Floreano
Toshio Fukuda
Robert Full
Philippe Gaussier
Gabriel Gomez
Fumio Hara
Alejandro Hernandez
Owen Holland
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Yasuo Kuniyoshi
Cecilia Laschi
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Lukas Lichtensteiger
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Max Lungarella
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Toshi Nakagaki
Stefano Nolfi
Kevin O'Regan
Norman Packard
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José Santos Victor
Matthias Scheutz
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Russ Tedrake
Esthen Thelen
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Barry Trimmer
Sethu Vijakyakumar
Oskar von Stryk
Hesheng Wang
Ruediger Wehner
George Whitesides
Martijn Wisse
Hiroshi Yokoi
Wenwei Yu
Marc Ziegler
Tom Ziemke

... for their ideas

Minoru Asada
Hajime Asama
Tamim Asfour
Rudolf Bannasch
Alain Berthoz
Josh Bongard
Simon Bovet
Rodney Brooks
Weidong Chen
Steve Collins
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“Soft Robotics”

Hypothesis: **The next generation of robots will be of the “soft” kind. Advances in “soft technology” will lead to a quantum leap in intelligent robotics.**

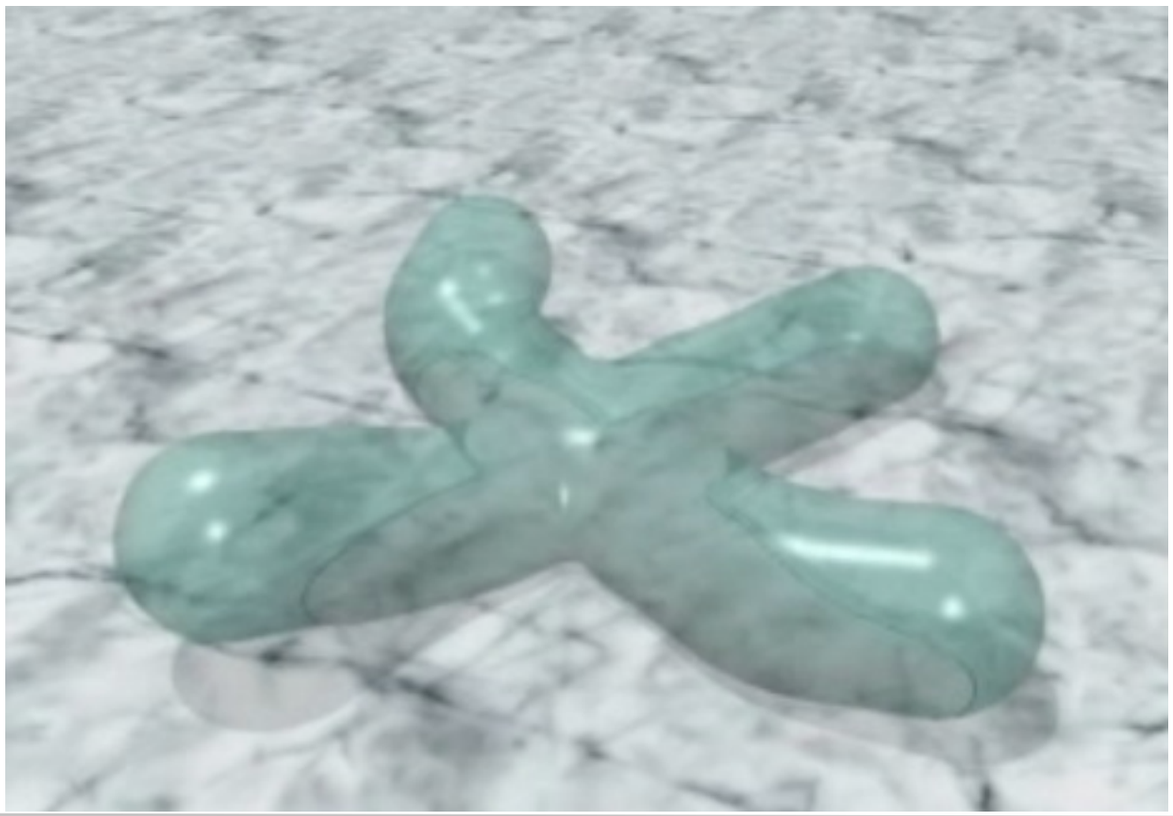
Theoretical underpinnings: **The key to “soft robotics” will be an understanding of embodiment.**

“Soft Robotics”

work by Dale Thomas, 2003

evolved, soft locomotion

Design and construction:
Dale Thomas, Osaka University
previously: Zurich AI Lab



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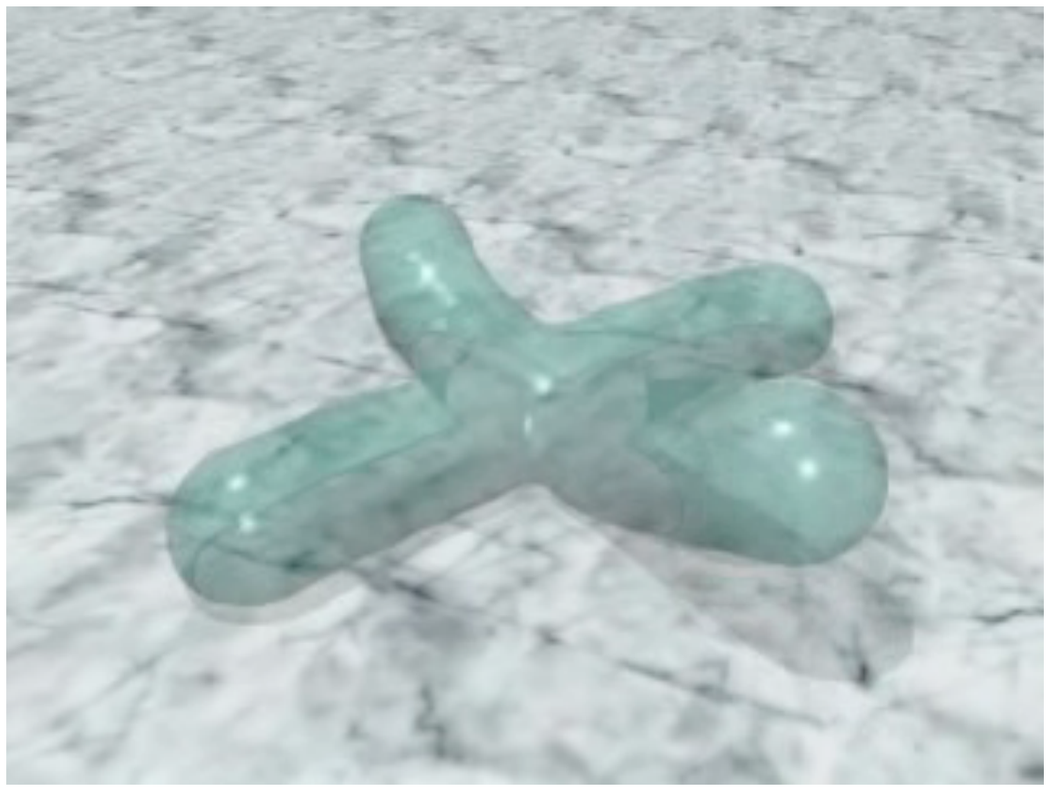
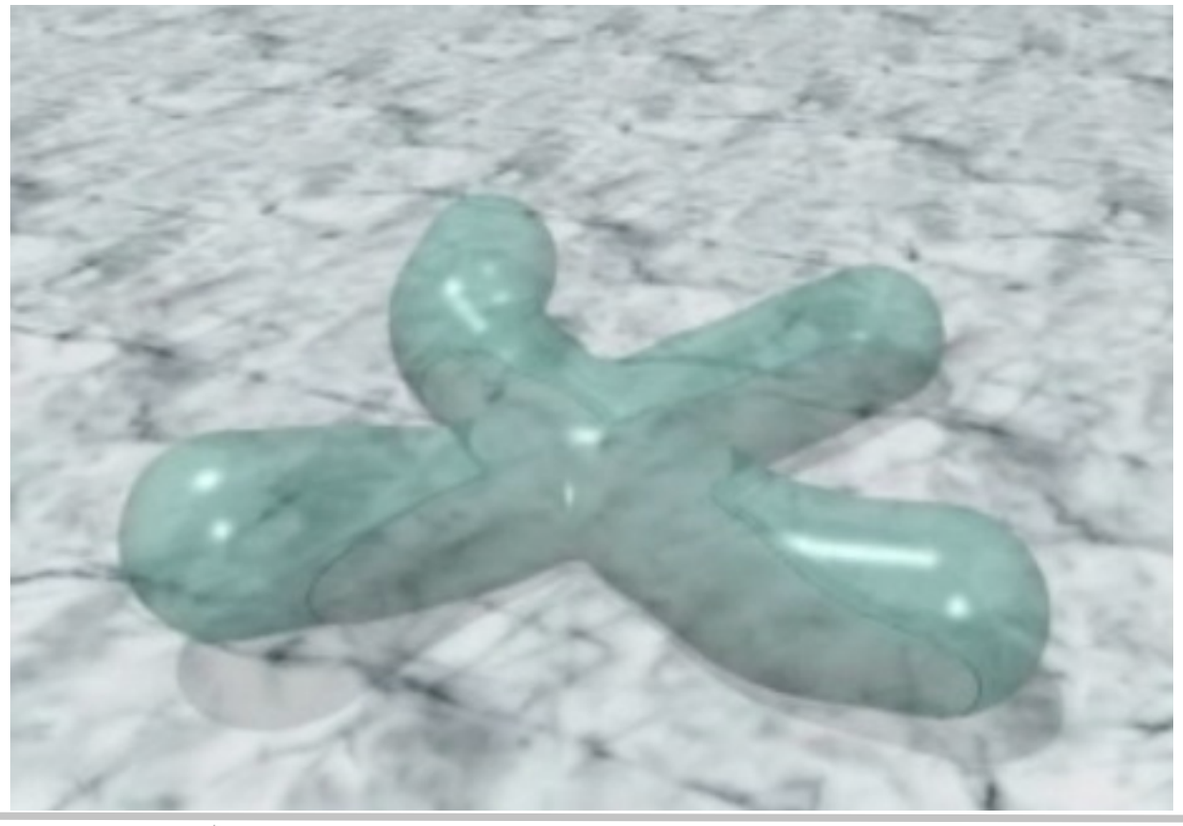




Contents

- introduction and background
- principles of embodied intelligence
- the “power of materials”
- guided self-organization
- the “Roboy” project
- summary and conclusions

Trends in AI/robotics

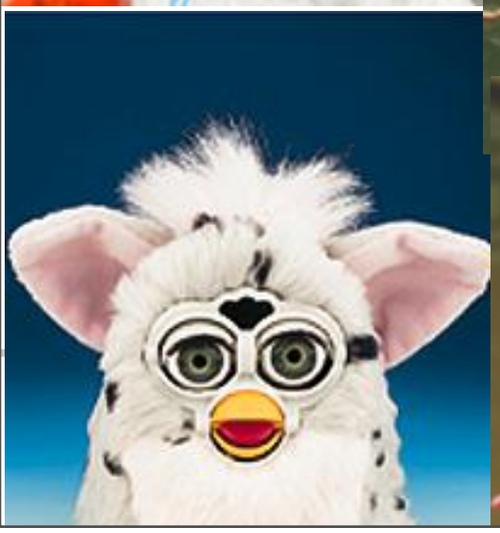
classical		*embodied*
centralized control	→	interplay of brain, body, and environment
top-down control	→	guided self-organization
algorithm	→	dynamical system
abstract symbol processing	→	sensory-motor coordination
top-down design	→	design for emergence
fixed morphology	→	morpho-functional machines

Trends in robotics/manufacturing

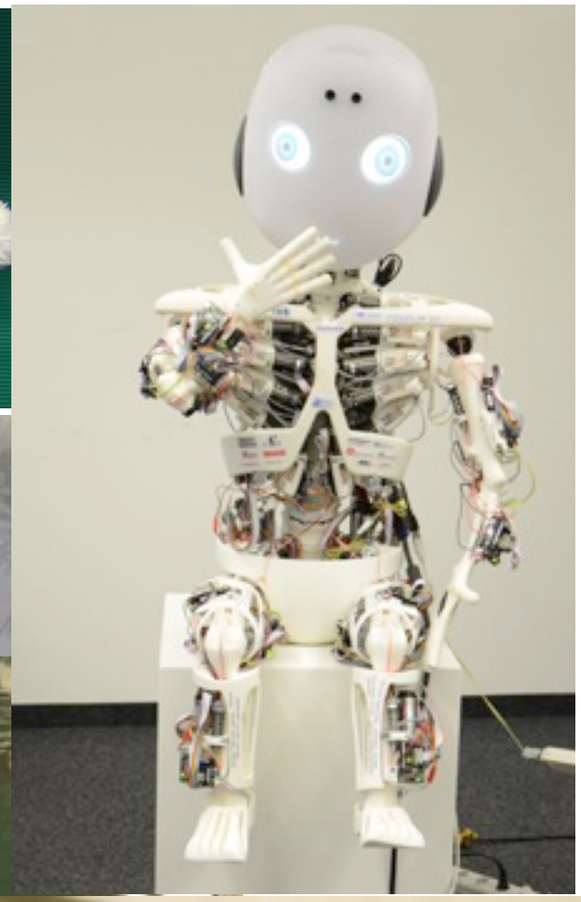
manufacturing, “hard”	→	service, “soft”
individual robots	→	robot “ecosystem”
isolated robots	→	the human/robot “cloud”
complete automation	→	human-robot cooperation
outsourcing production	→	re-insourcing
software, “bits”	→	physical system, “atoms”
centralized manufacturing	→	distributed “makers”
big industries, high invest-ments	→	SMEs, small investment

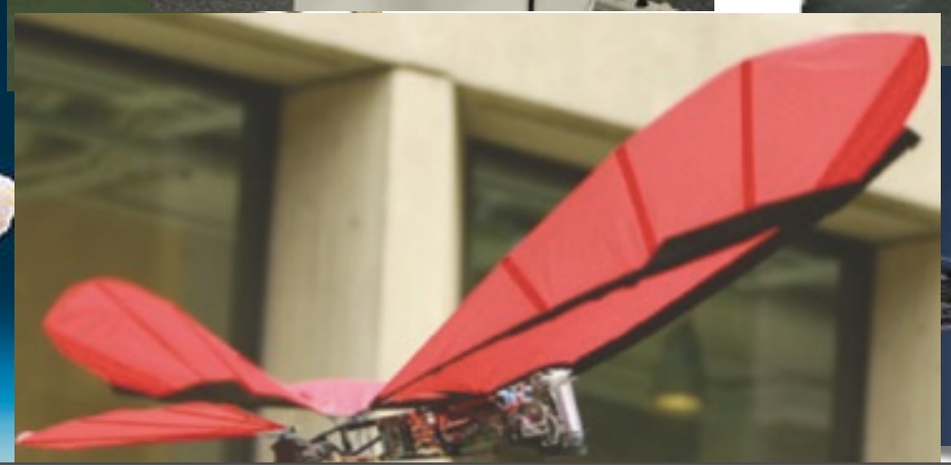
“Soft Robotics”

Soft to touch

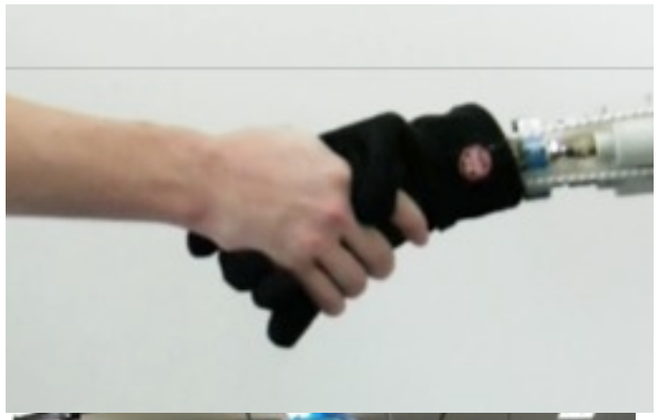


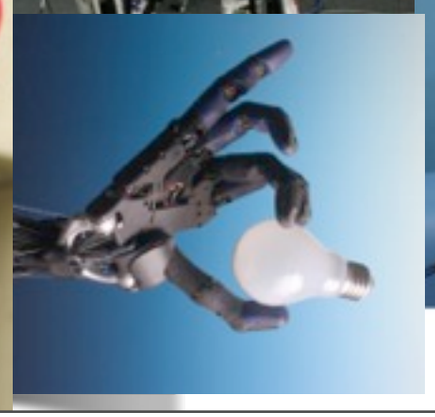
Soft movement

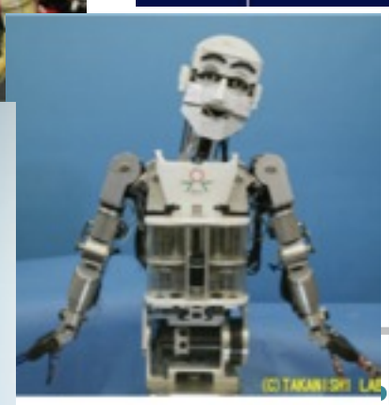




Soft interaction



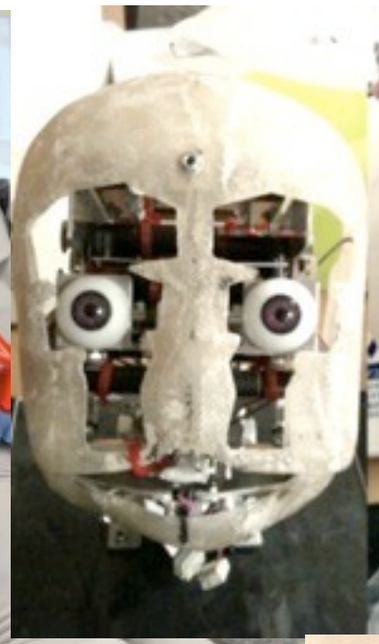


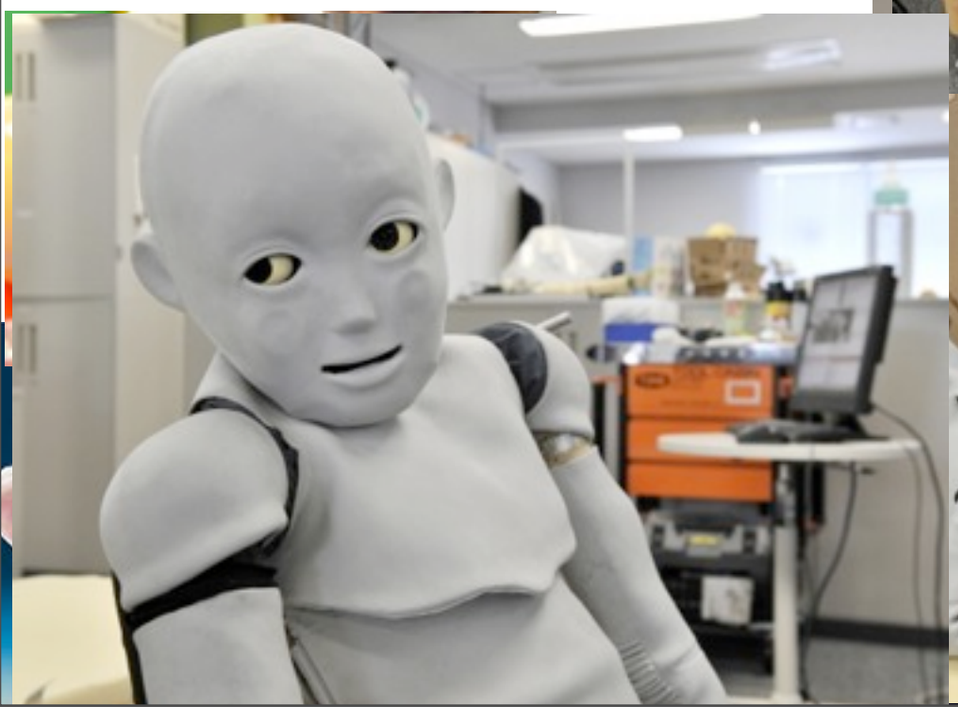


“Soft Robotics”

(Osaka University)

Soft to touch **Soft movement** **Soft interaction**



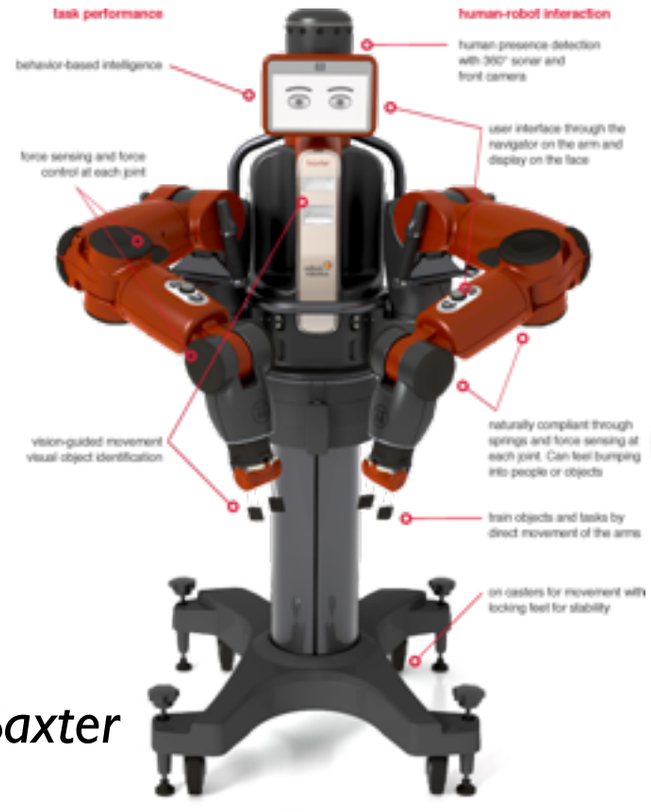


Dienstag, 1. April 14

Building robots

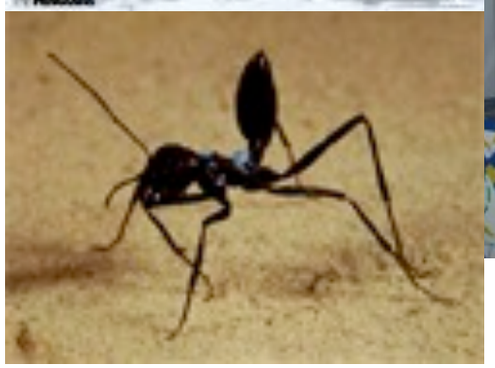
unterstanding intelligence

applications



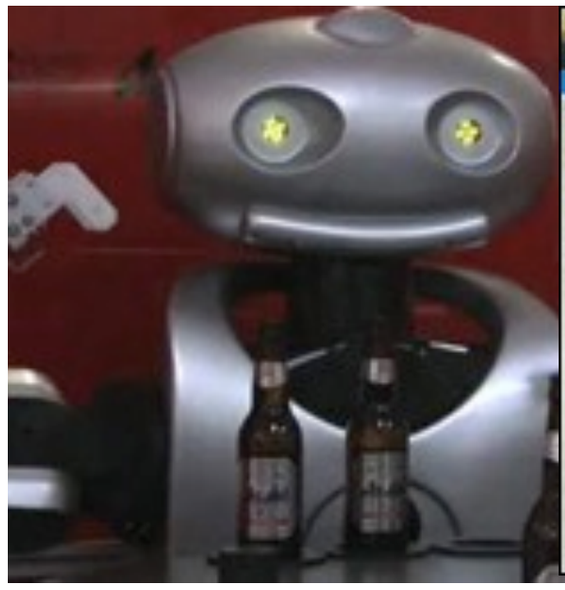
Baxter

vacuum cleaner



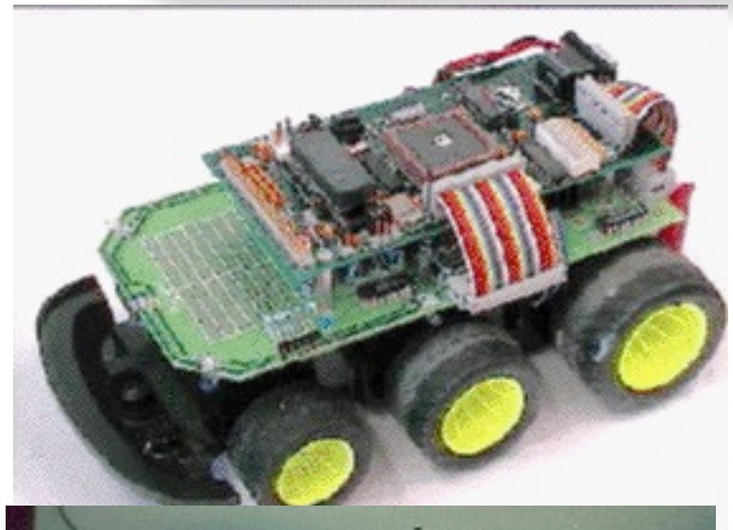
animals *humans*

robot “bar man”



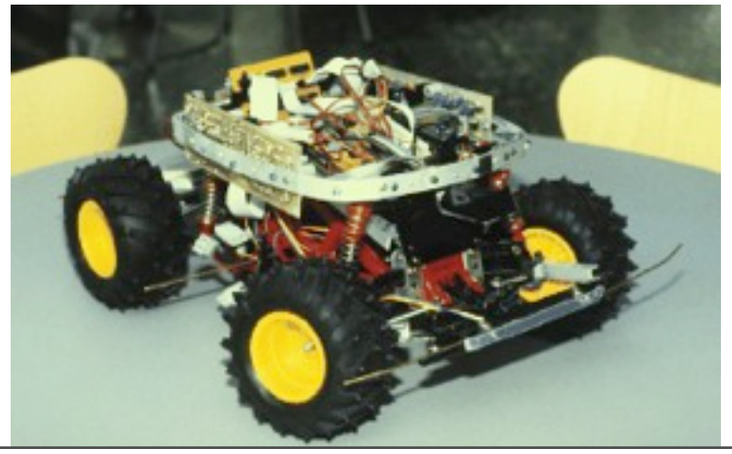
Engkey

Zurich AI Lab robots



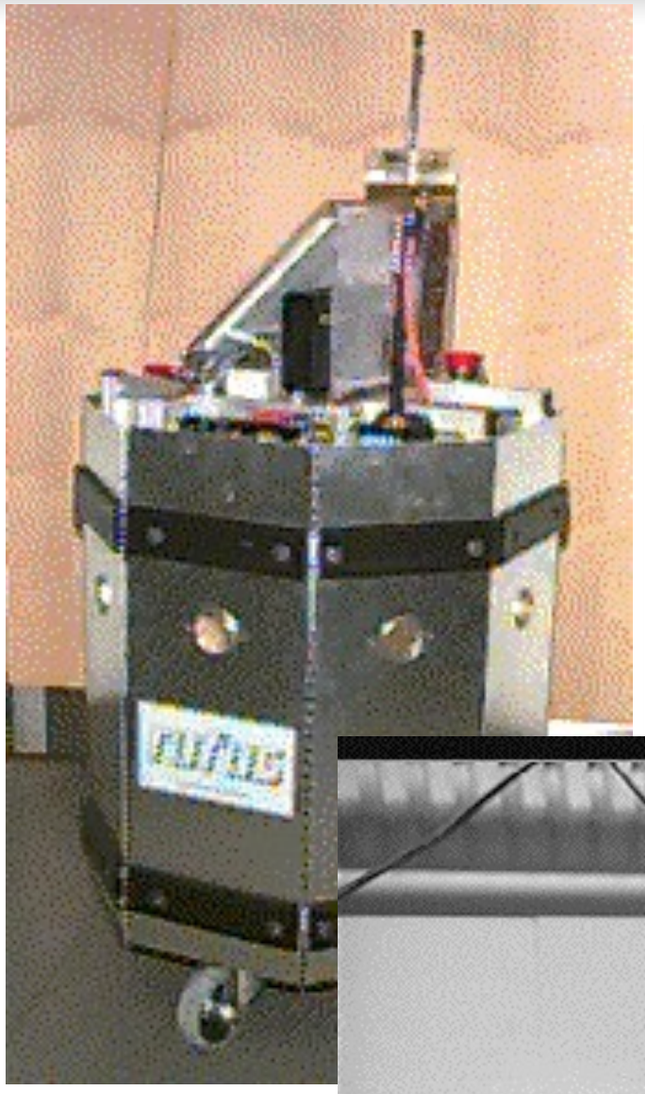
Didabot

Famez



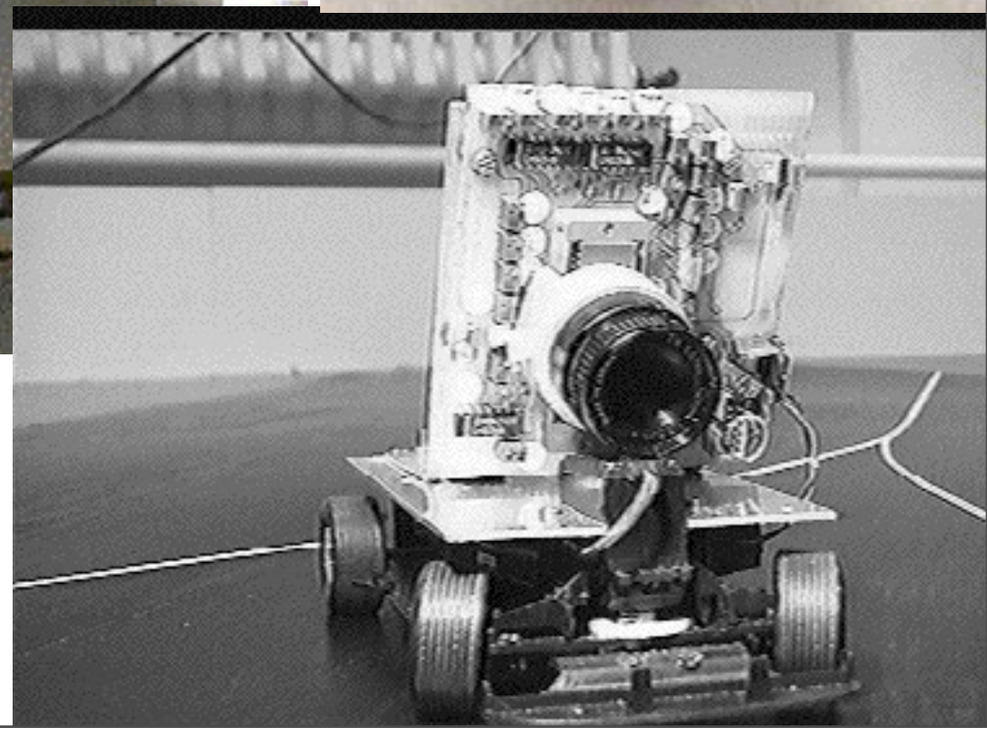
Sita

Rufus T. Firefly

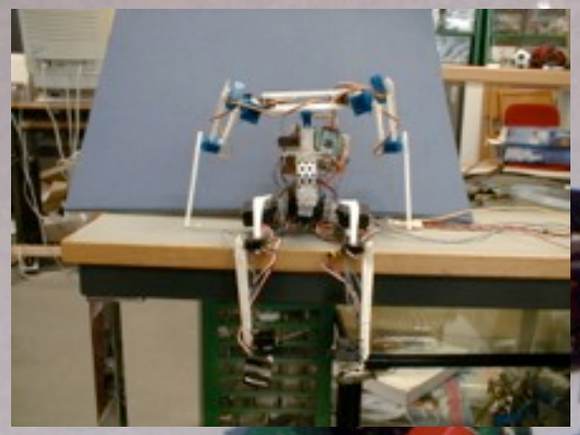


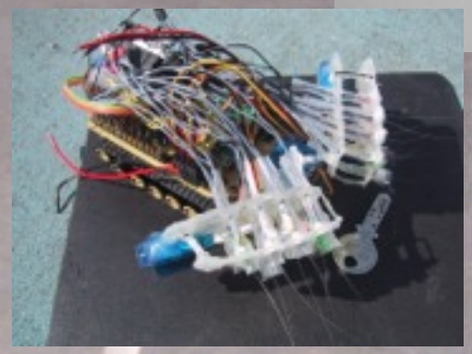
Morpho

Ms. Gloria Teasdale

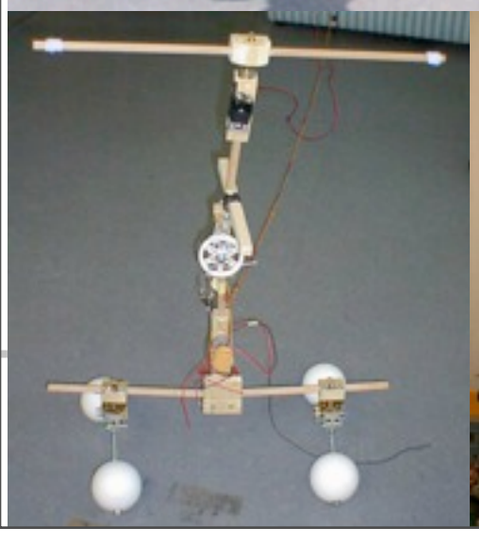


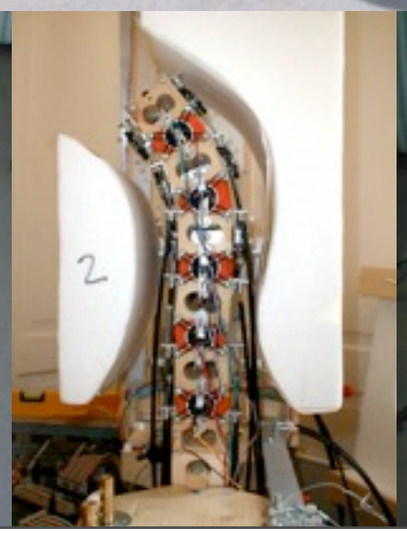
Zurich AI Lab robots

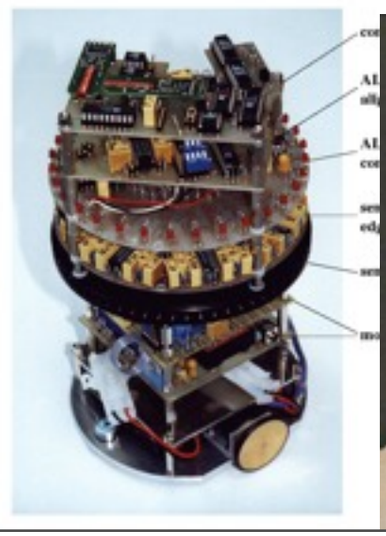




- Amouse
- SahabotI/II
- Melissa
- Tripp
- Samurai
- Analogrob
- Dexterolator
- Stumpy
- Eyebot
- Mindstorms
- Kheperas
- Mitsubishi
- Forkleg

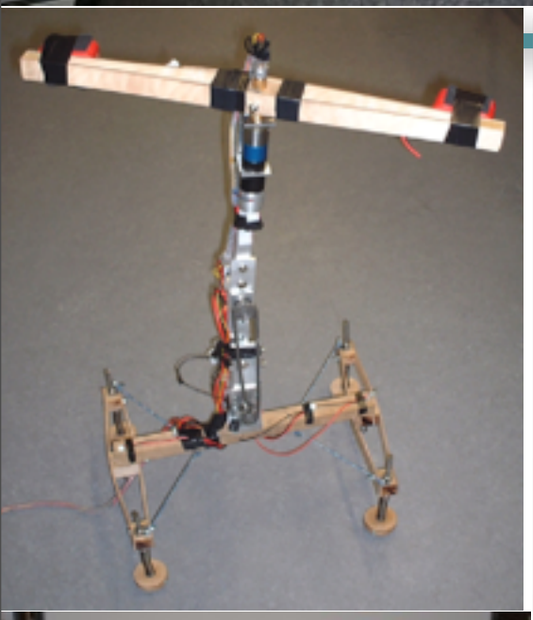
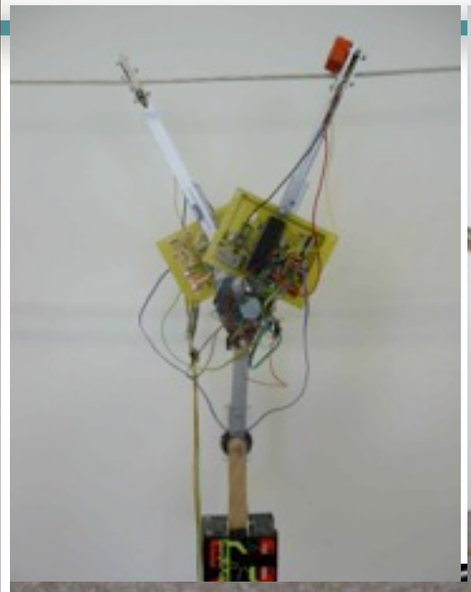
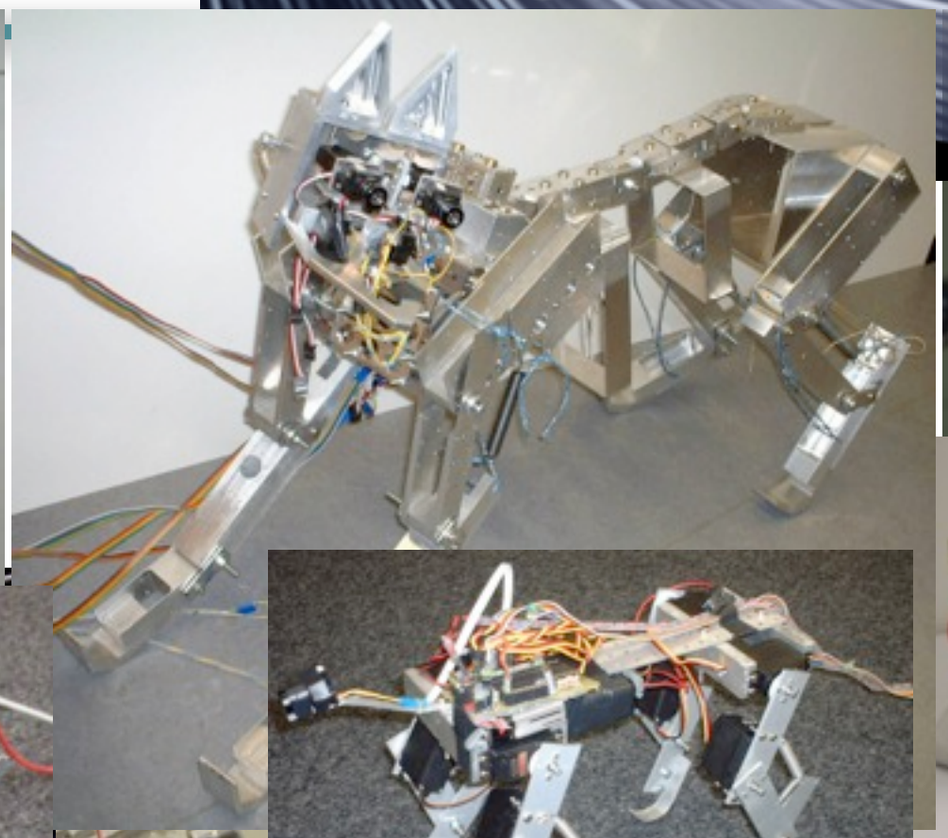
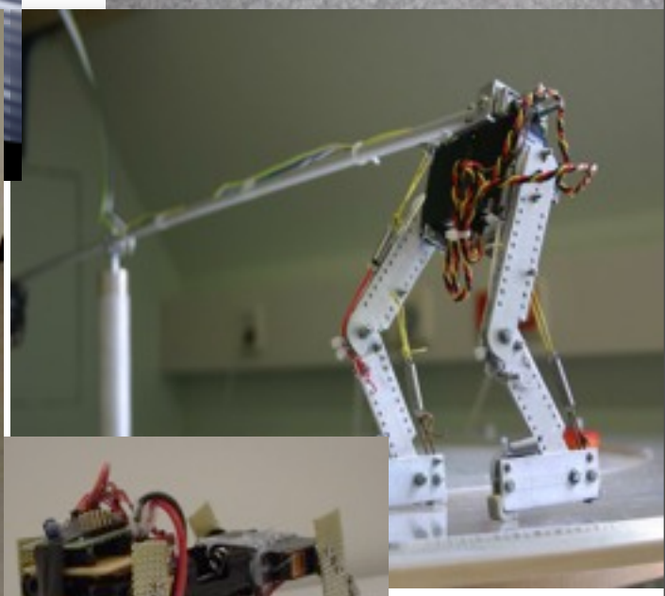
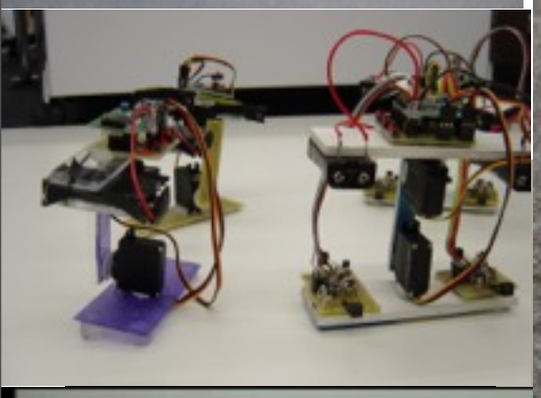
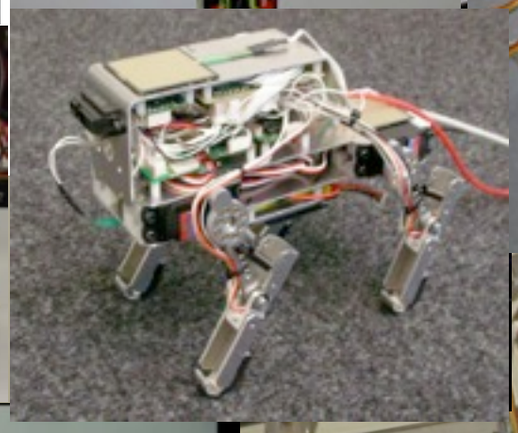


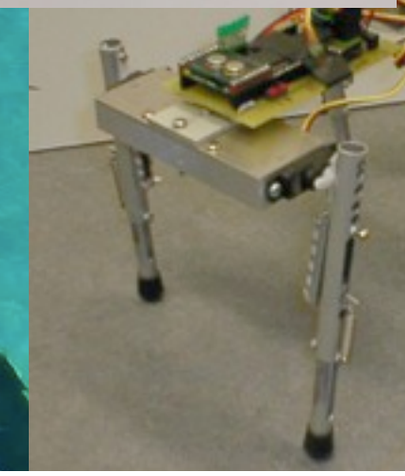
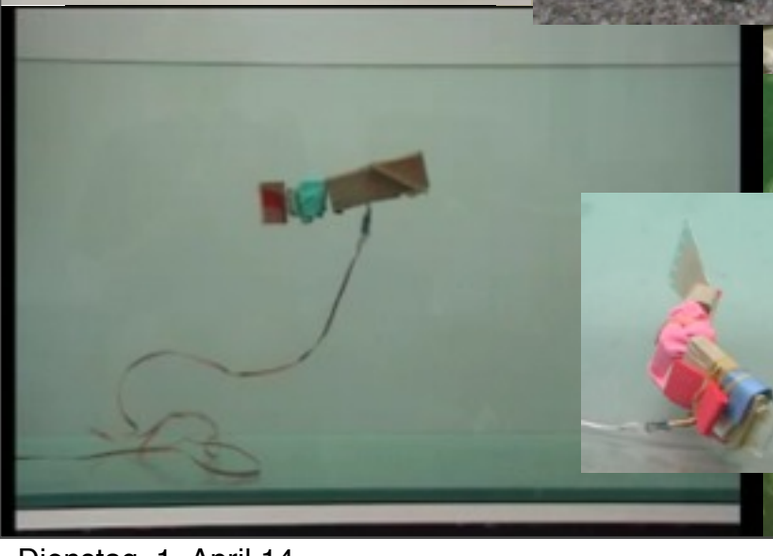


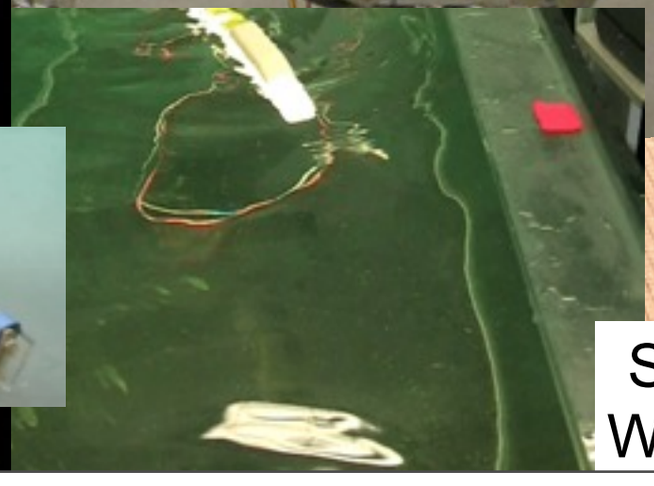


Zurich
AI Lab robots



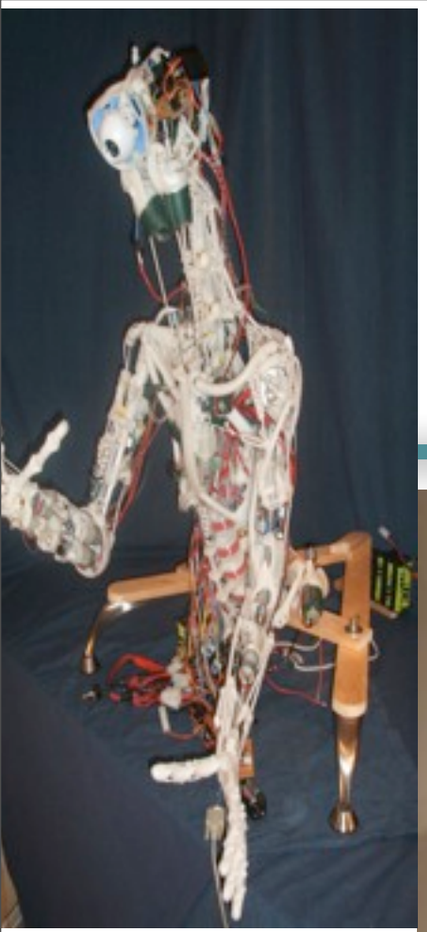








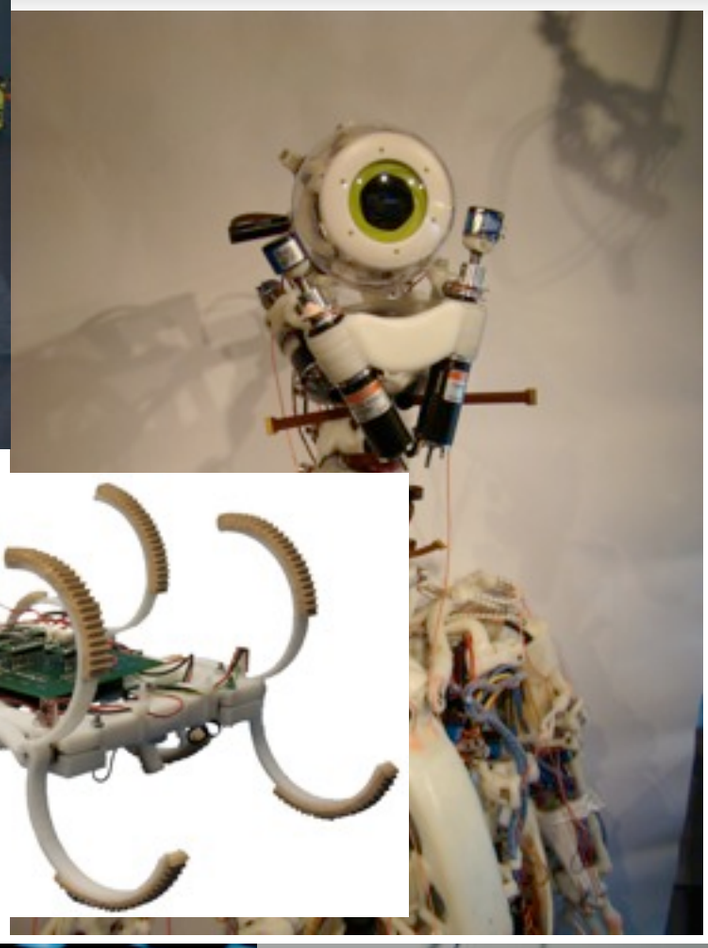



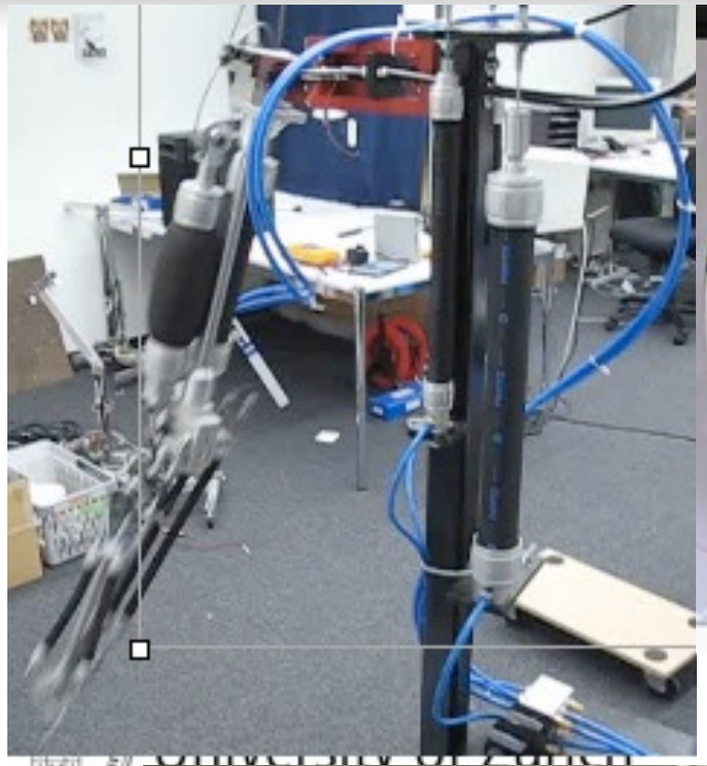


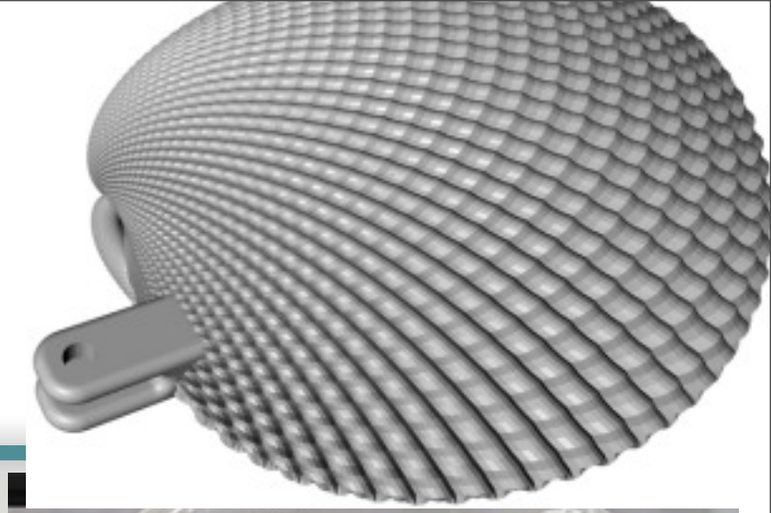

Stumpy, Monkey, Puppy, Min-dog, Wheeled Walker, Mini-Stumpy, Wanda, Dumbo, Rabbit

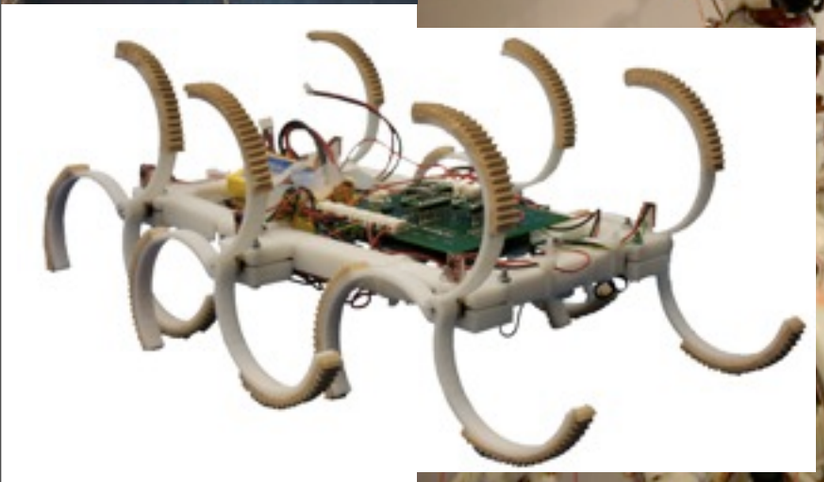
Zurich AI Lab robots

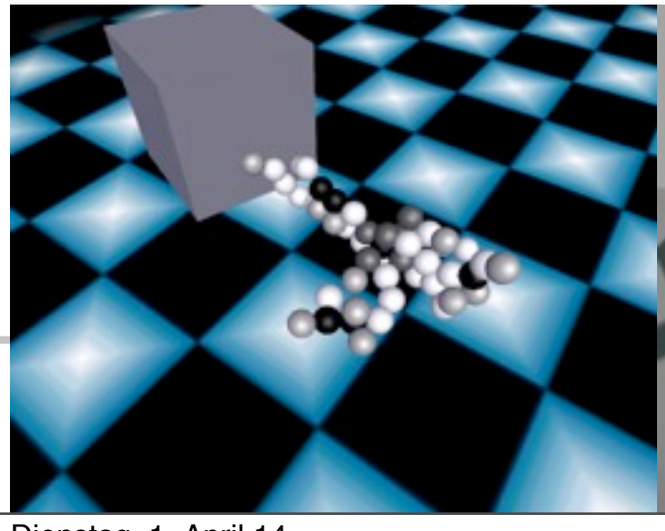


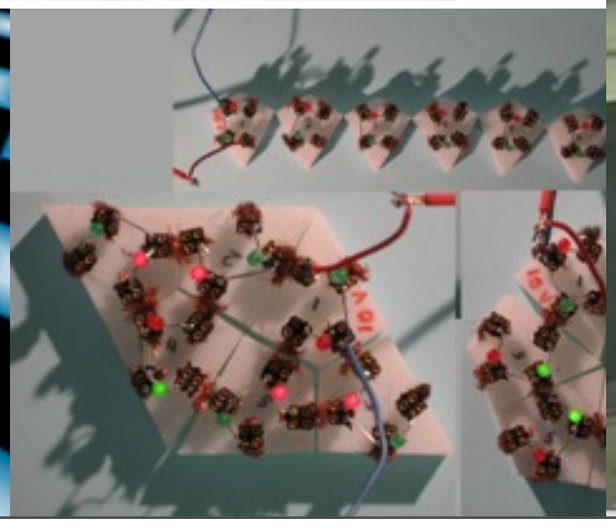


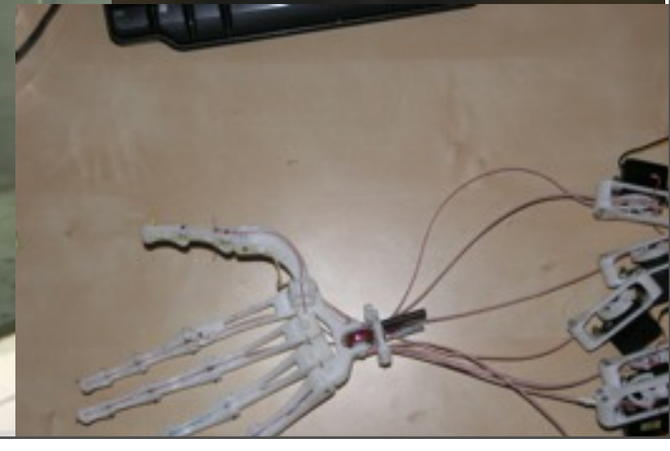




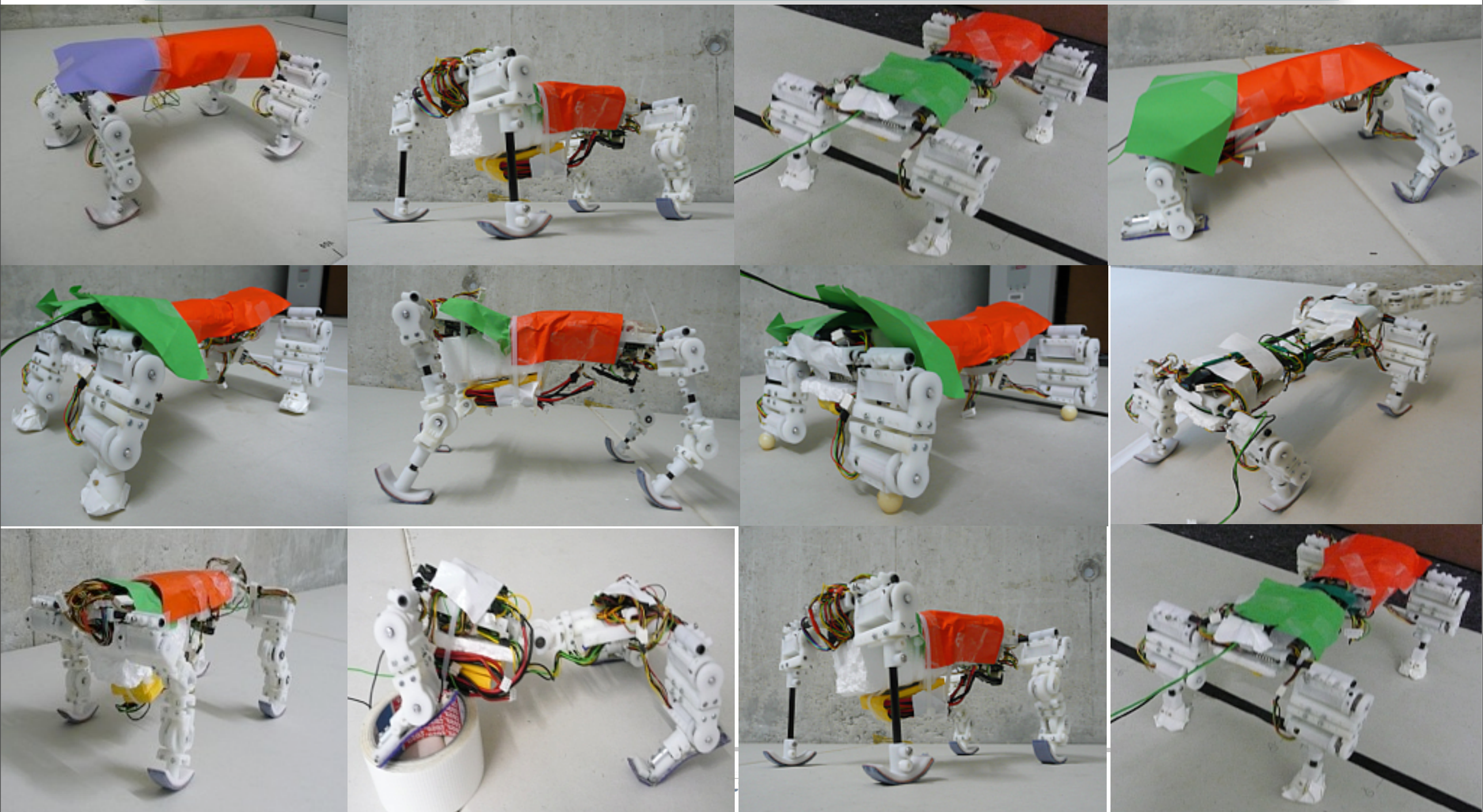




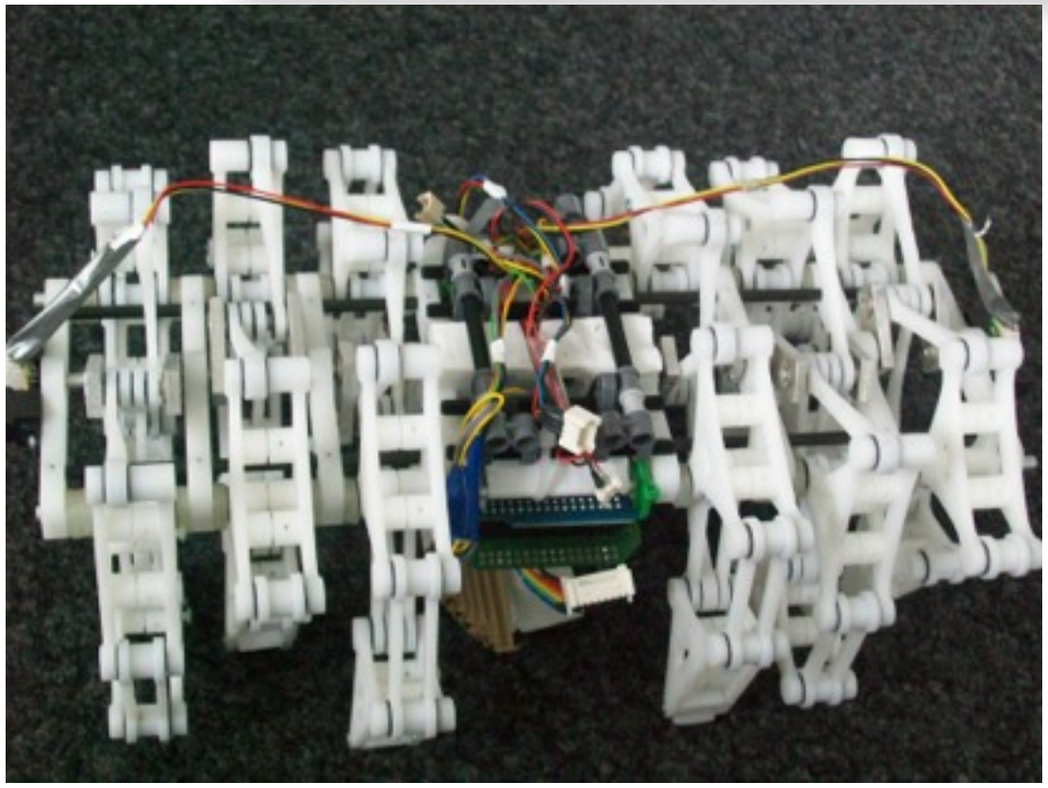


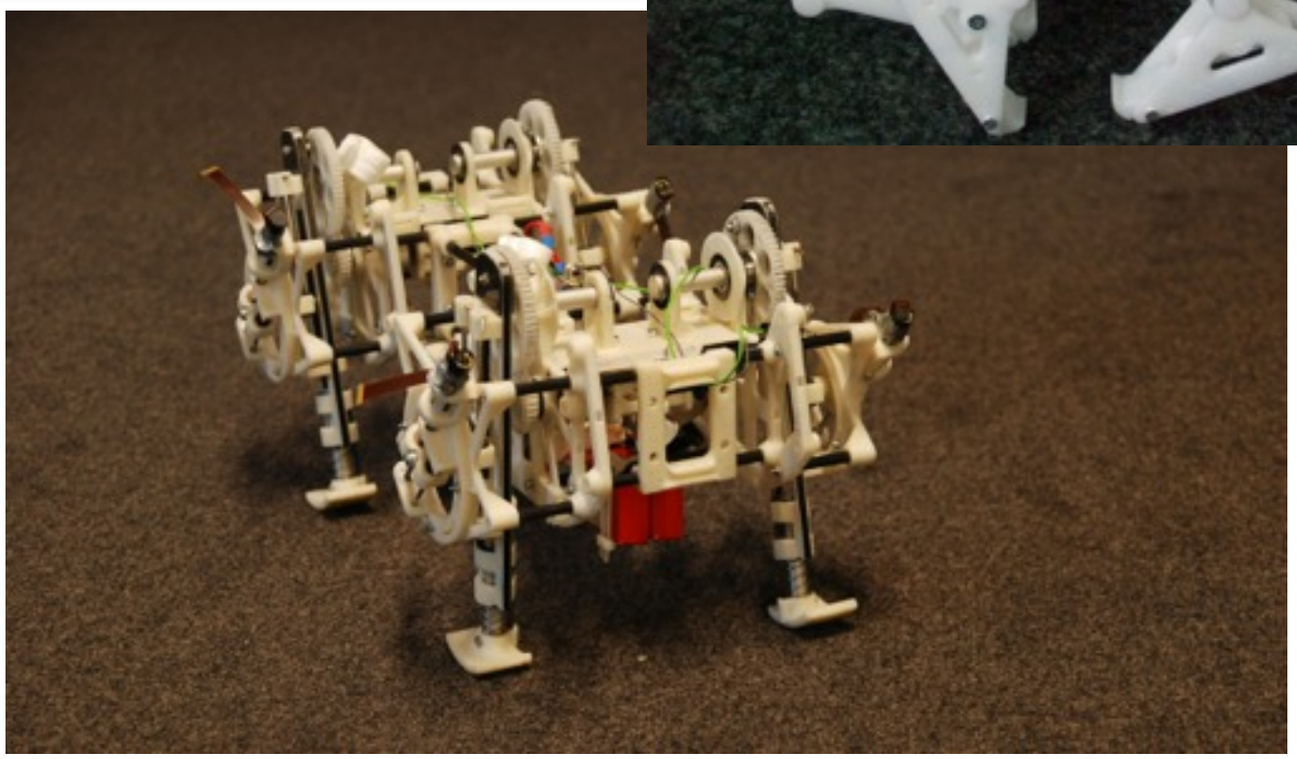


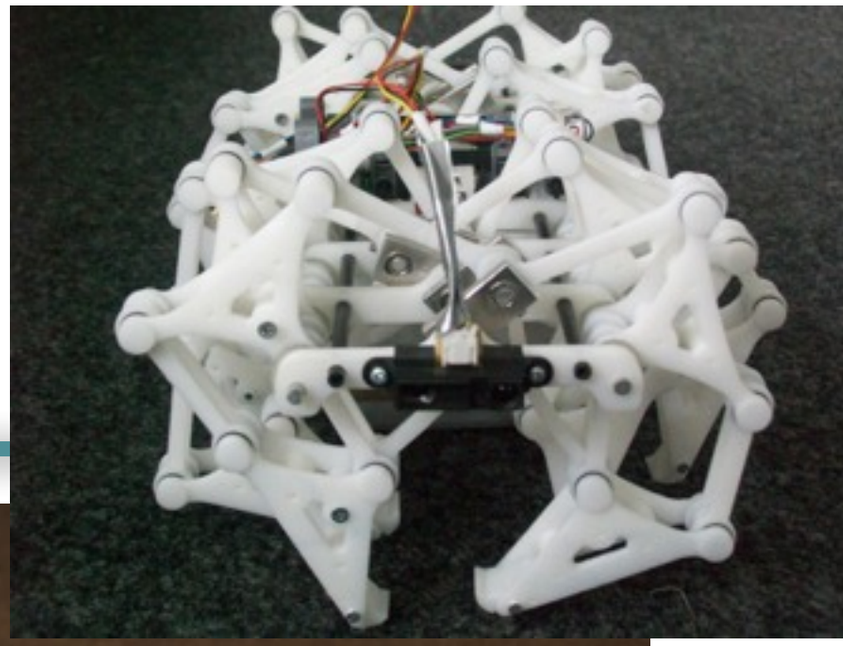
AI Lab Robots

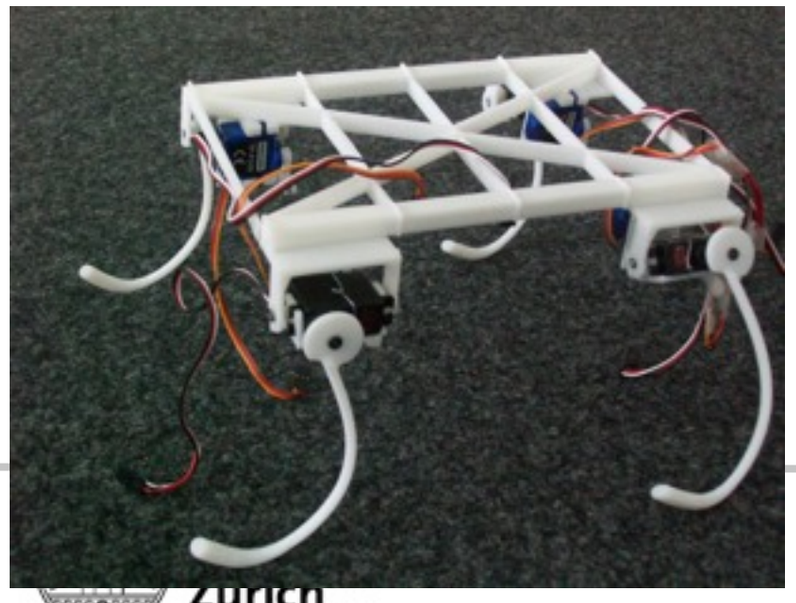


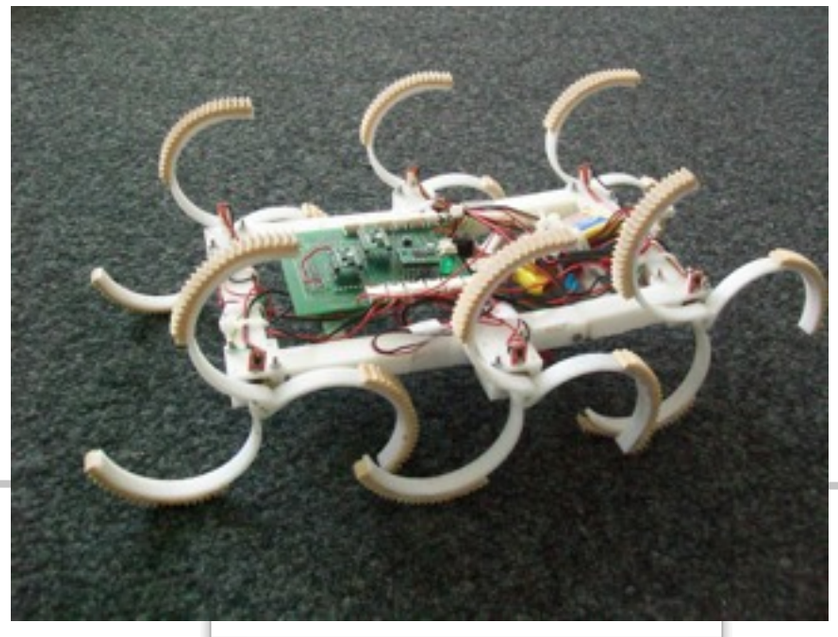
Zurich AI Lab
Robots (Locomorph)

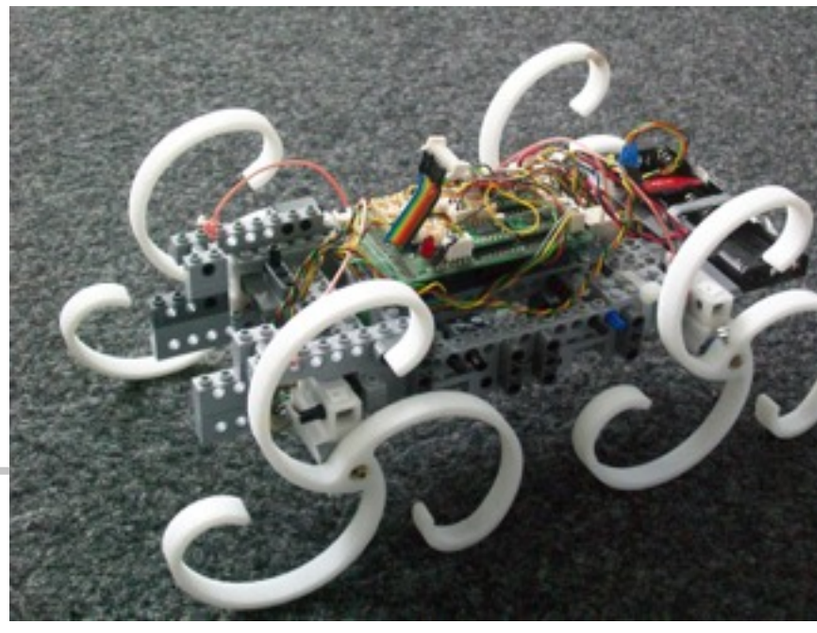


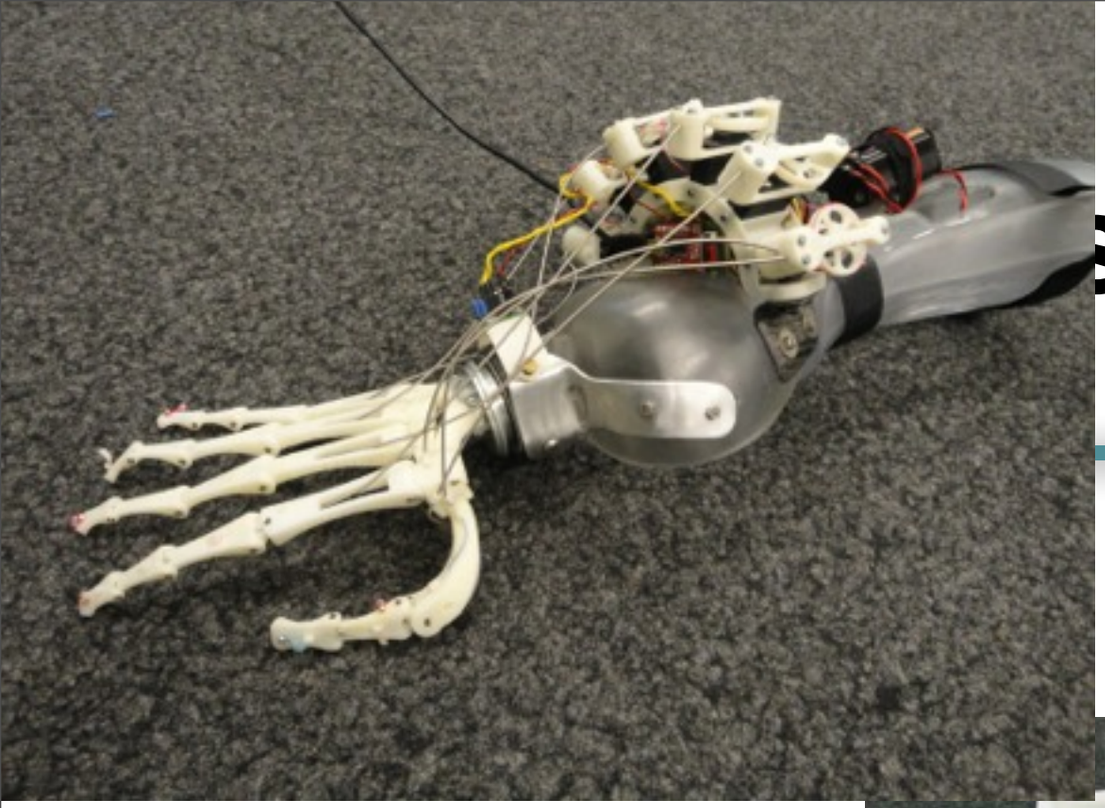


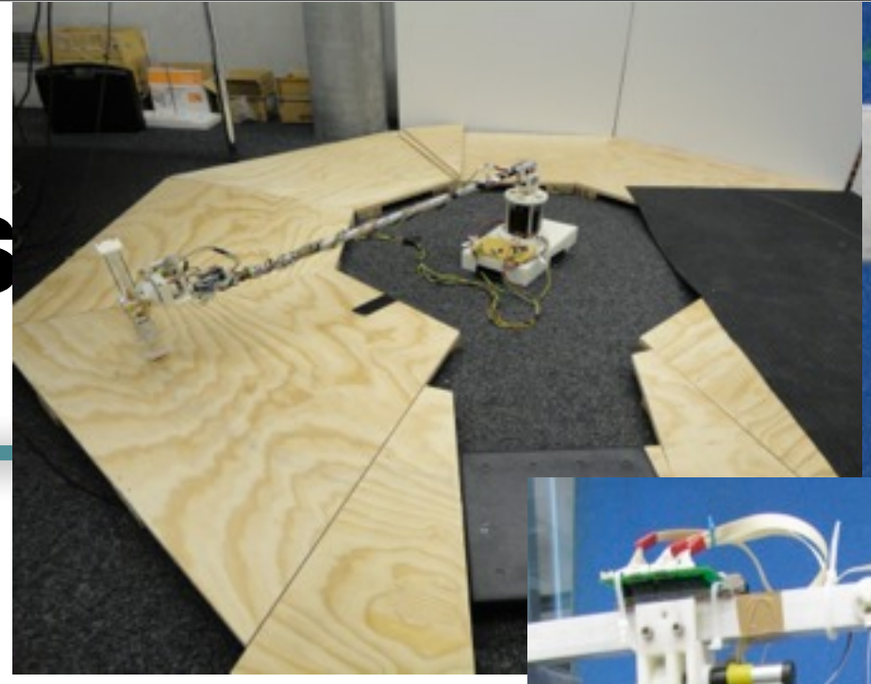


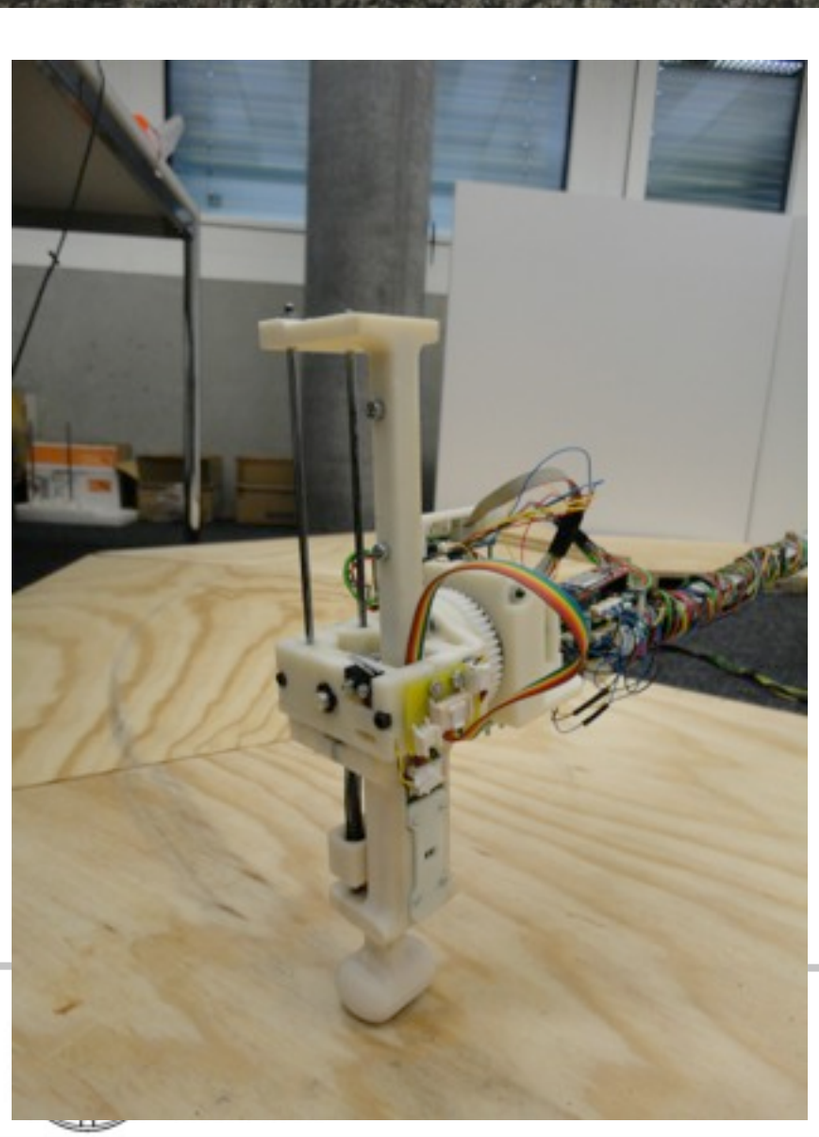


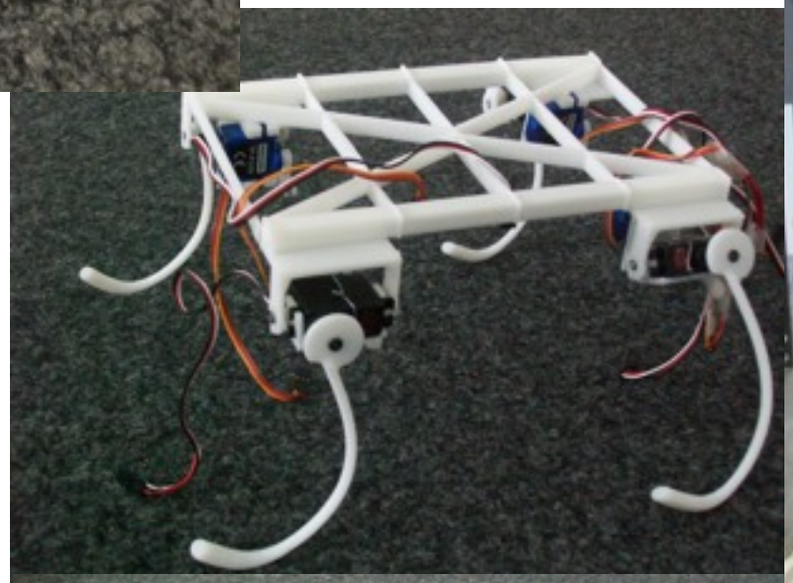


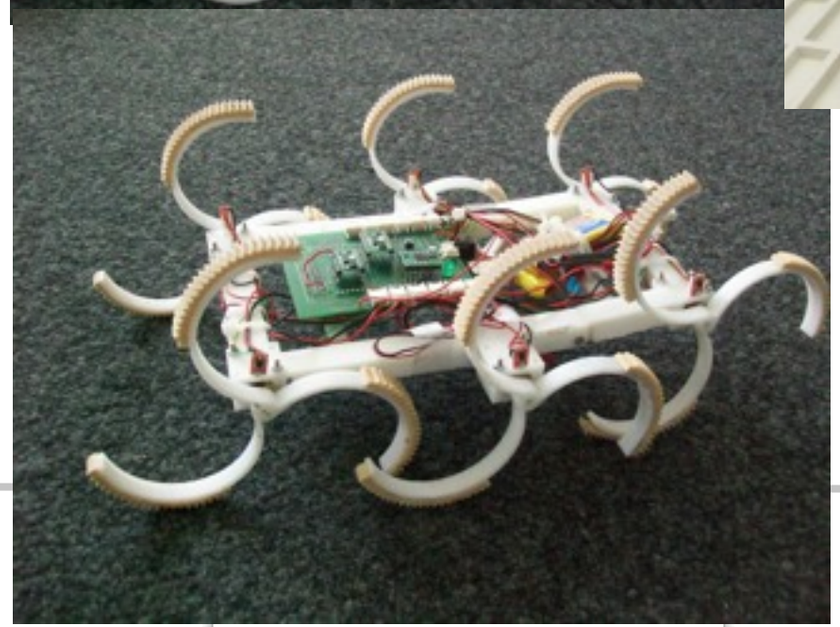


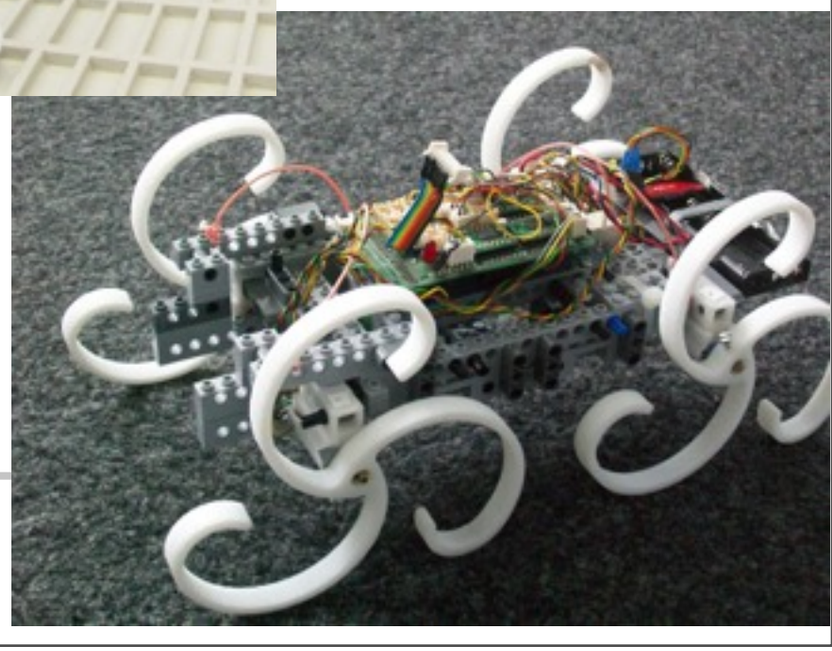




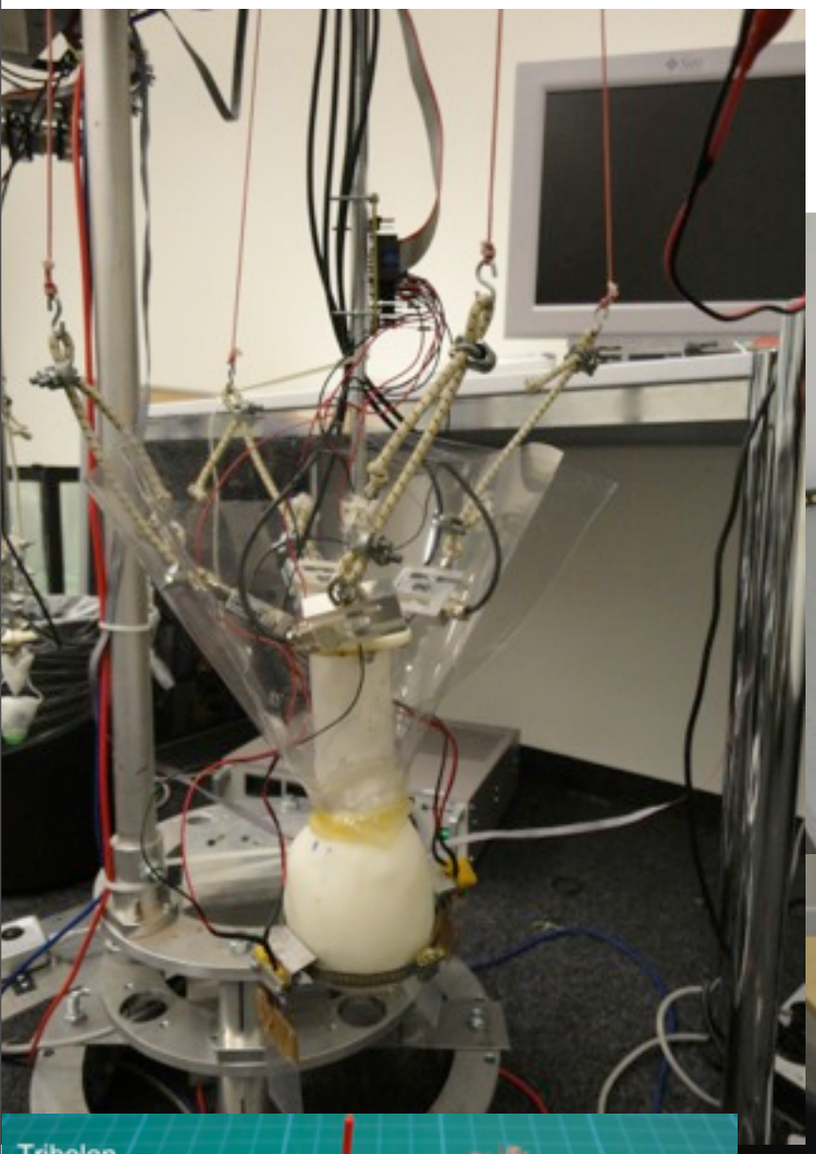


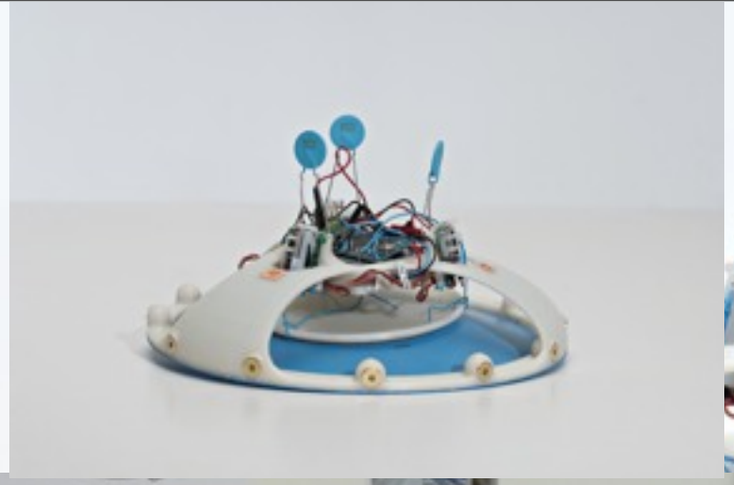


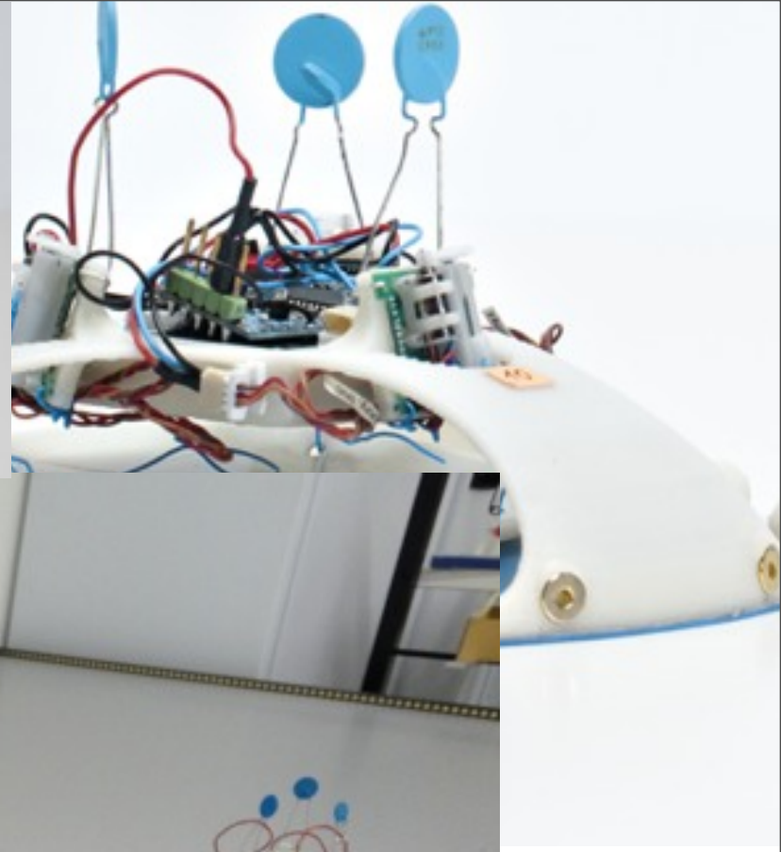


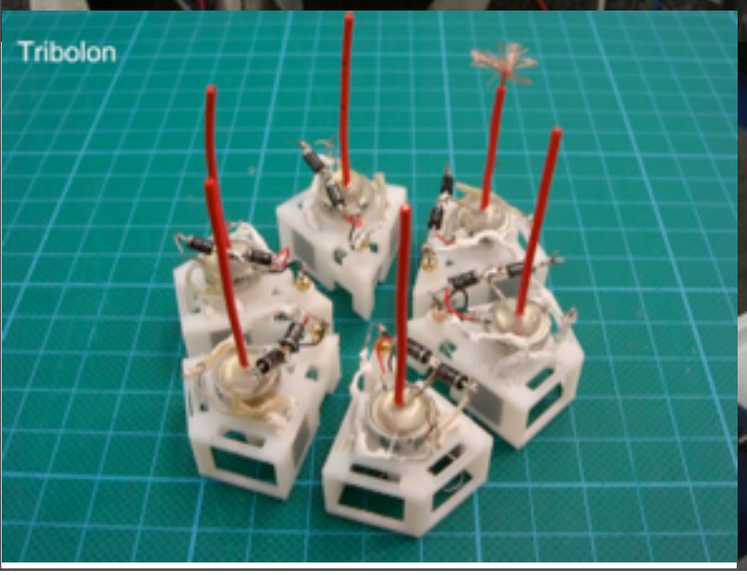


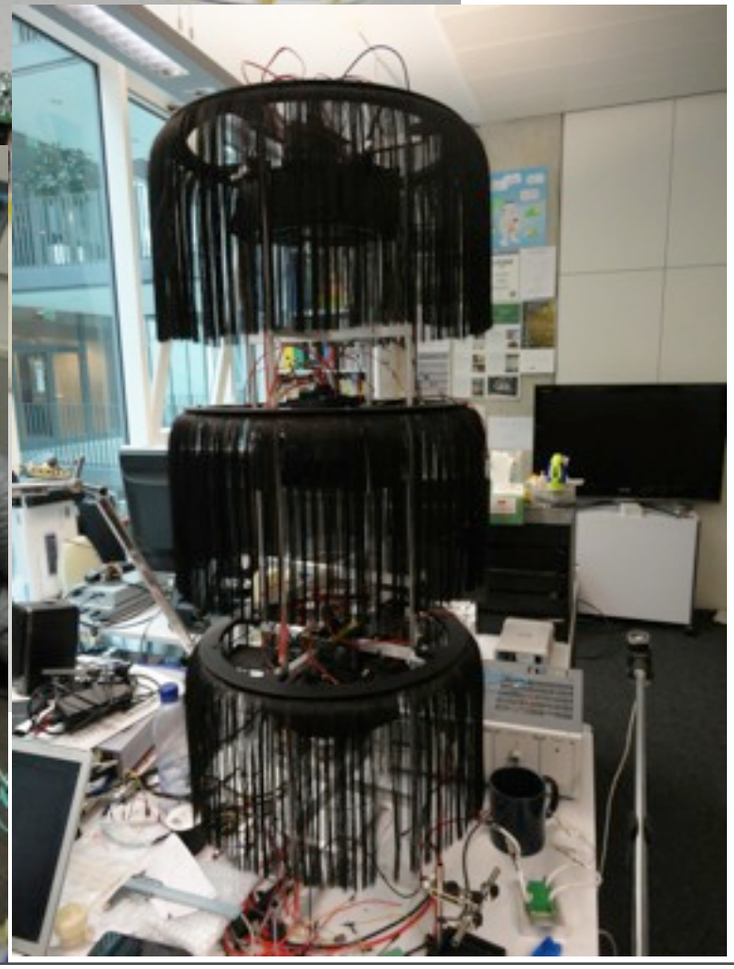
Zurich AI Lab robots

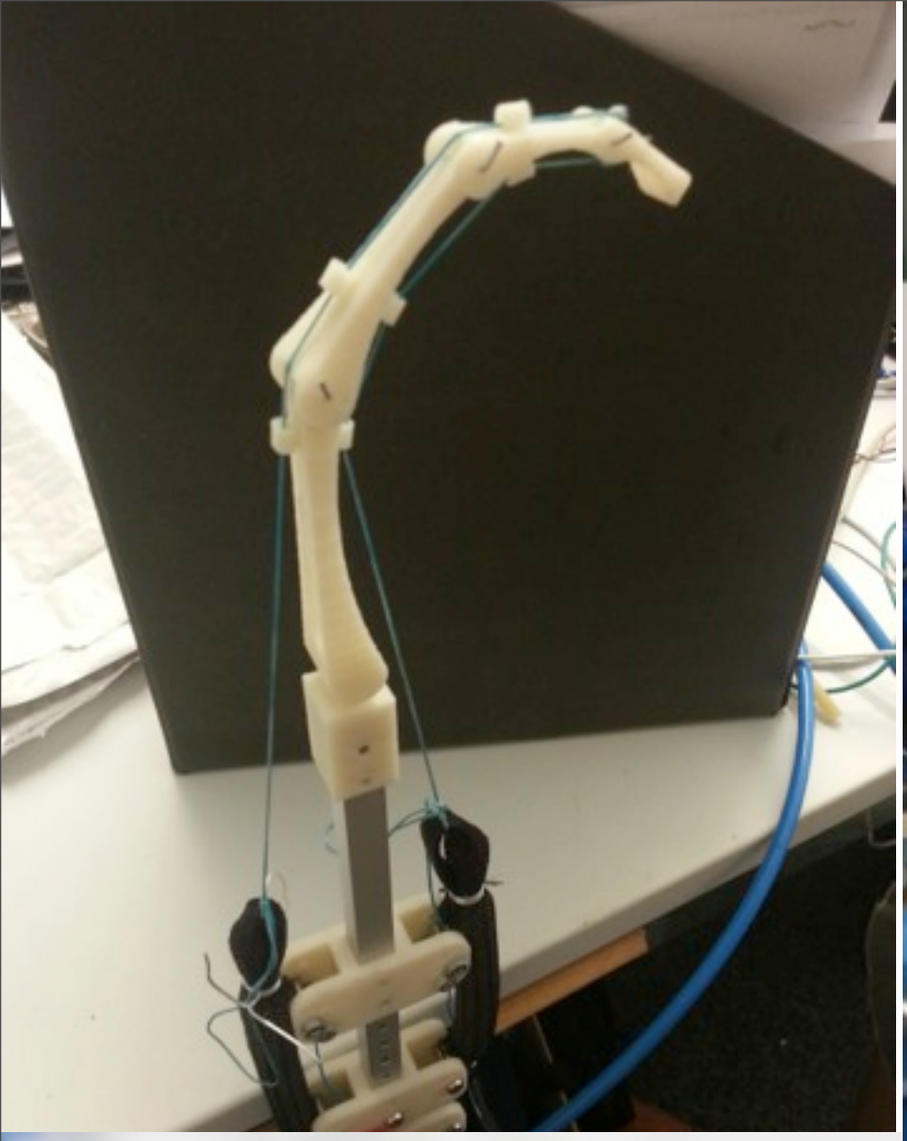


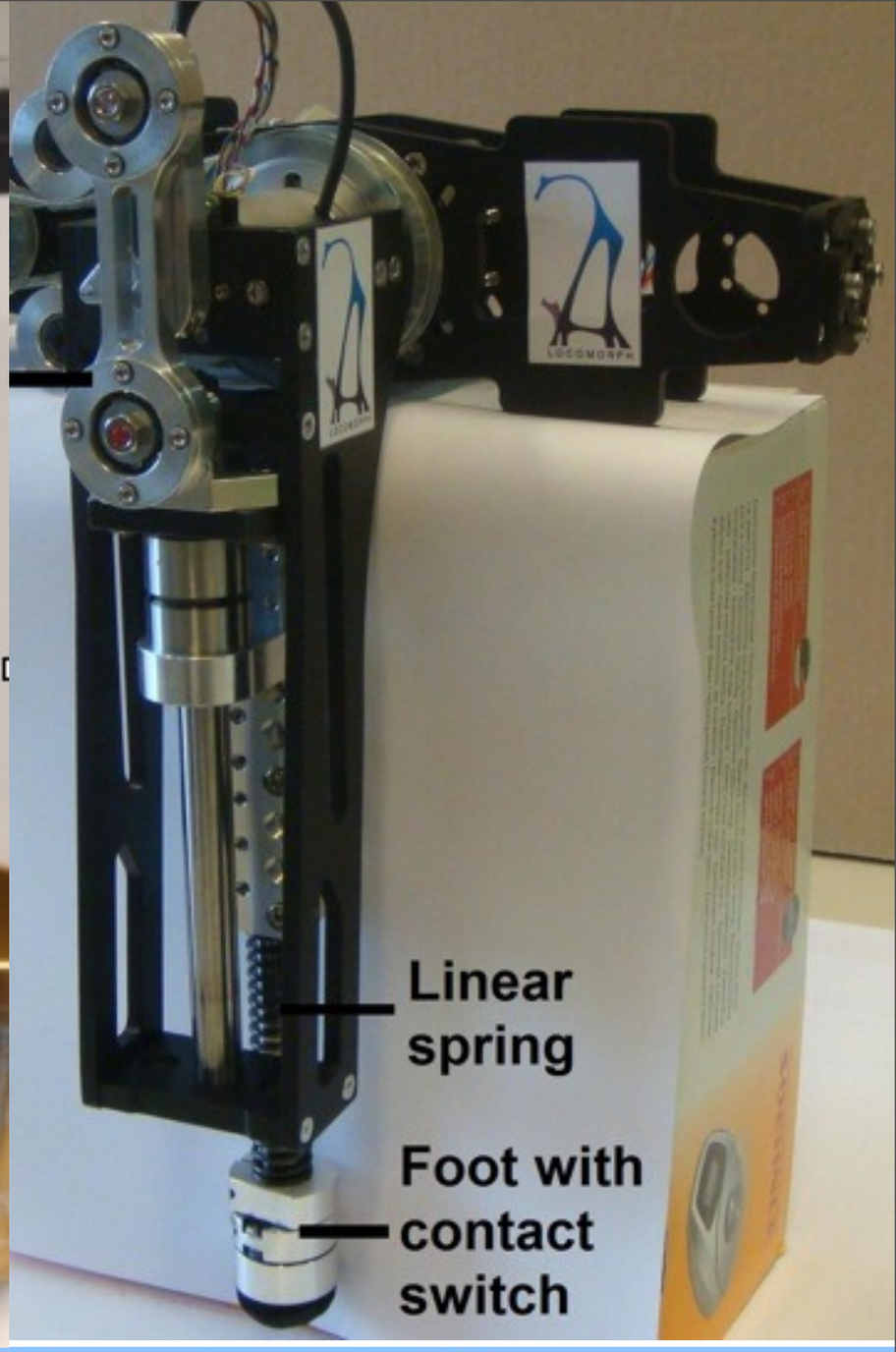


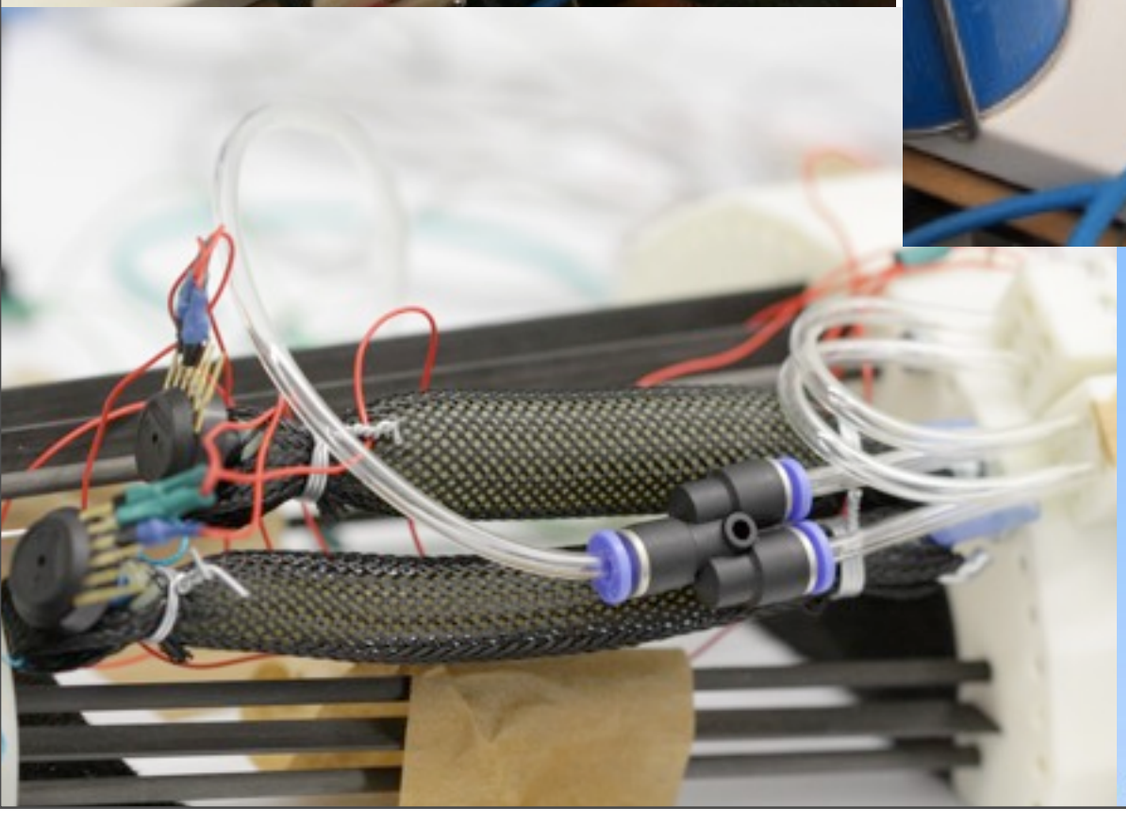


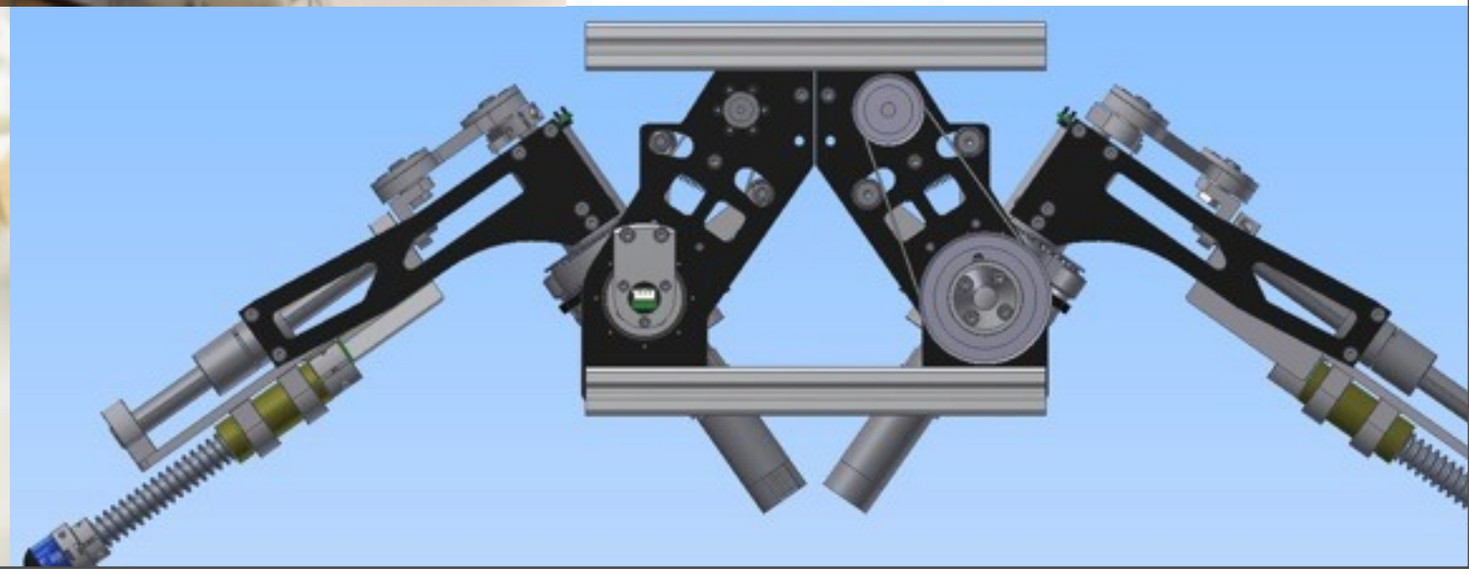




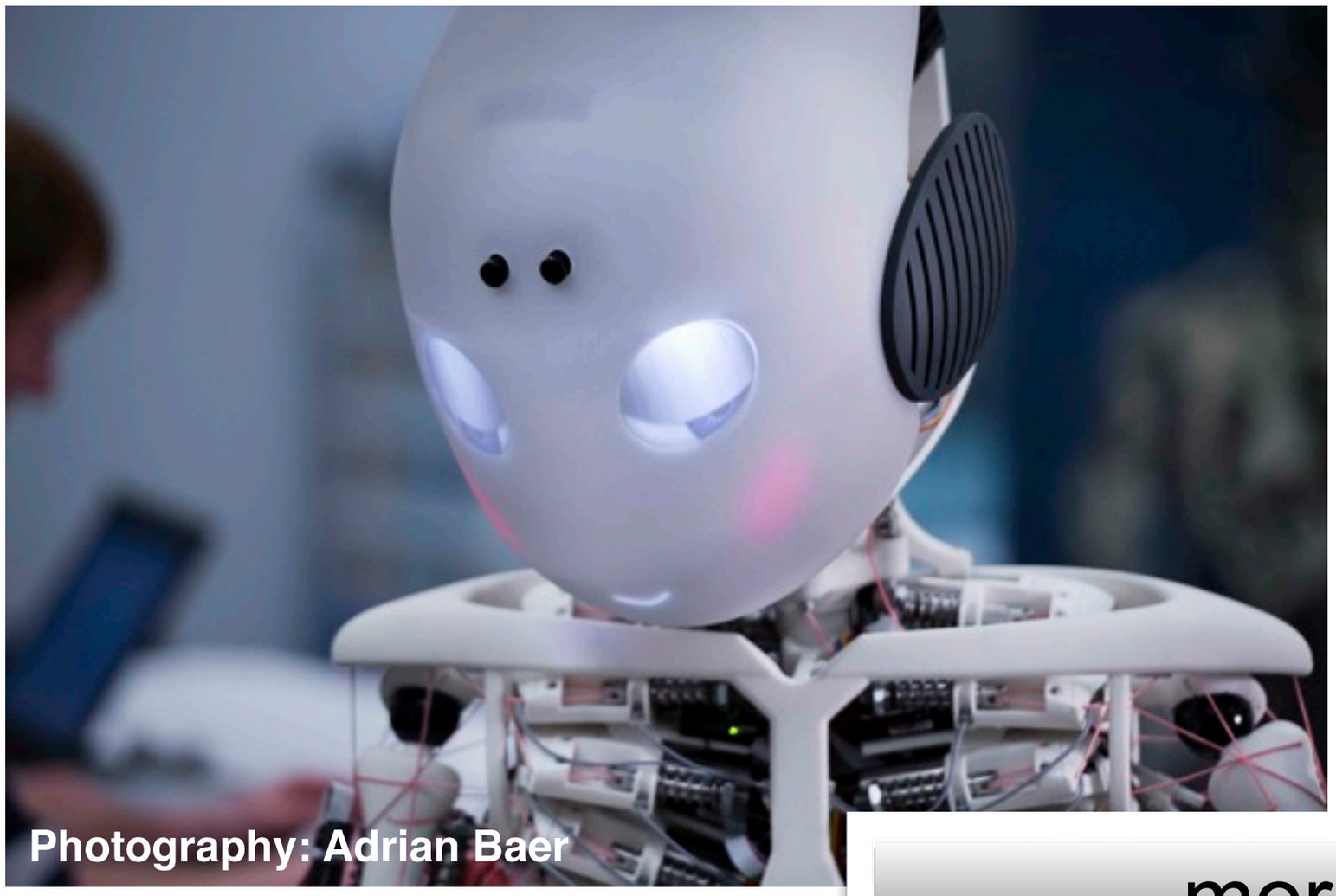



Linear spring
Foot with contact switch





Recent development: the “soft robot” Roboy



Photography: Adrian Baer

more later

“Soft Robotics”

Hypothesis: **The next generation of robots will be of the “soft” kind. Advances in “soft technology” will lead to a quantum leap in intelligent robotics.**

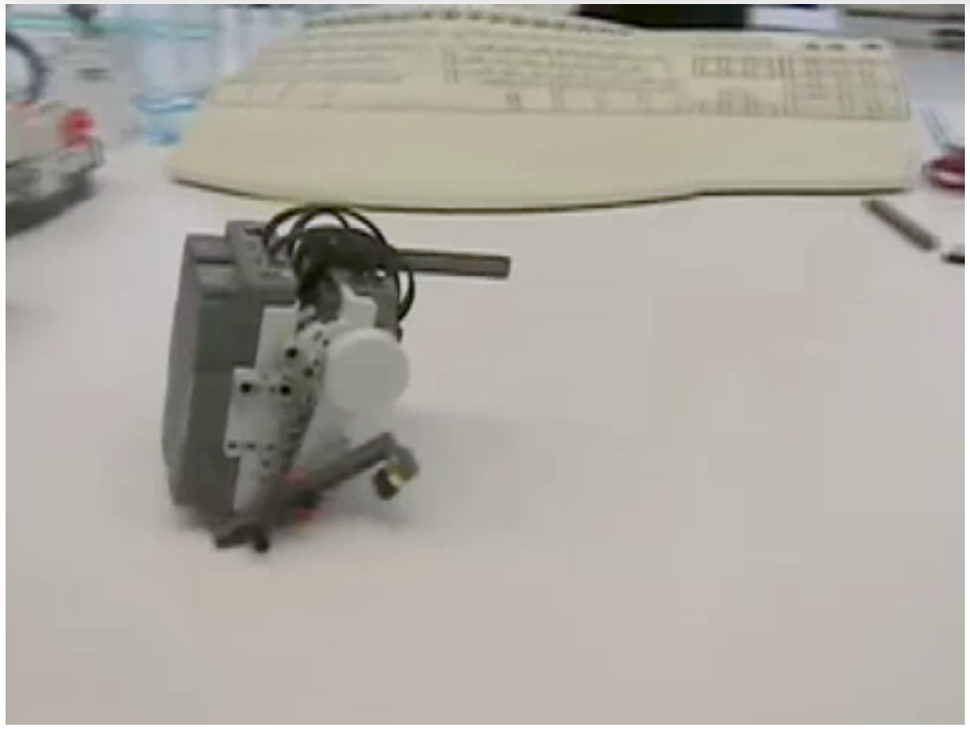
Theoretical underpinnings: **The key to “soft robotics” will be an understanding of embodiment.**

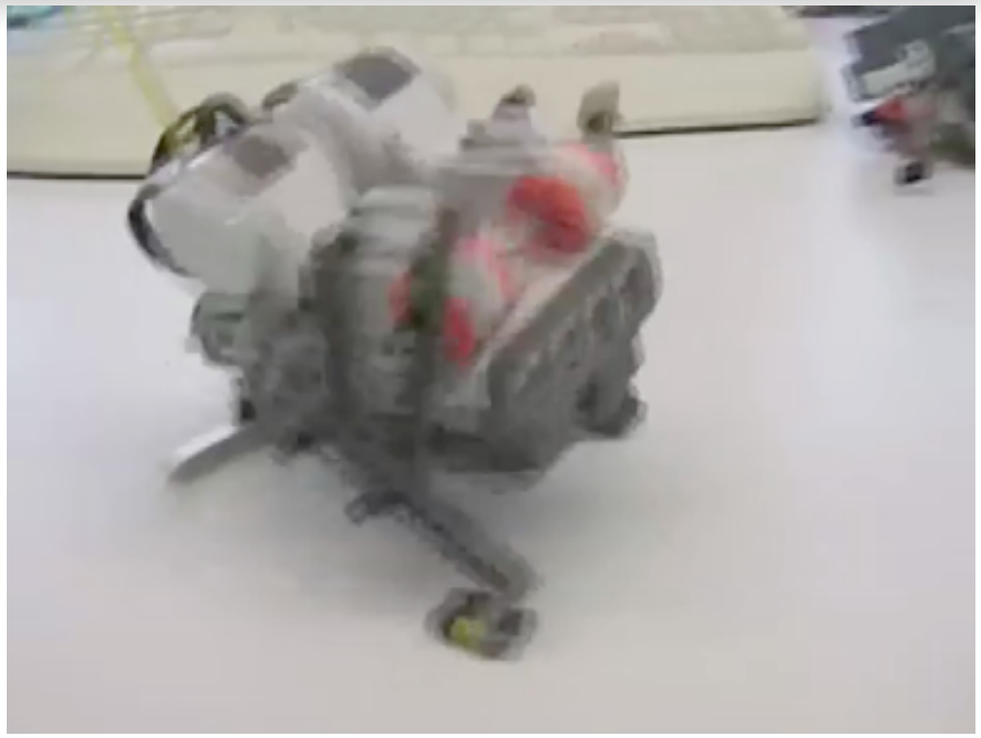
Contents

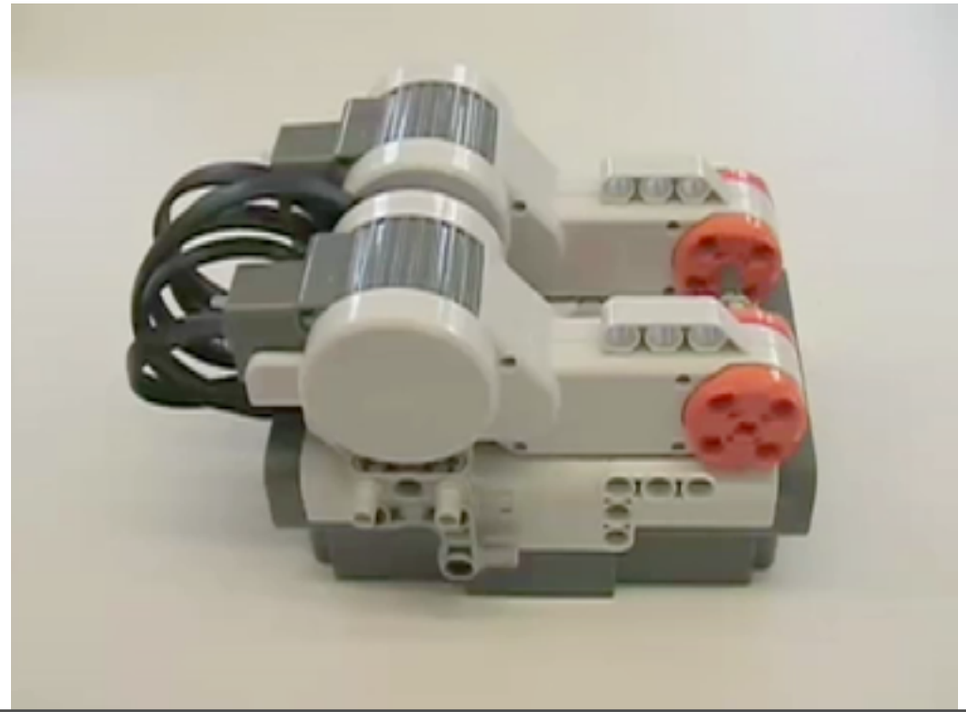
- introduction and background
- **principles of embodied intelligence**
- **the “power of materials”**
- **guided self-organization**
- **the “Roboy” project**
- **summary and conclusions**

The spirit of embodiment

The spirit of embodiment







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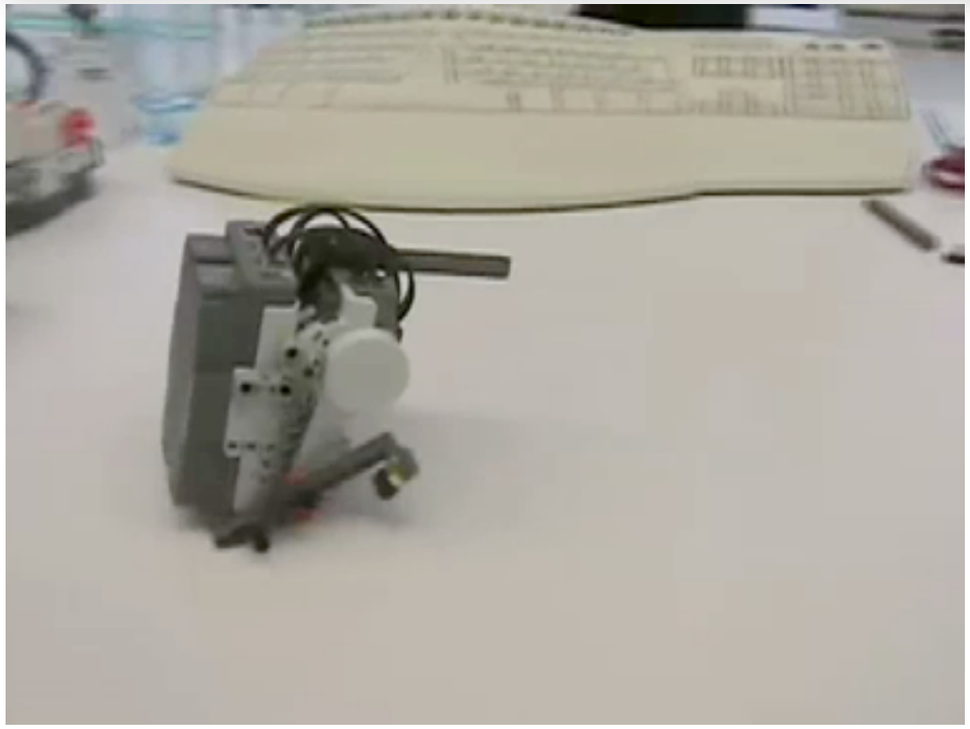

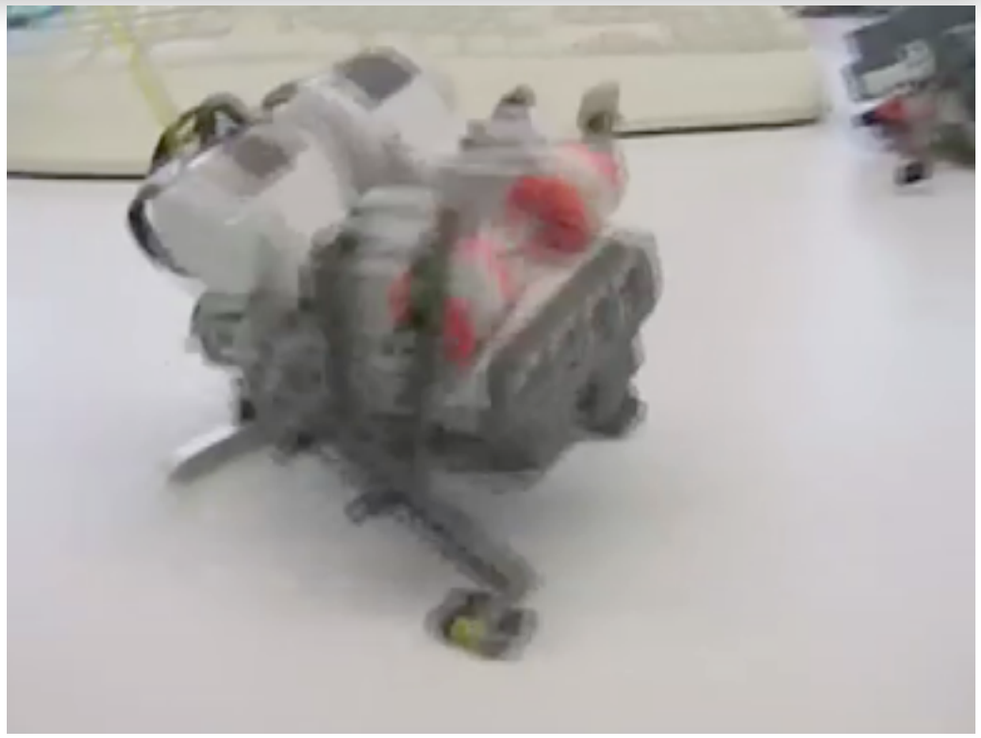

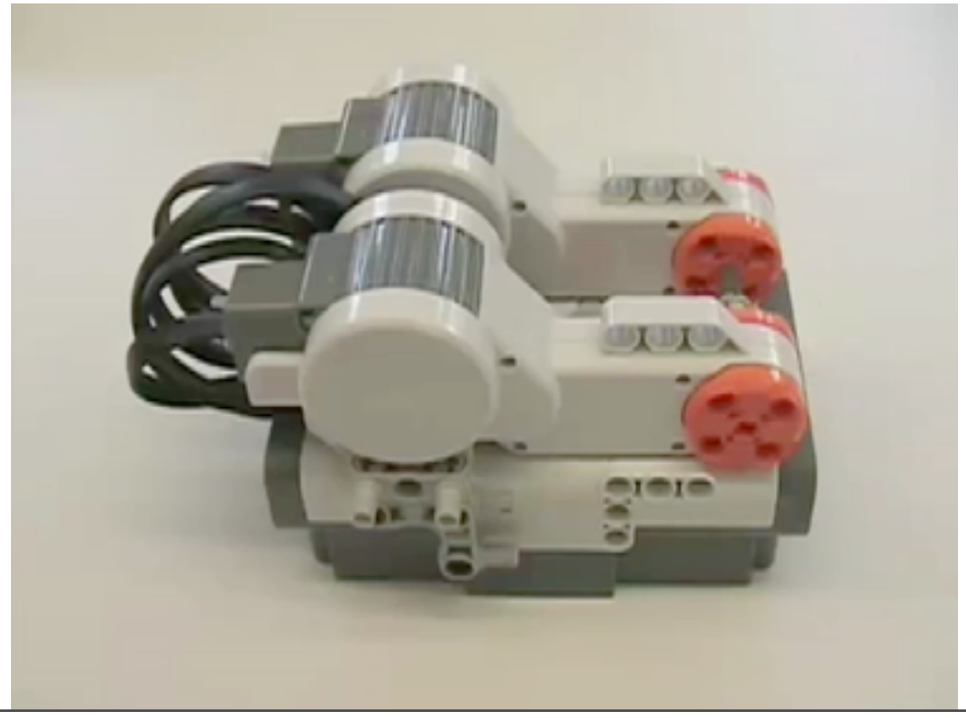

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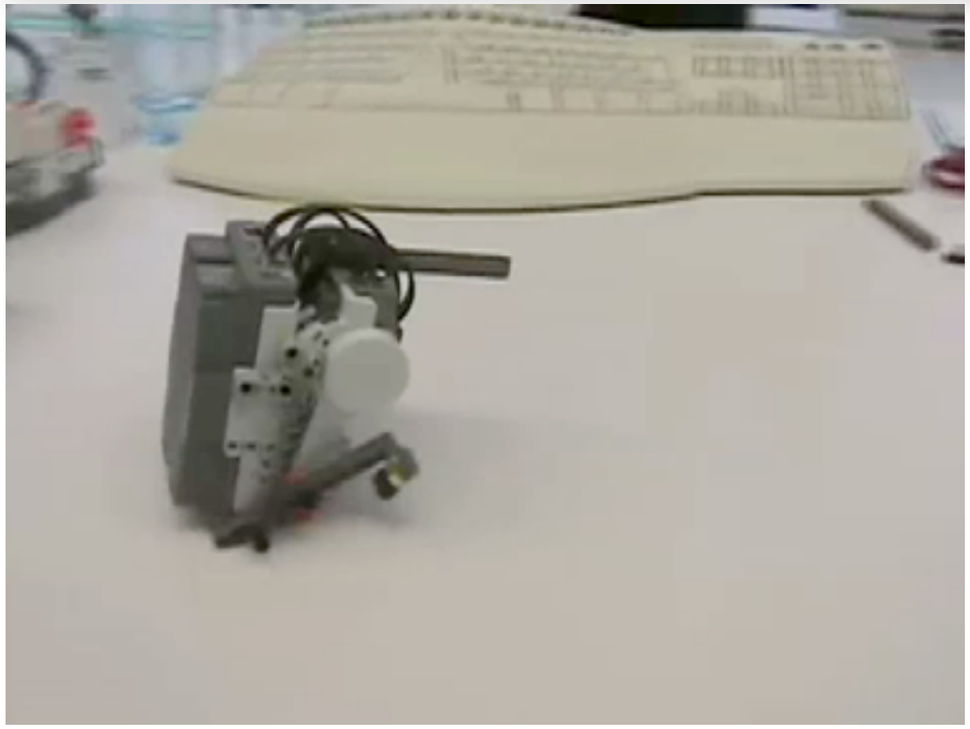

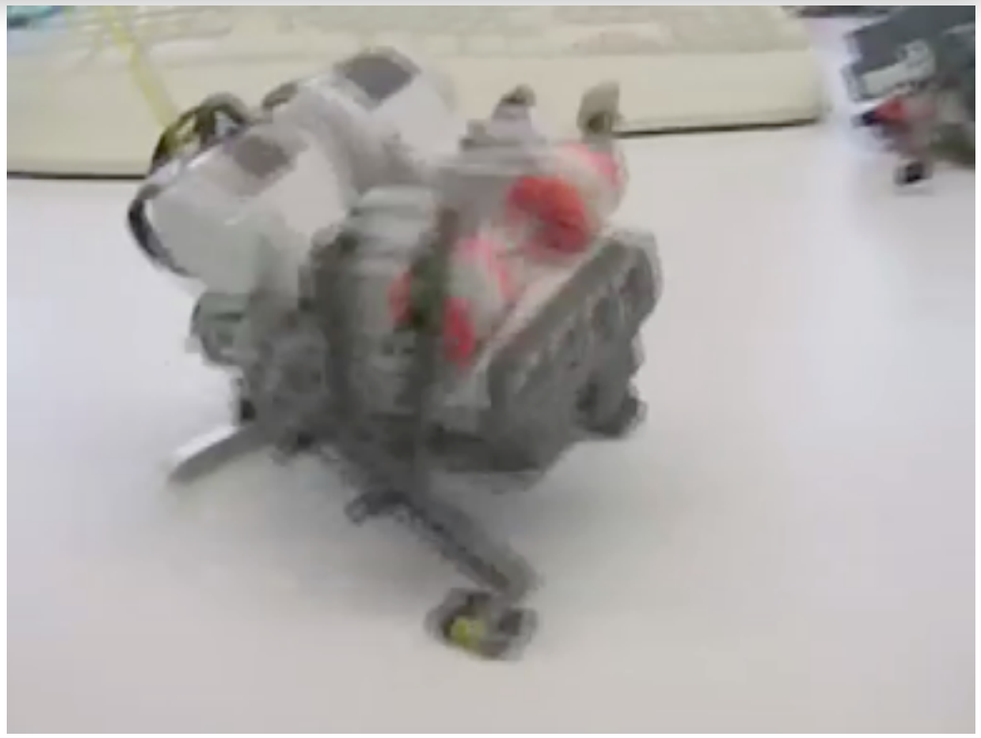

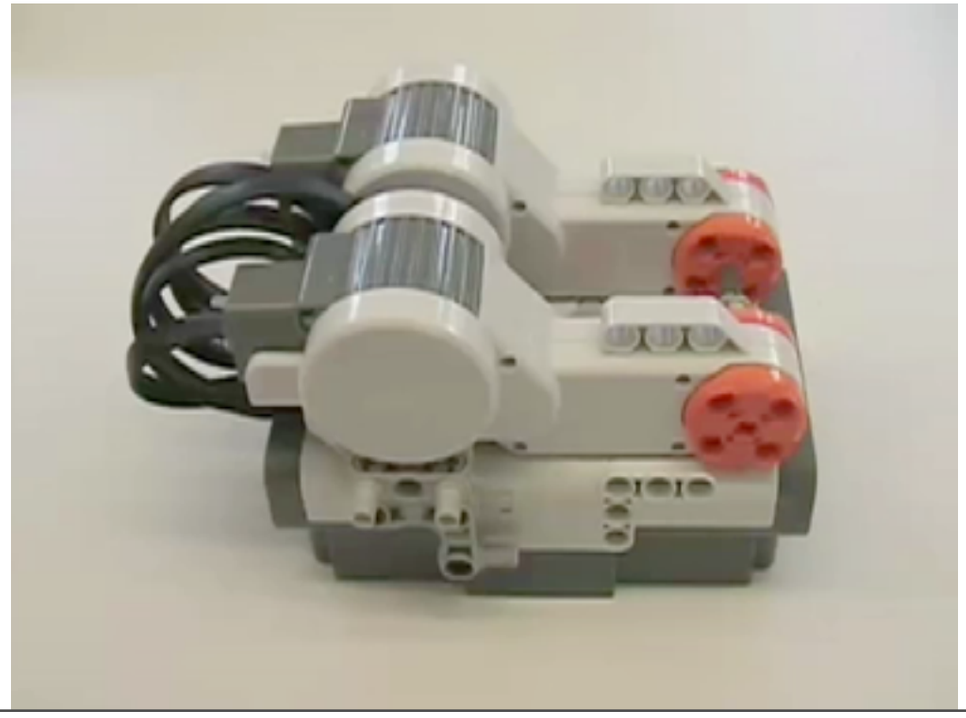

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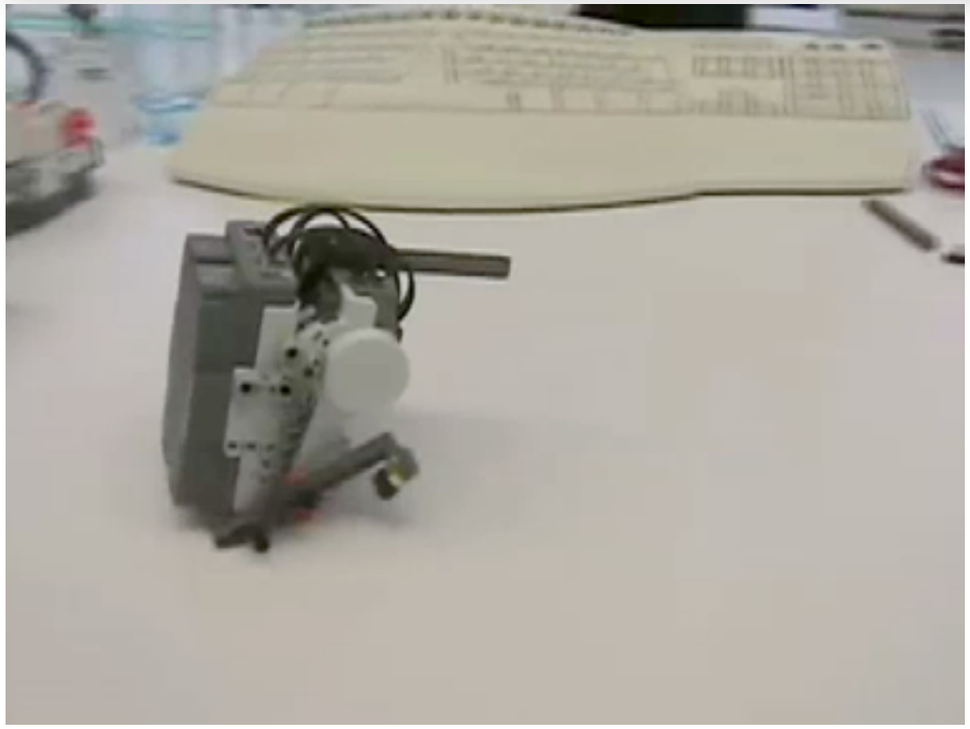
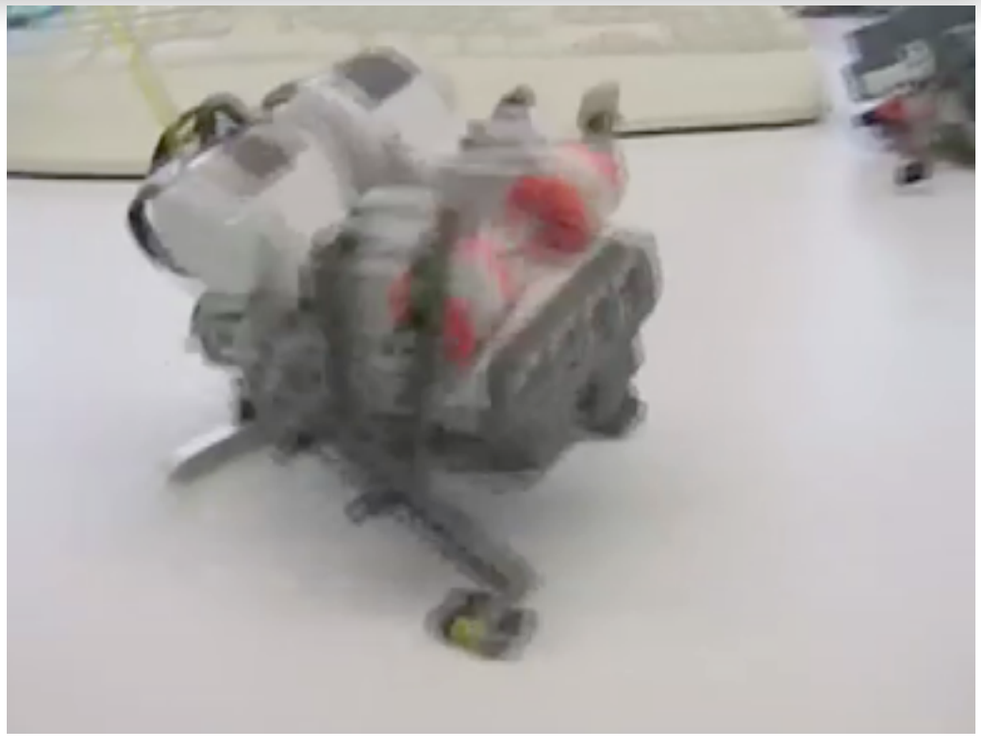
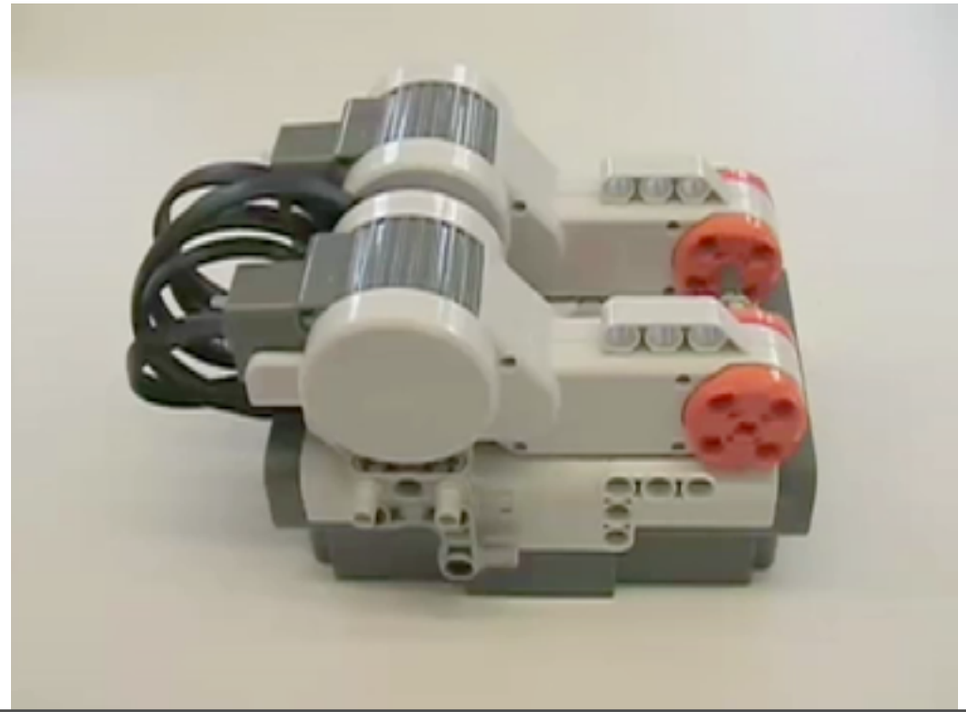
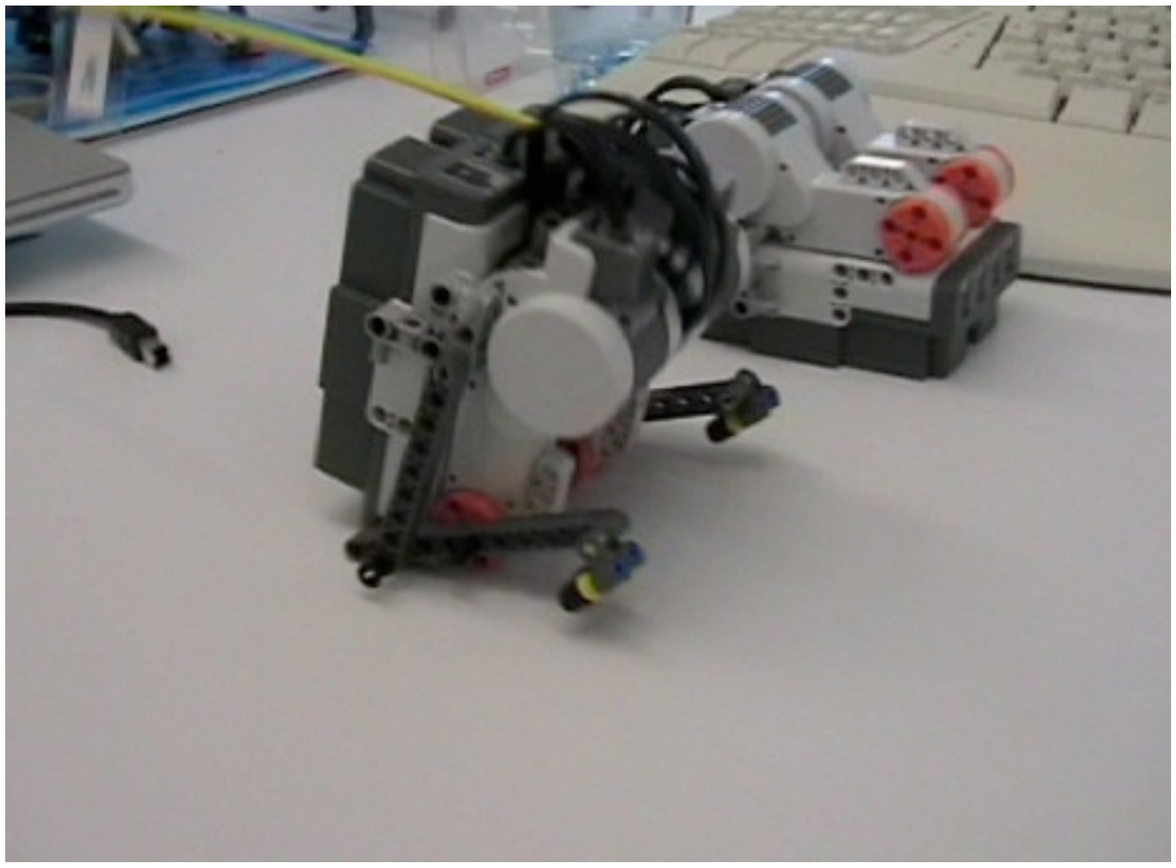




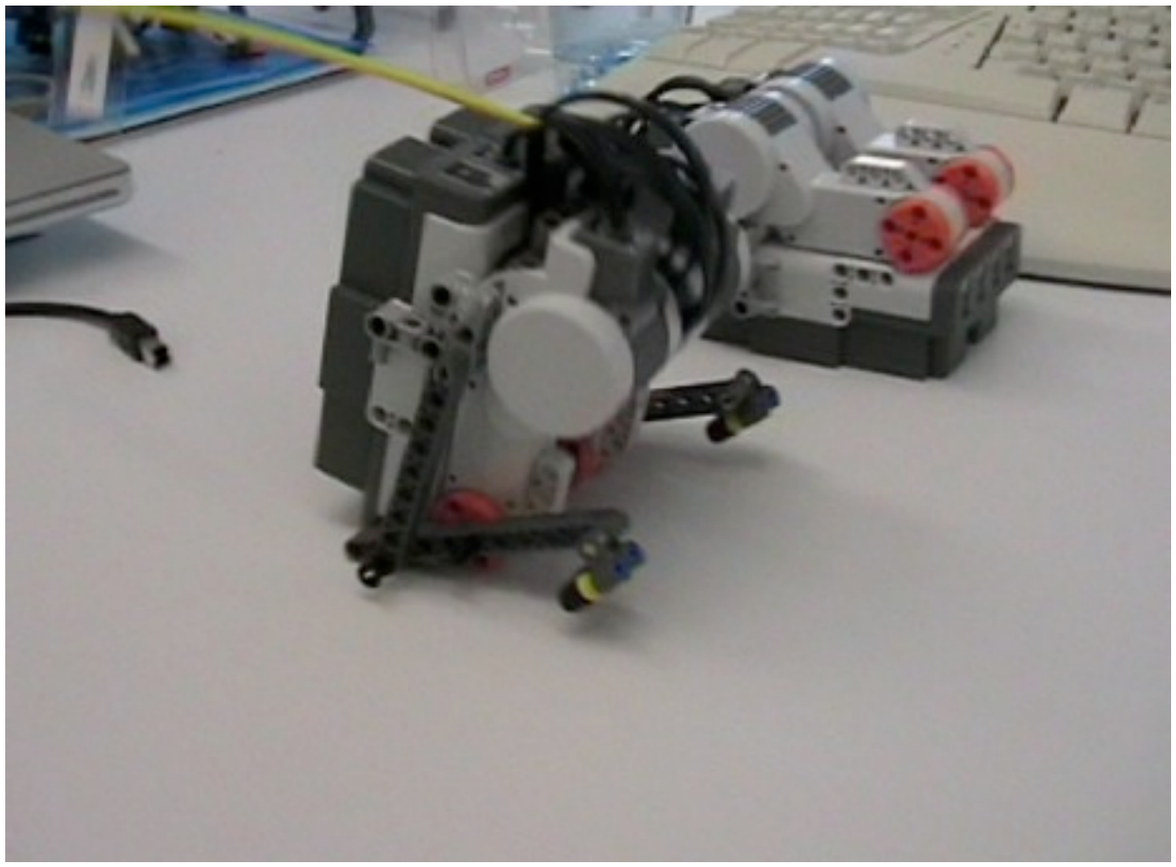


“Crazy Bird” — Morphology, Control



loosely hanging feet
rubber/plastic

“Crazy Bird” — Morphology, Control



loosely hanging feet
rubber/plastic

behavior of “Crazy Bird”:
cannot be inferred from program ⟶ emergence

Principles

- **physical embedding**
- **behavior emergent from morphology, materials, control, environment**
- **“design for emergence”**

Trends in AI/robotics

classical		*embodied*
centralized control	→	**interplay of brain, body, and environment**
top-down control	→	guided self-organization
algorithm	→	dynamical system
abstract symbol processing	→	sensory-motor coordination
top-down design	→	**design for emergence**
fixed morphology	→	morpho-functional machines

Artificial vs. real worlds

industrial environment

real-world environment

- high predictability
- programmability

industrial robots (“hard”)

- low predictability
- coping with uncertainty

humans (“soft” to varying degrees)

industrial environment

- high predictability
- programmability

industrial robots (“hard”)

real-world environment

- low predictability
- coping with uncertainty

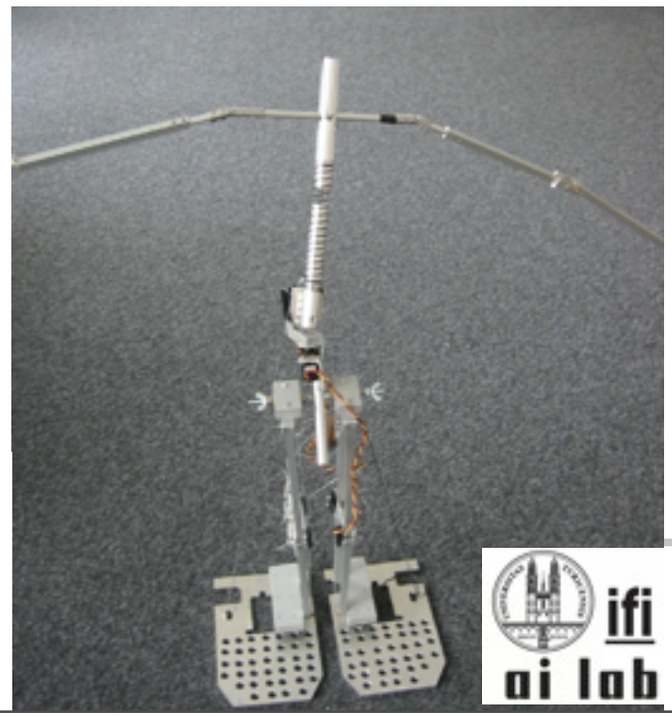
humans (“soft” to varying degrees)

humans: 85% “soft”

By comparison: The “Passive Dynamic Walker”

the “brainless” robot:
walking without control

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



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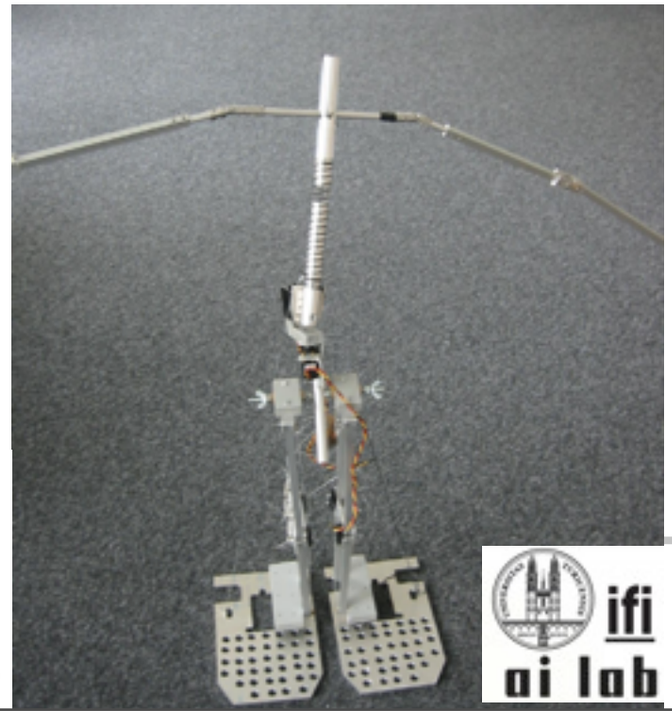

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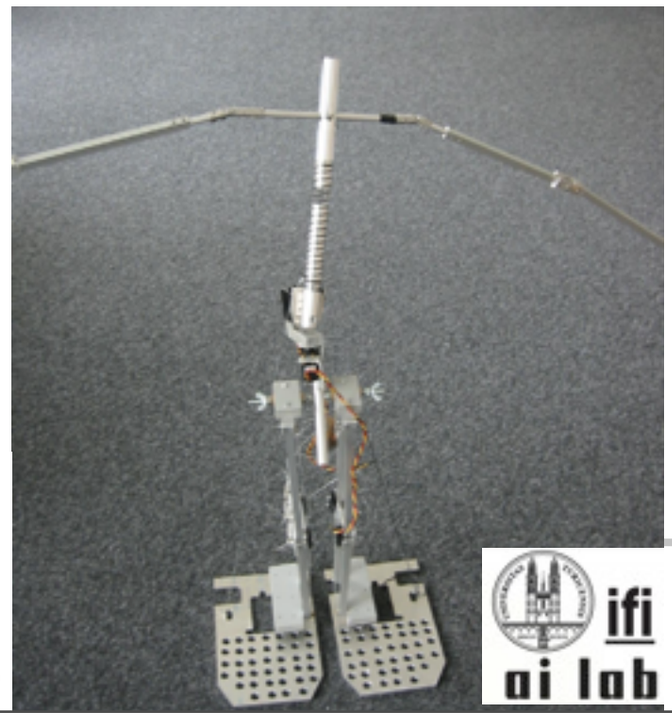

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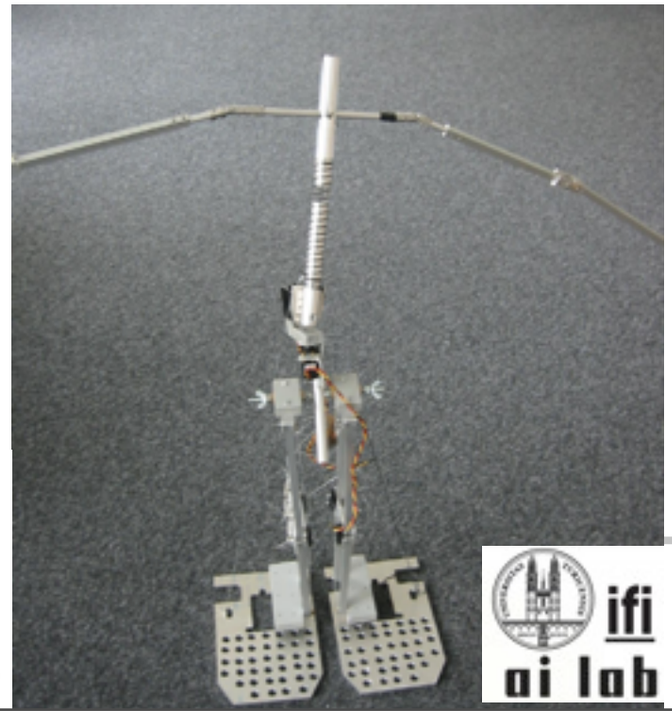

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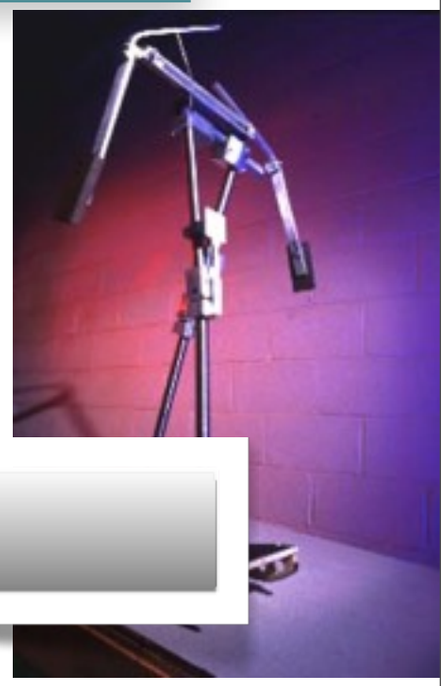
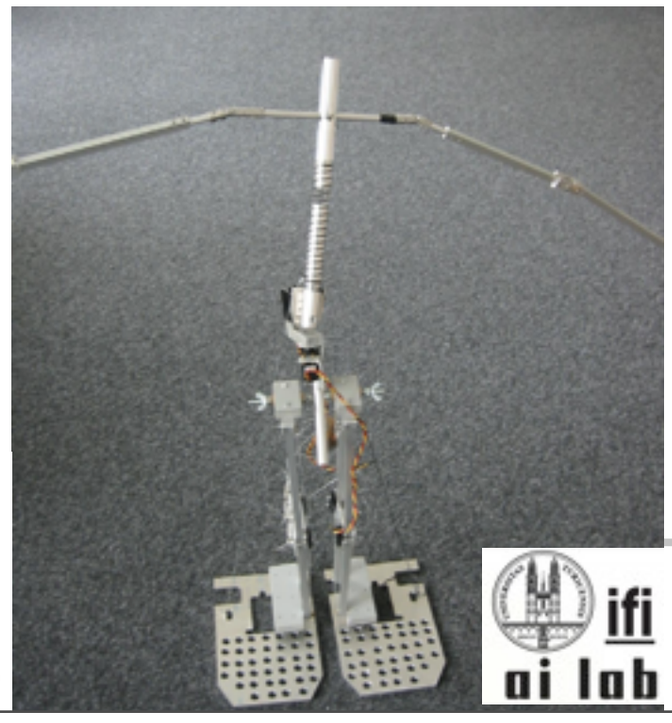


self-stabilization



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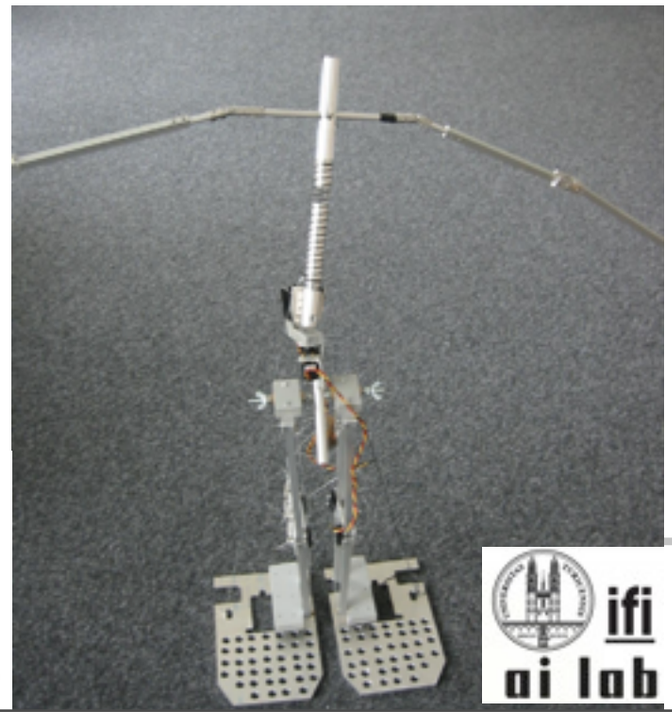

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joints: self-organize into proper trajectories

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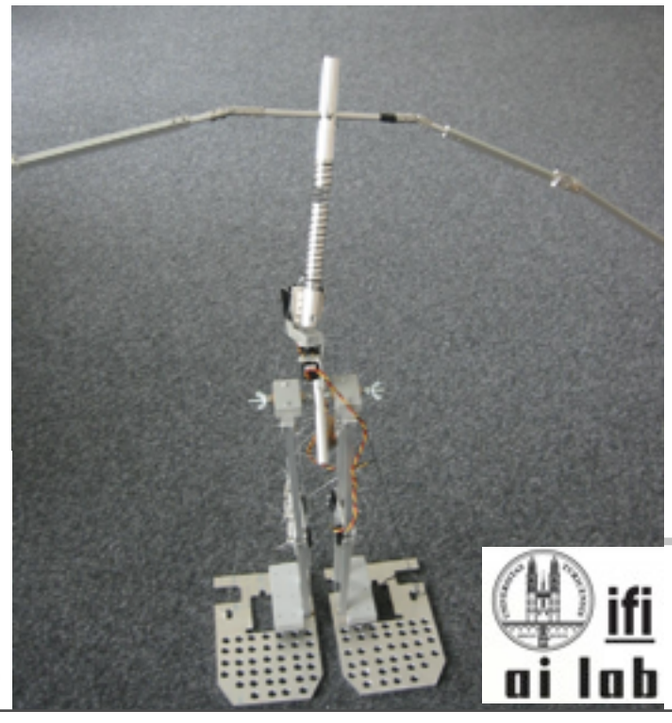

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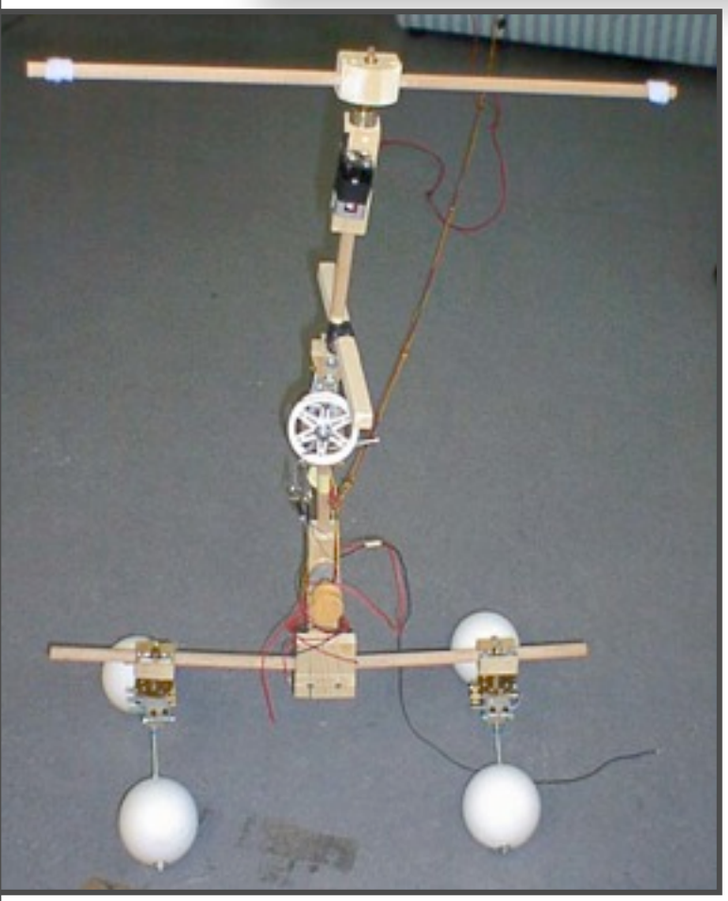
Short question

memory for walking?

Principles

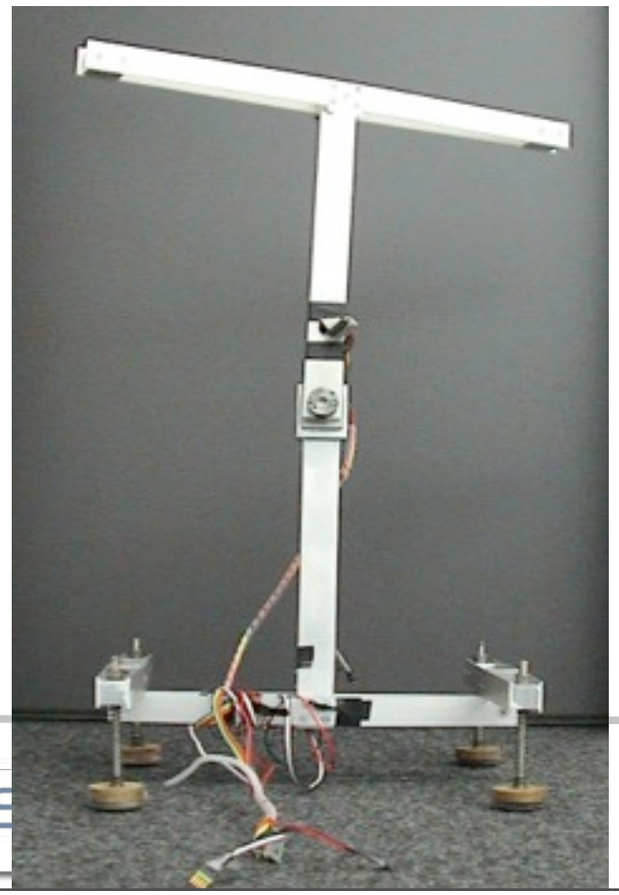
- exploitation of self-organization
- functionality distributed throughout entire system
- humans: guided self-organization (stiffness of muscles)
- task-distribution between brain (control), body (morphology, materials), and environment
- control and controlled no longer clearly separated (especially in case of soft systems)
- morphological computation

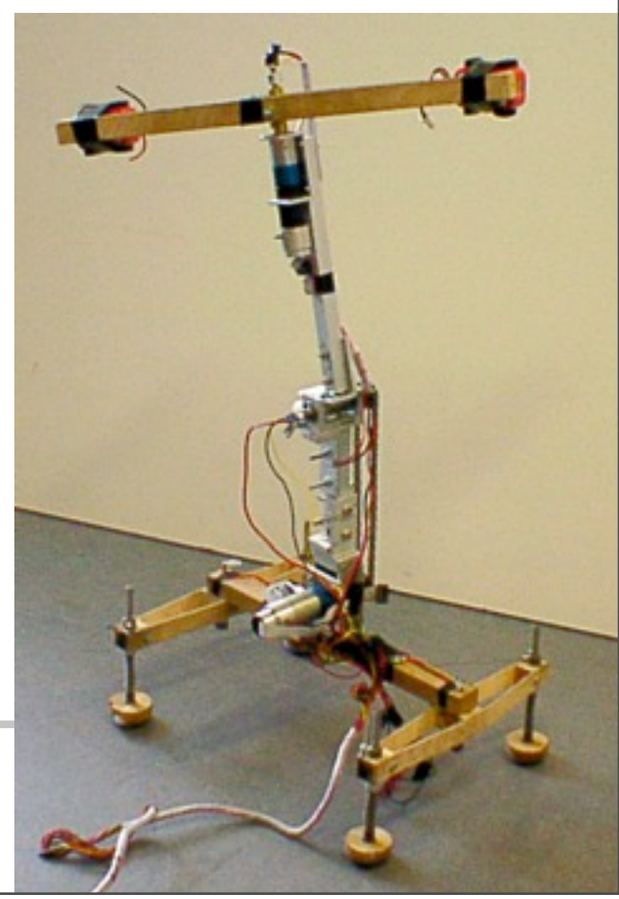
“Stumpy”: task distribution



almost brainless: **2 actuated joints**
springy materials
surface properties of feet

Design and construction: **Raja Dravid, Chandana Paul, Fumiya Iida**





self-stabilization

The dancing robot “Stumpy”

Collaboration with Louis-Philippe Demers,
Nanyang Technological University, Singapore

Movie:
Max Lungarella
Raja Dravid
Dynamic Devices and AILab, Zurich

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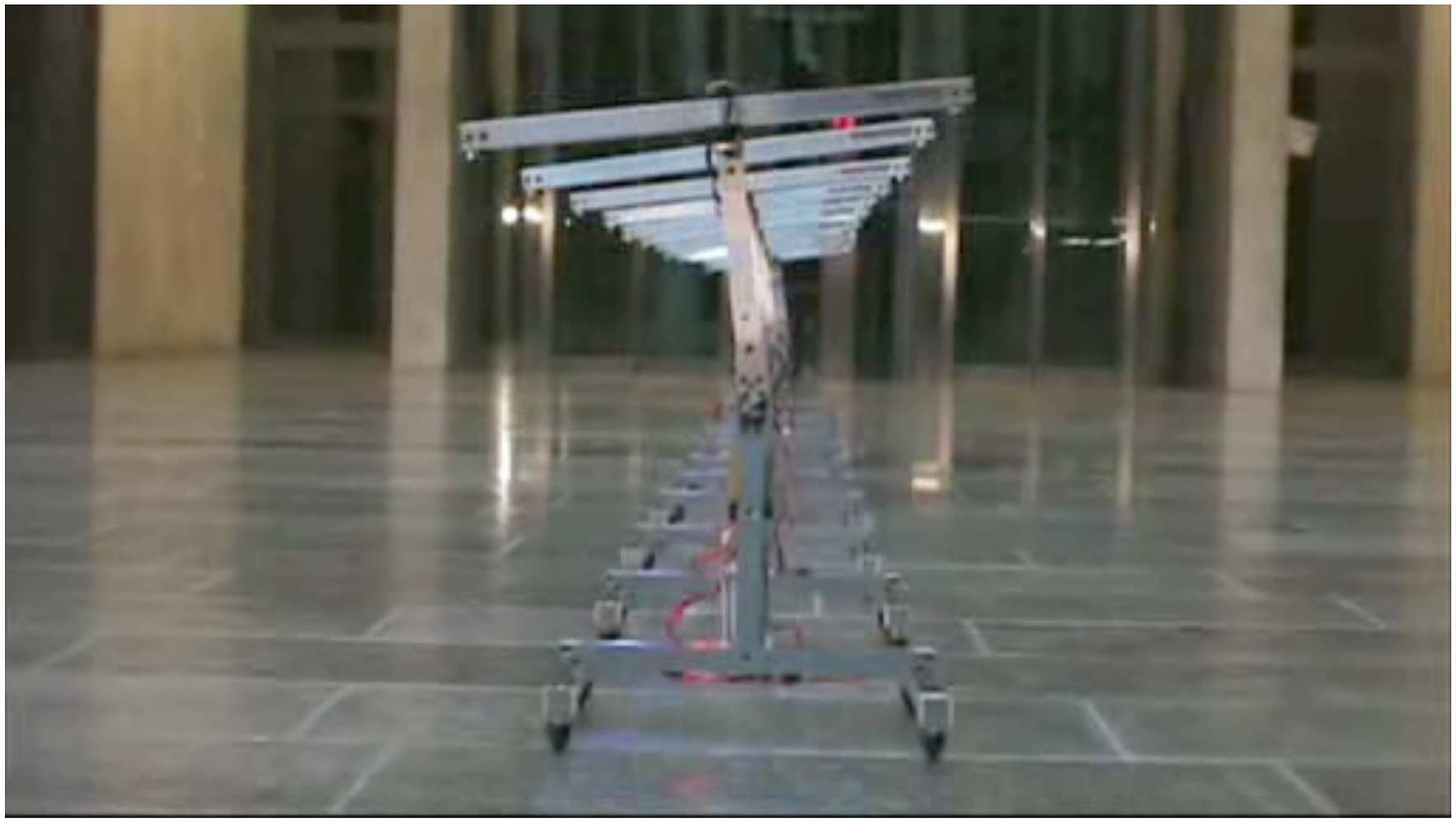

Movie:
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Raja Dravid
Dynamic Devices and AILab, Zurich

The “robot frog” driven by pneumatic actuators (UTokyo)

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

pneumatic actuators:
compliant materials

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Contents

- introduction and background
- principles of embodied intelligence
- **the “power of materials”**
- **guided self-organization**
- **the “Roboy” project**
- **summary and conclusions**

“Power of materials”

- soft robotics: much work on - fabrication technologies
- our goal: embed materials into intelligent agents
- must understand interaction between control and materials

The power of materials: The robot fish “Wanda”

design and construction:
Marc Ziegler, AI Lab, UZH

materials

changeable stiffness

Note: **can reach any point in 3D space**

The power of materials: The robot fish “Wanda”

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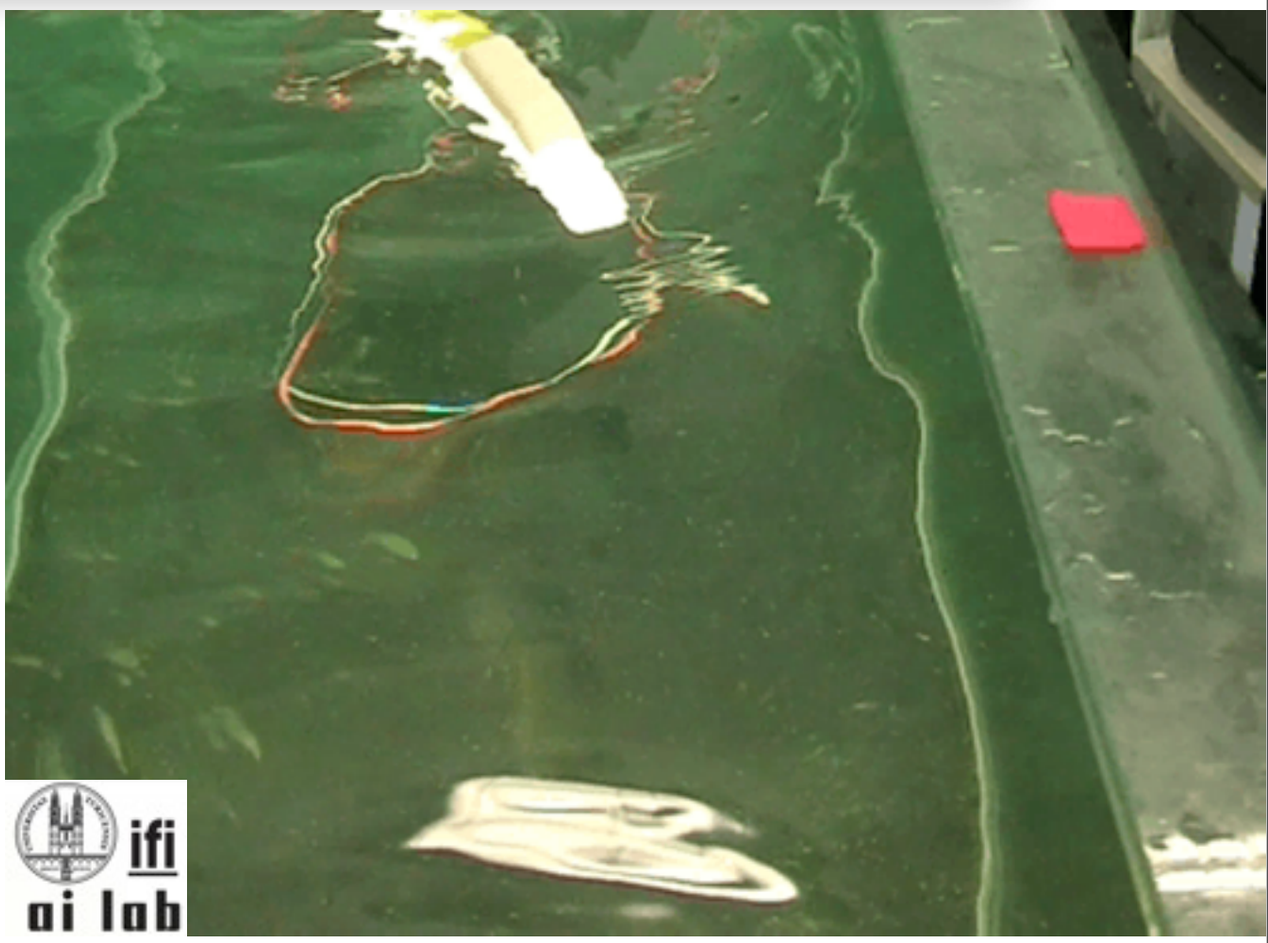

materials

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Daniela Rus's "soft fish"

design and construction:
Daniela Rus and Andrew Marchese
MIT CSAIL

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design and construction:
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MIT CSAIL

Daniela Rus's "soft fish"

design and construction:
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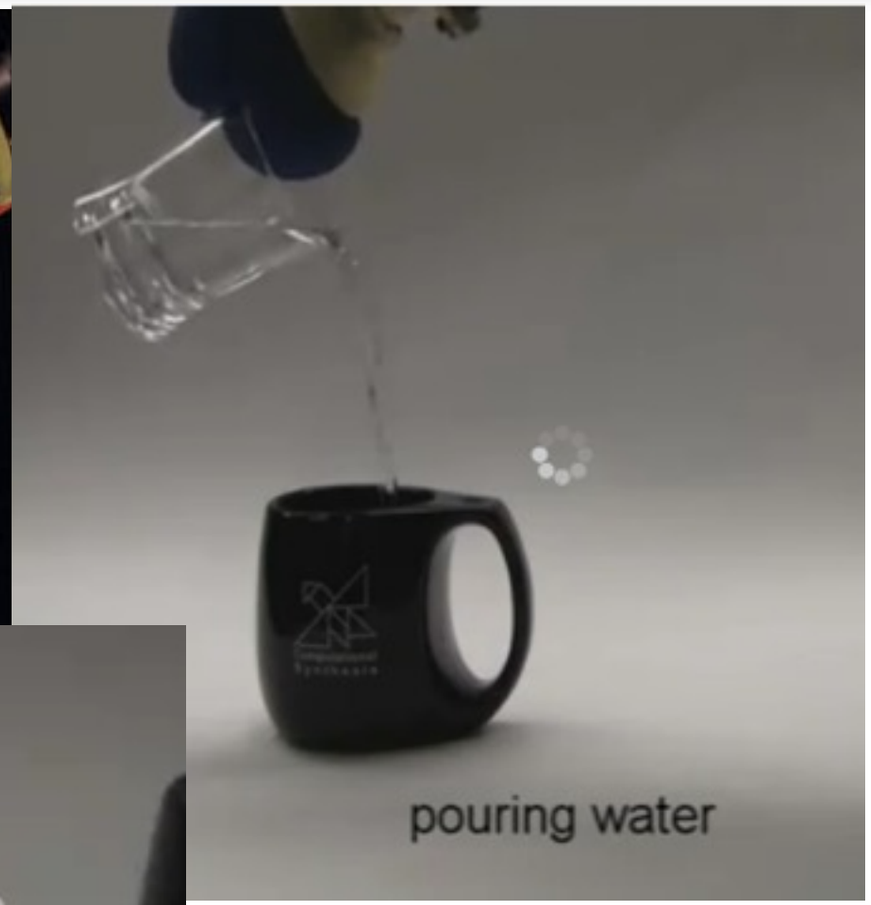
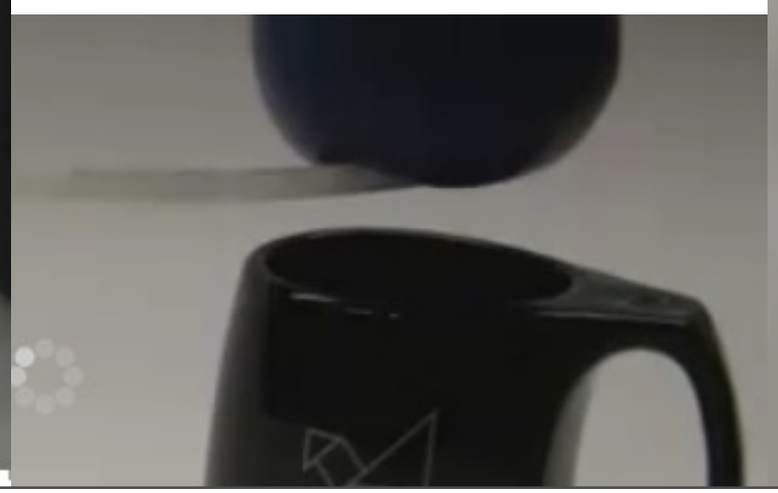
MIT CSAIL

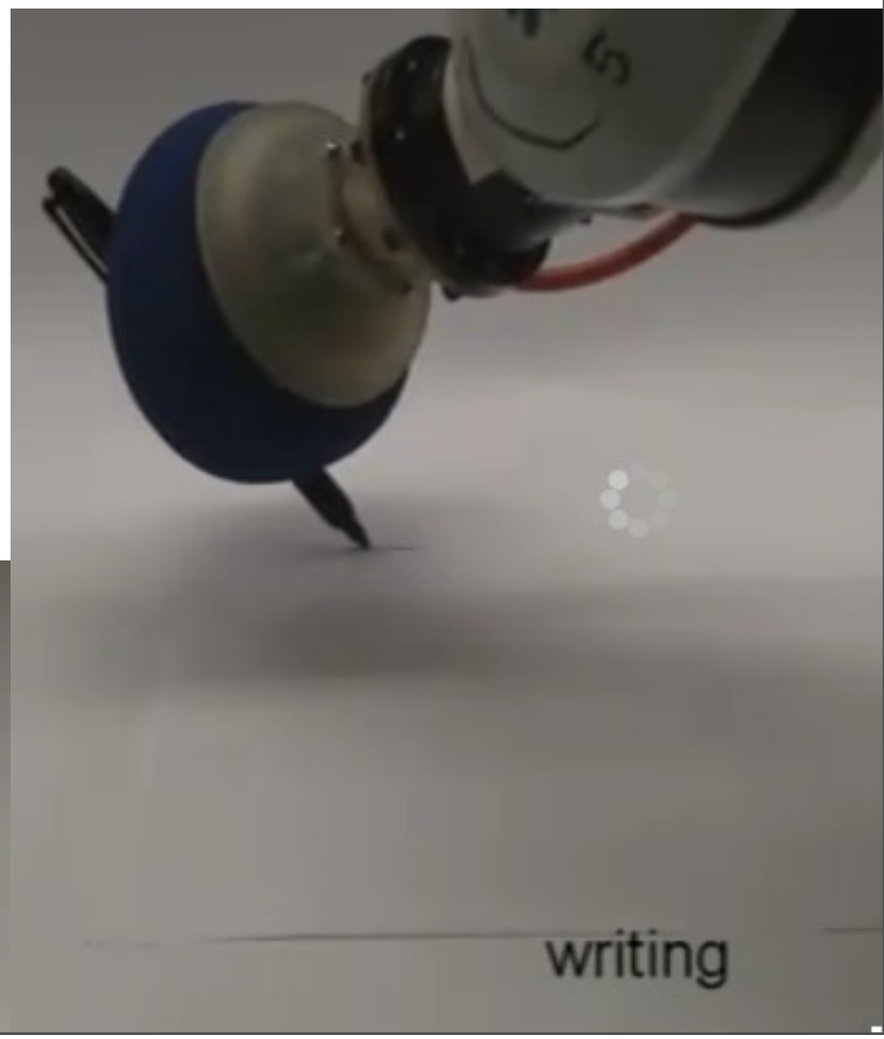
The Bionic Handling Assistant

- inspiration: elephant trunk
- pneumatic system (air chambers)
- high dexterity
- intrinsic compliance
- 3D printed

Jaeger/Lipson “coffee balloon gripper”

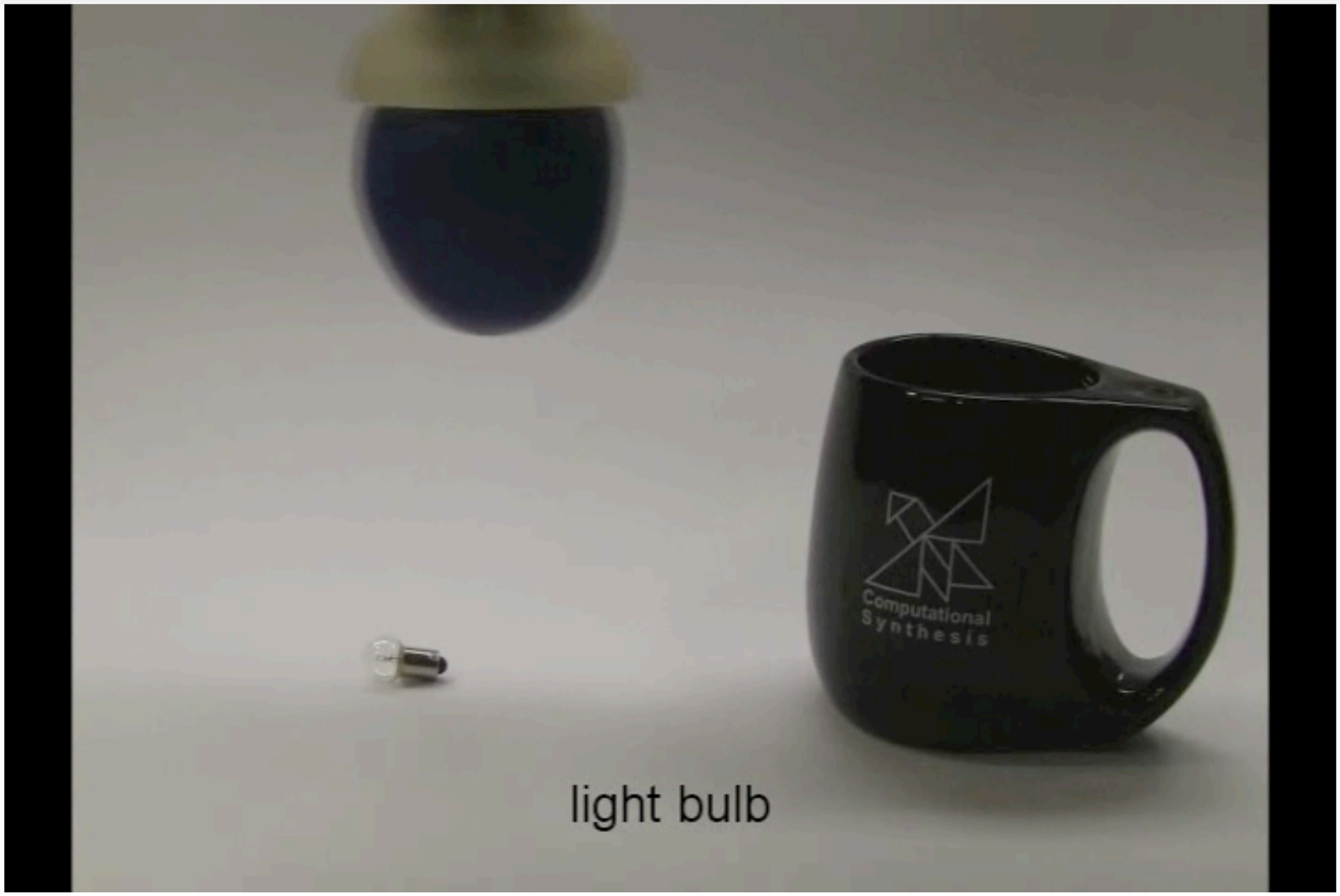






Jaeger/Lipson “coffee balloon gripper”

Jaeger/Lipson “coffee balloon gripper”



Orchestration of grasping

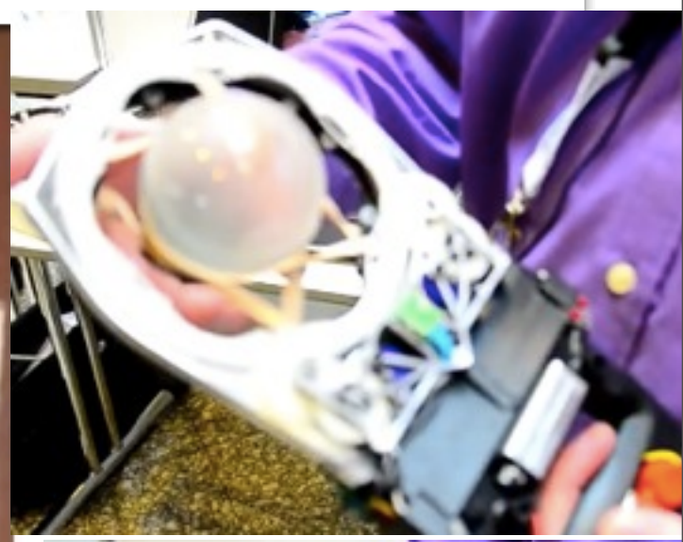
"holding a hard object"
exploiting morphology and materials for control

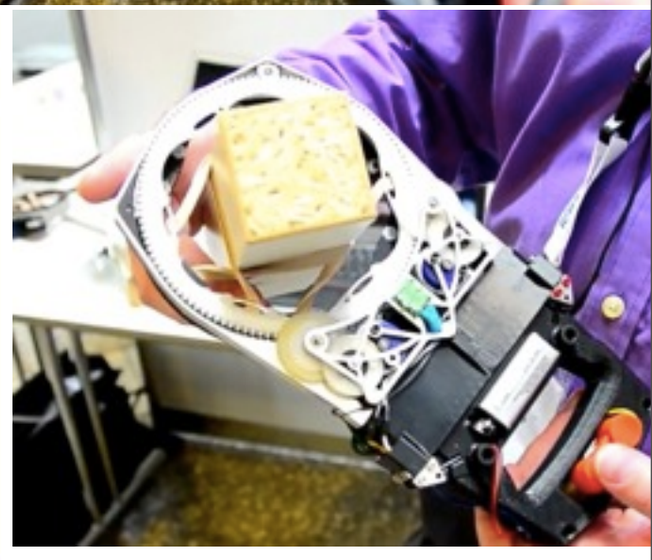
MIT Robots Can Assemble Your IKEA Furniture For You

By Evan Ackerman
Posted 8 May 2013 | 1:33 GMT

IEEE SPECTRUM

Gripper with deformable materials (rubber bands)



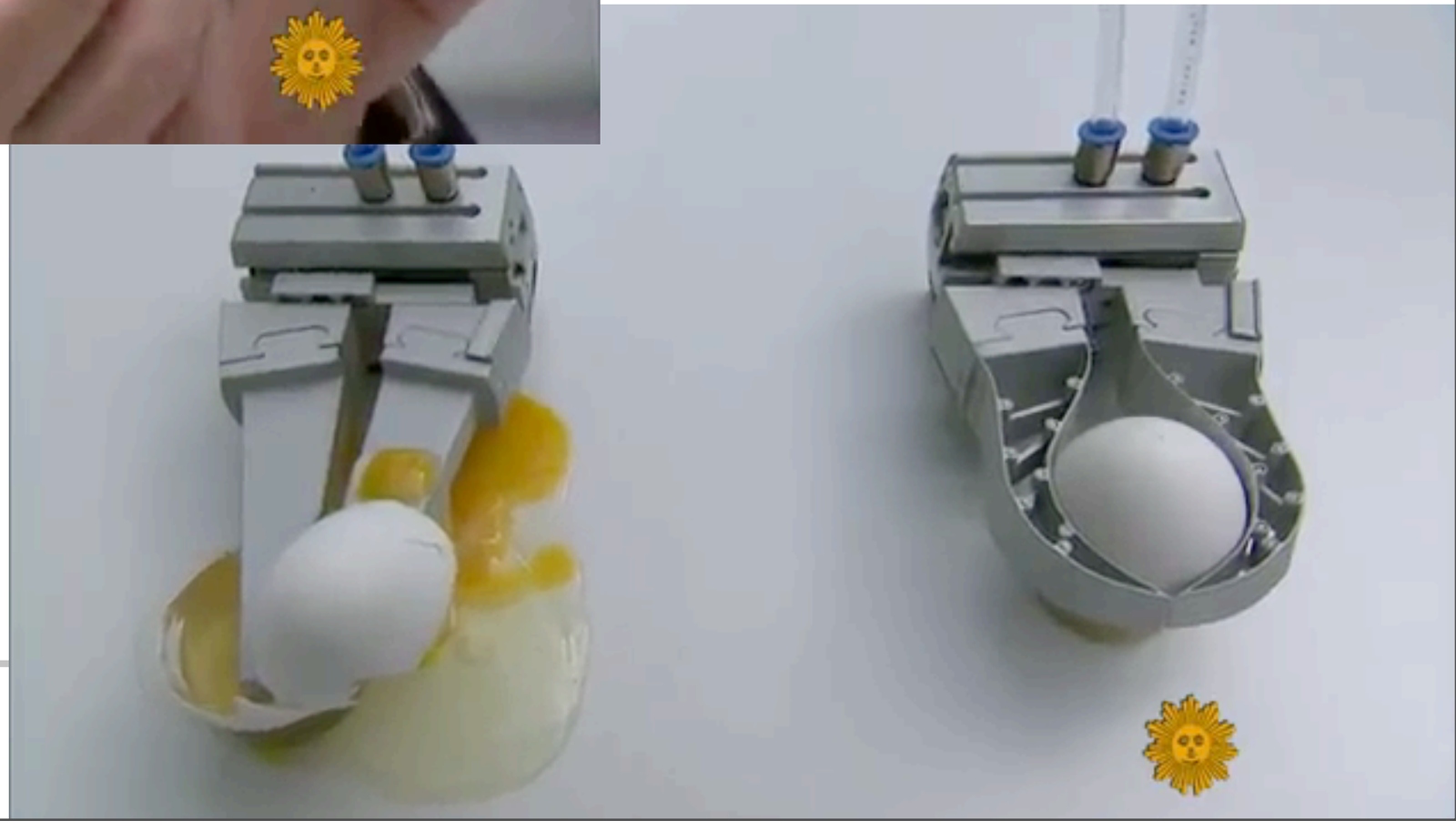


Festo trunk and gripper

Gripper with deformable materials based on the “Finray” effect

Festo trunk and gripper

Gripper with deformable materials based on the “Finray” effect



University of Zurich[UZH]

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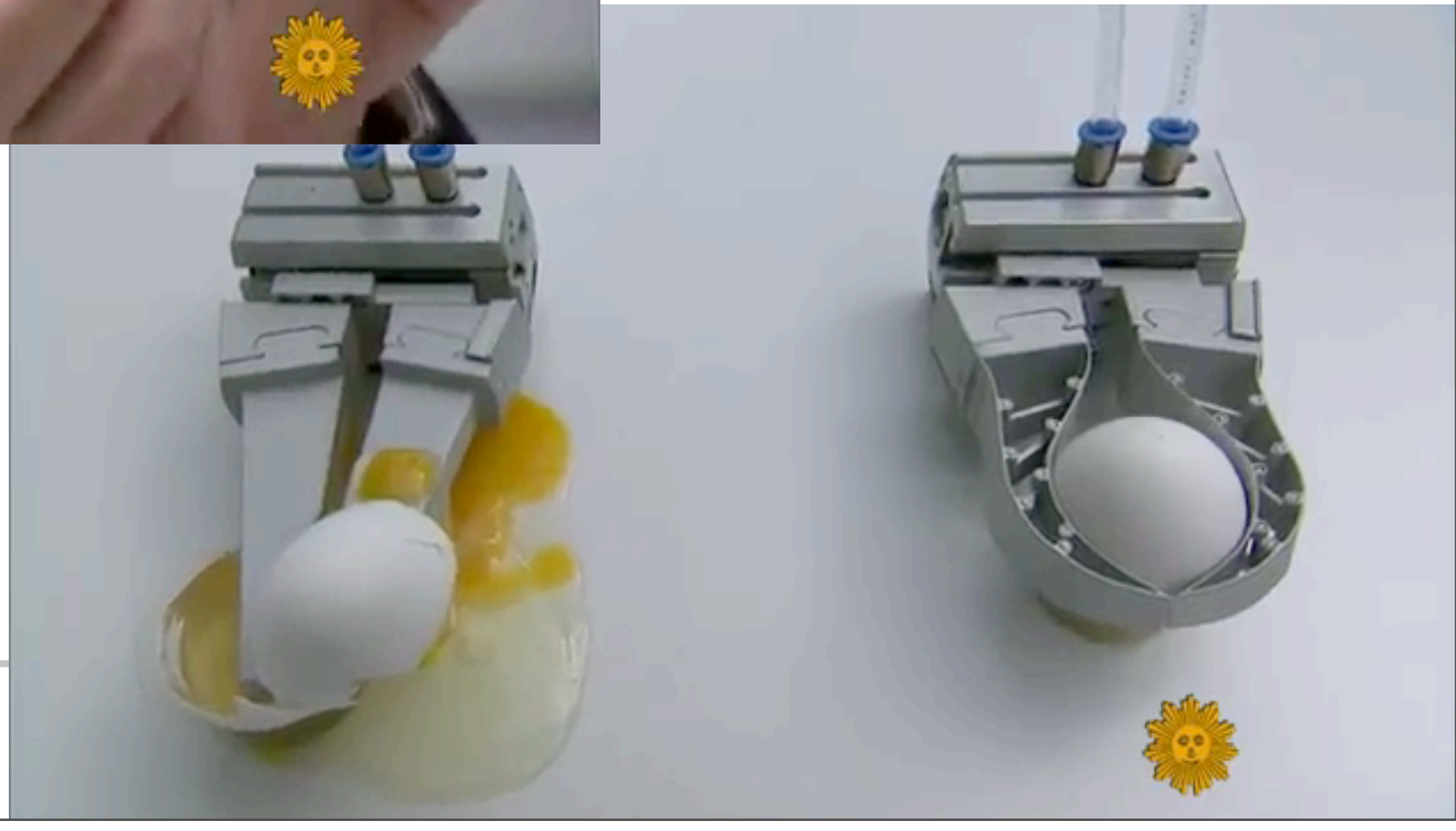

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Industrial applications

New trend: Food industry

- considerable variation —> unpredictability
- extremely delicate
- materials crucial (e.g. gripper)

industrial environment

Recall

real-world environment

- high predictability
- programmability

- low predictability
- coping with uncertainty

industrial robots (“hard”)

humans (“soft” to varying degrees)

industrial environment

Recall

real-world environment

- high predictability
- programmability

high predictability —> shrinking

industrial robots (“hard”)

- low predictability
- coping with uncertainty

humans (“soft” to varying degrees)

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robotics Swiss National Centre of Competence in Research

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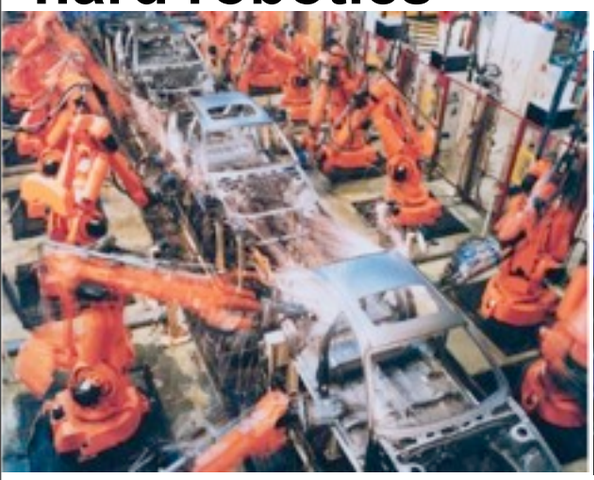
New manipulation skills:

New manipulation skills: what's hard about them?

The next “industrial revolution”

beyond traditional manufacturing:
new manipulation skills

hard robotics

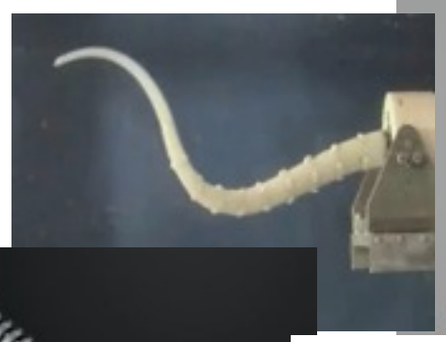


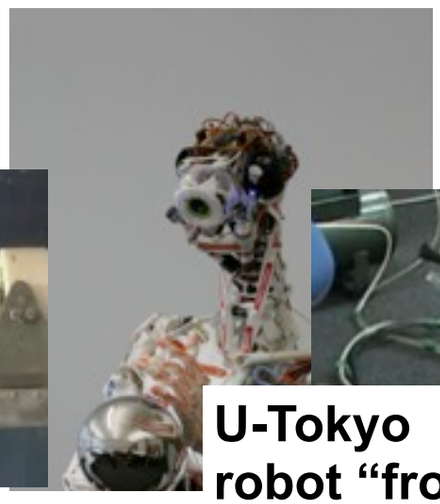
“soft robotics”

new manufacturing technology

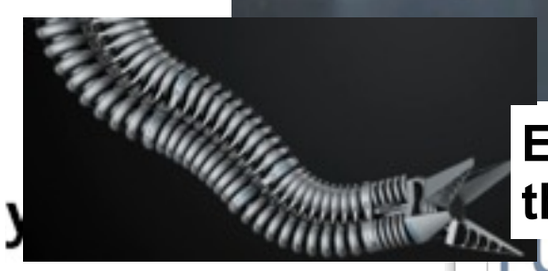
new industrial revolution

OCTOPUS
arm prototype





U-Tokyo
robot “frog”



Festo Bionic
Handling assistant

ECCE
the super-compliant robot

rethink robotics

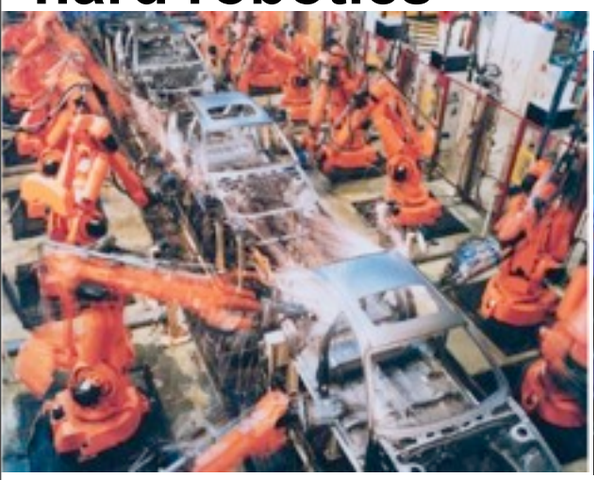
Rodney Brooks

adept
YOUR INTELLIGENT ROBOTICS PARTNER

The next “industrial revolution”

beyond traditional manufacturing:
new manipulation skills

hard robotics



“soft robotics” **new manufacturing technology**

rethink robotics™

OCTOPUS
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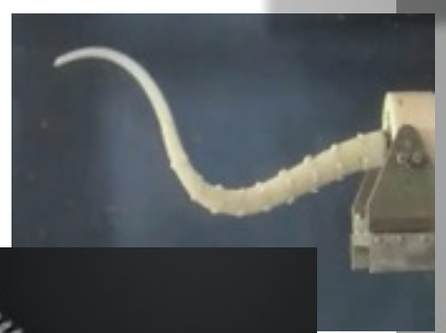

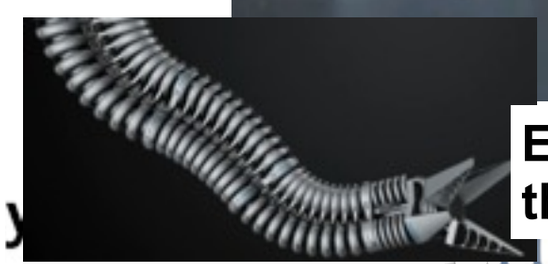

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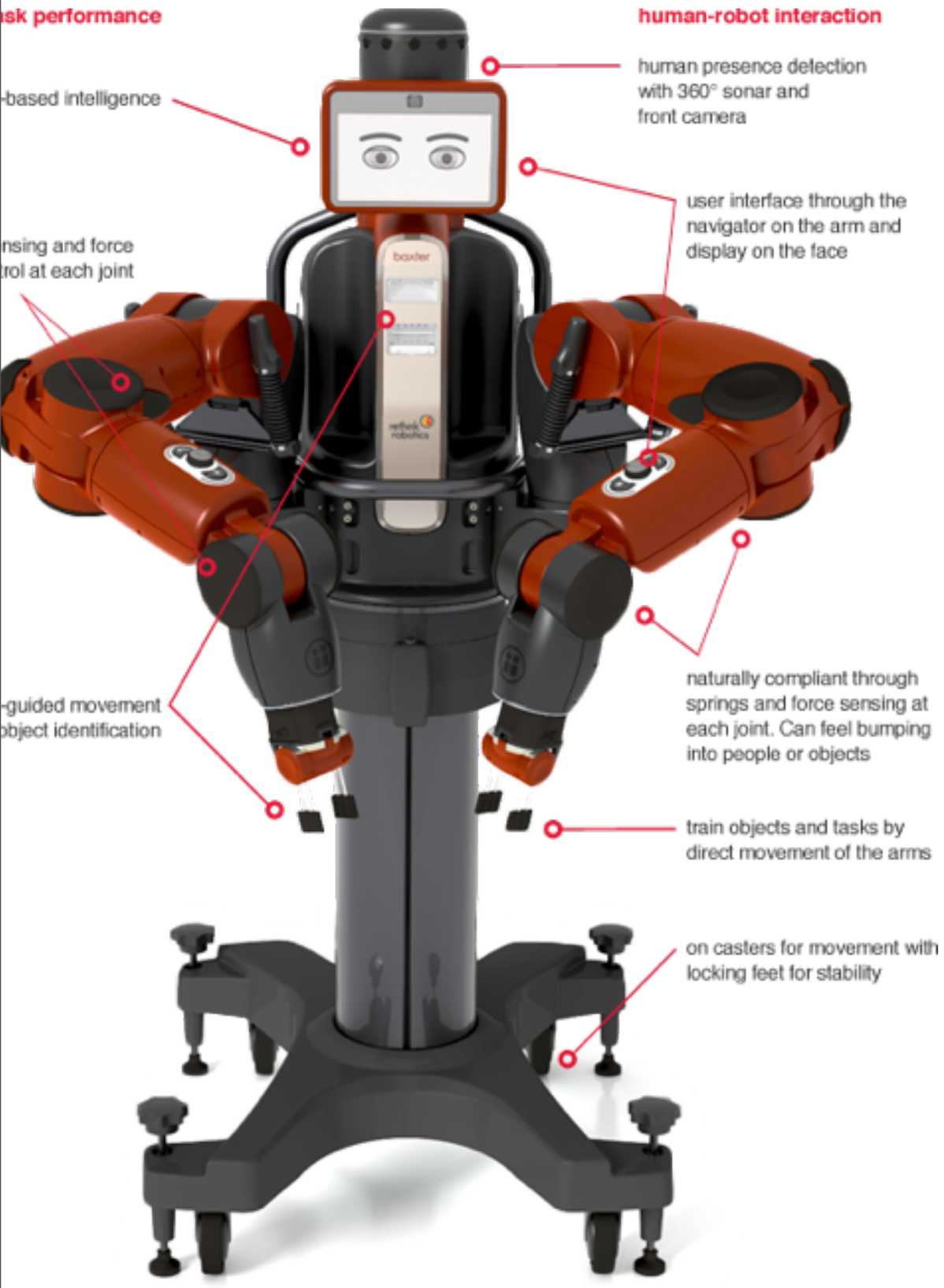
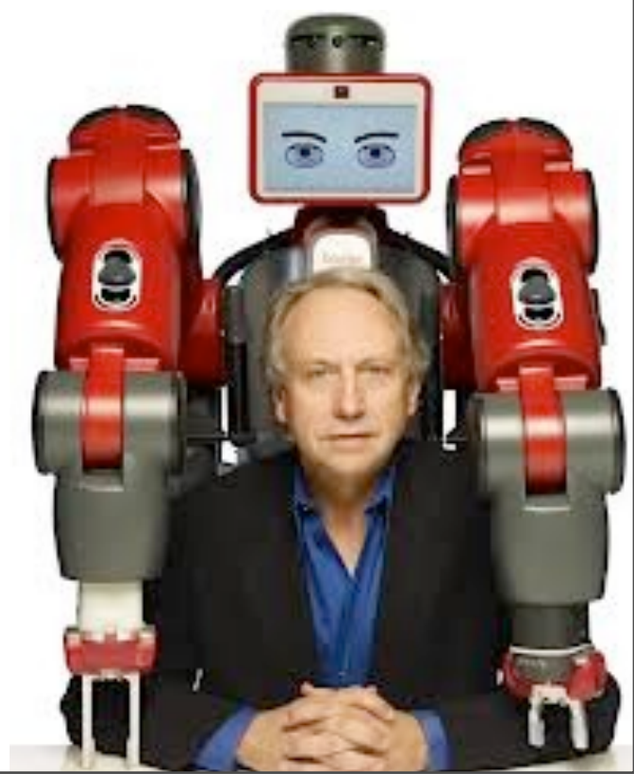
factory “humanoid” robot “Baxter”





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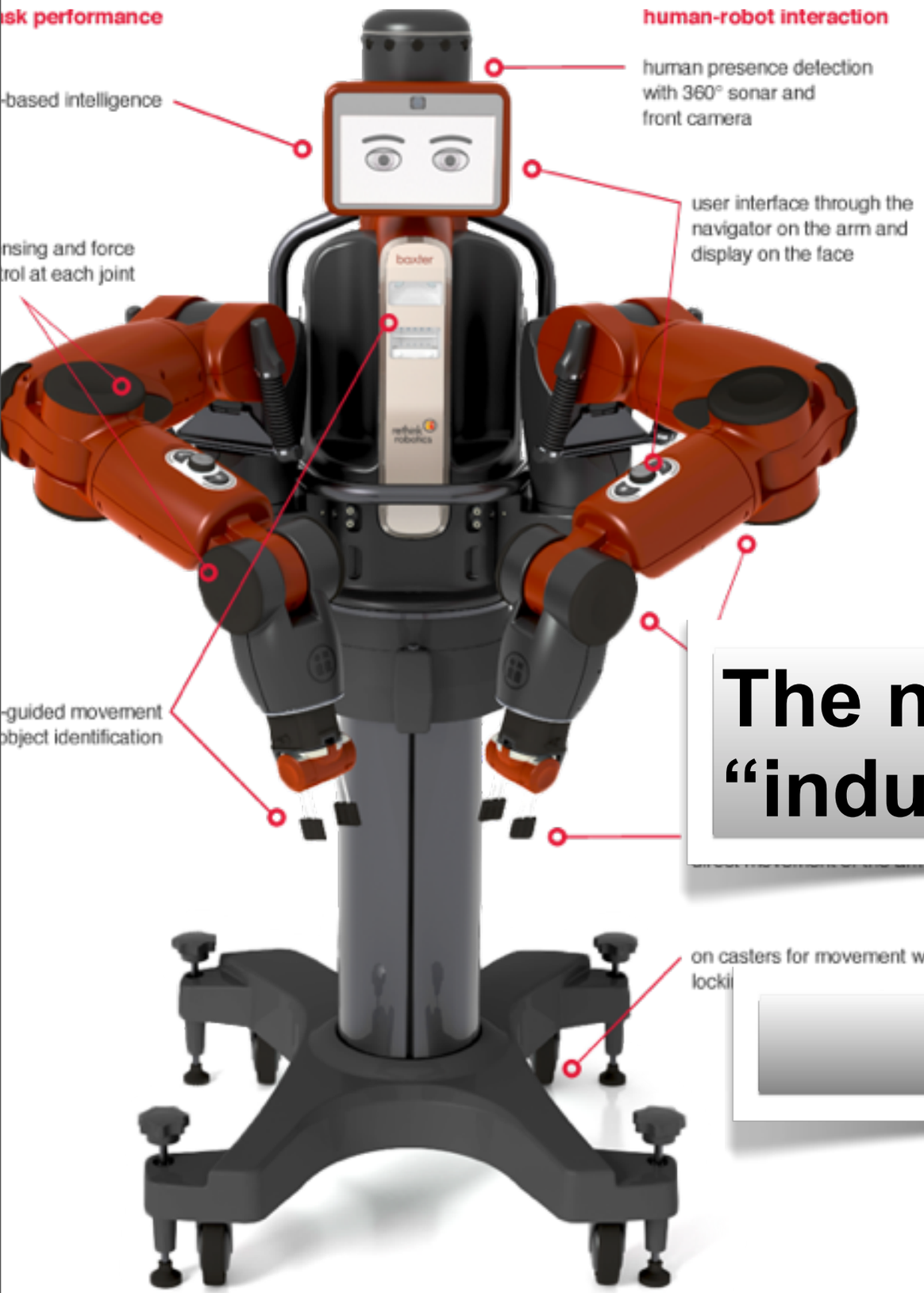
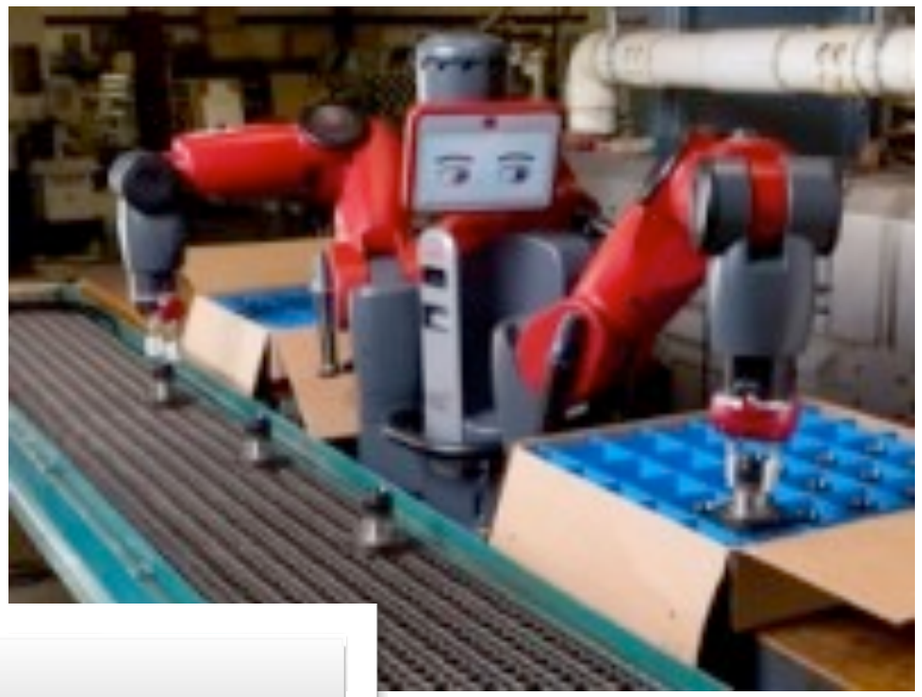
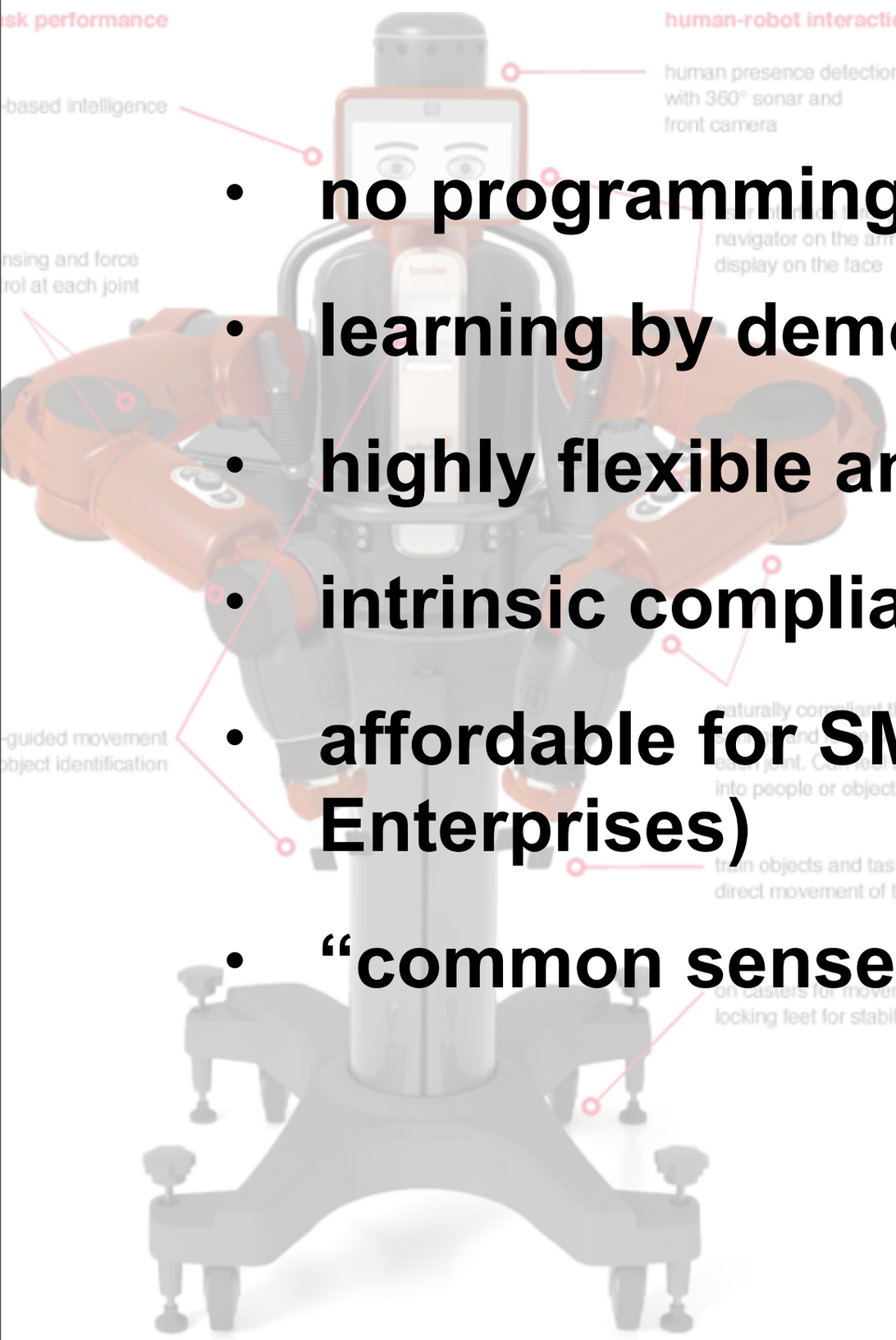


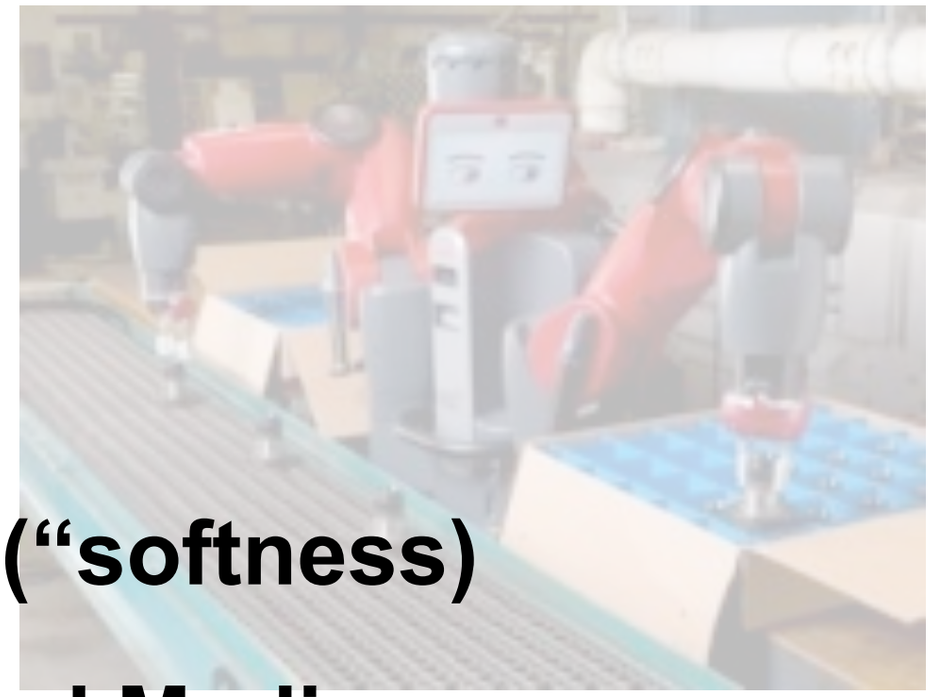


The next “industrial revolution”

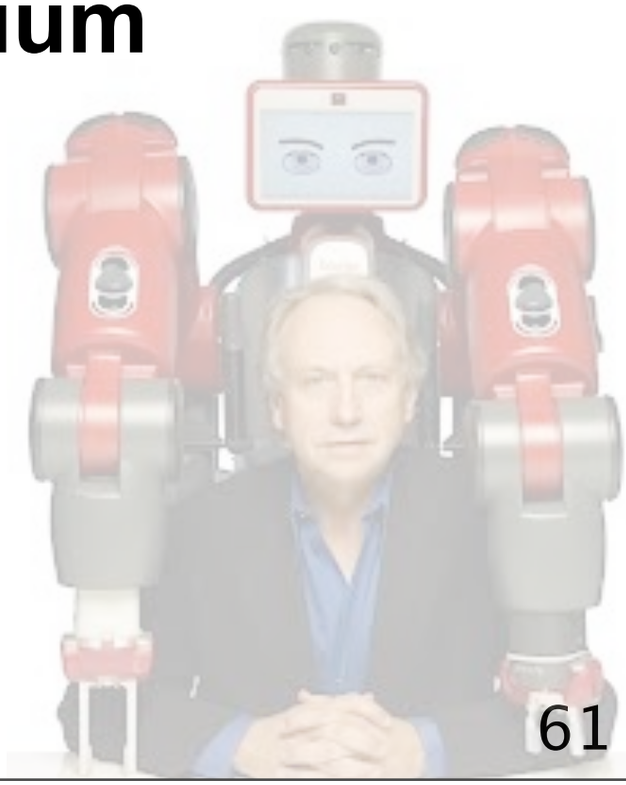
Rodney Brooks

factory “humanoid” robot “Baxter”





- no programming
- learning by demonstration
- highly flexible and versatile
- intrinsic compliance (safety) (“softness)
- affordable for SMEs (Small and Medium Enterprises)
- “common sense”



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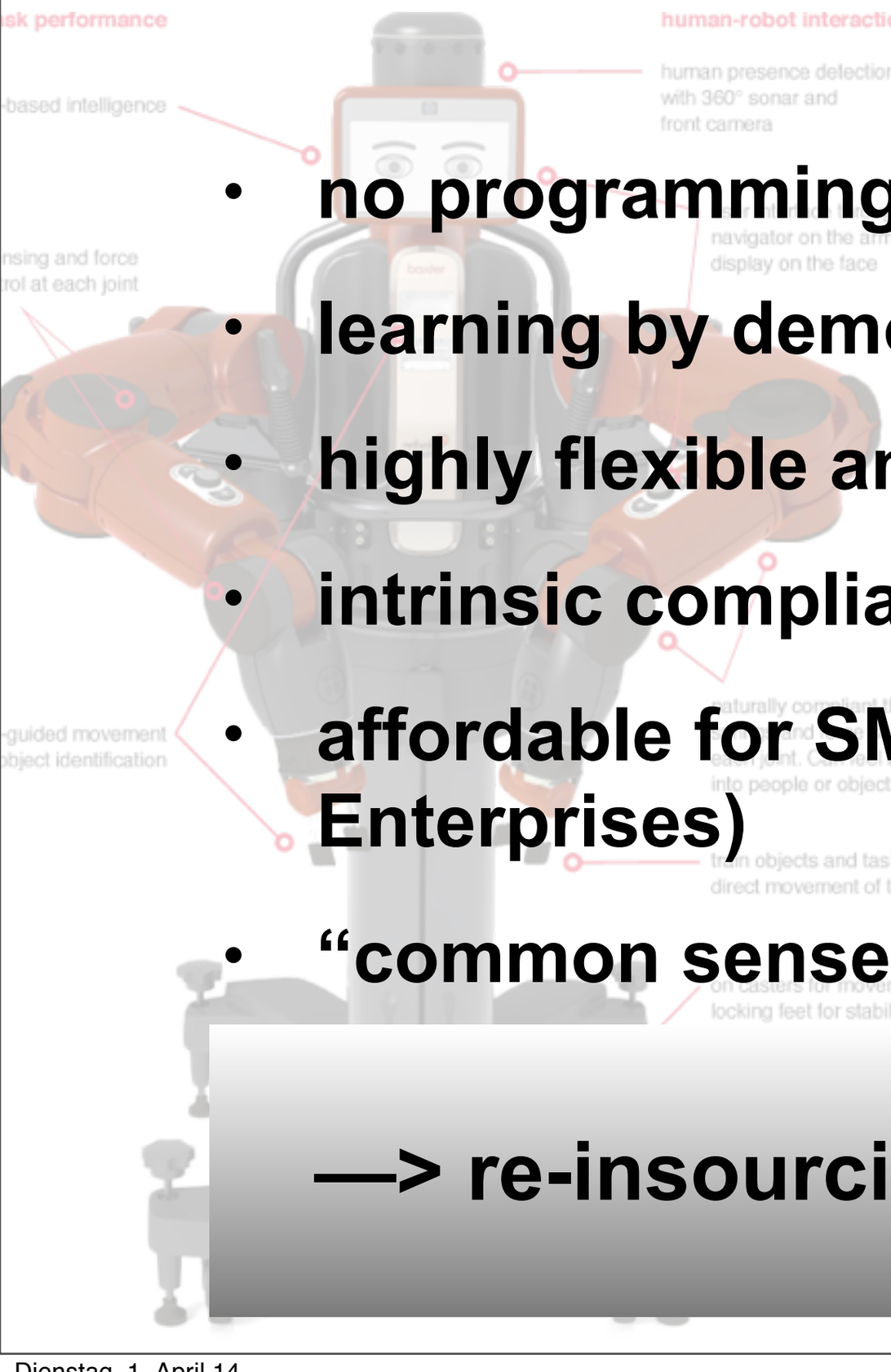

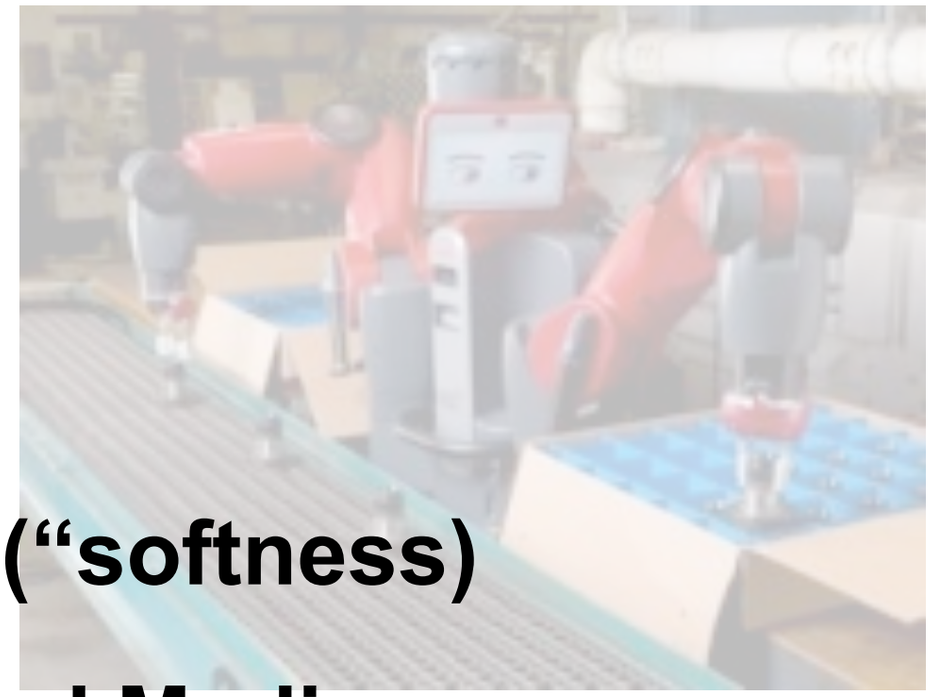

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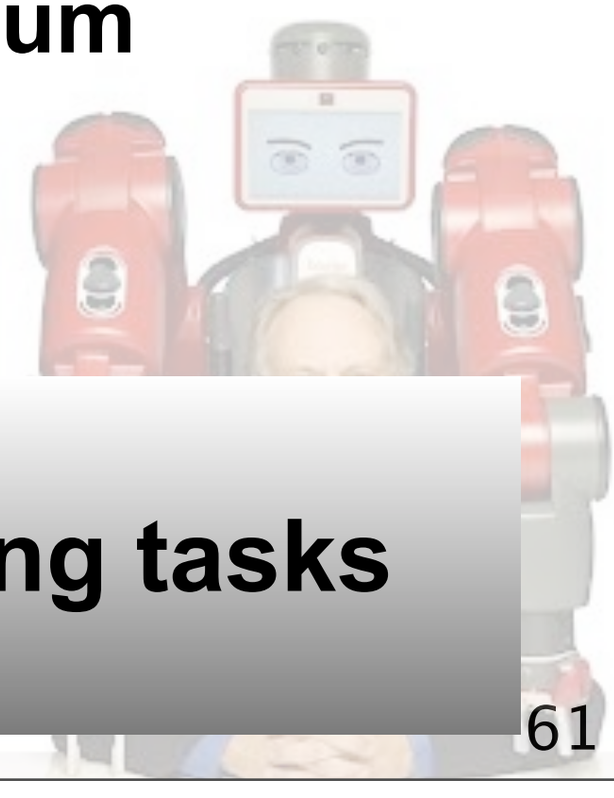


—> re-insourcing of manufacturing tasks

Principles

- human-robot cooperation (rather than complete automation)
- safe human-robot interaction
- maintain jobs in country - re-insource

Trends in robotics/manufacturing

manufacturing, “hard”	→	**service, “soft”**
individual robots	→	robot “ecosystem”
isolated robots	→	the human/robot “cloud”
complete automation	→	**human-robot cooperation**
outsourcing production	→	**re-insourcing**
software, “bits”	→	physical system, “atoms”
centralized manufacturing	→	distributed “makers”
big industries, high invest-ments	→	**SMEs, small investment**

Contents

- introduction and background
- principles of embodied intelligence
- the “power of materials”
- guided self-organization
- the “Roboy” project
- summary and conclusions

Morphology and computation: “trading spaces”

increasing dominance of morphology and materials
decreasing dominance of control

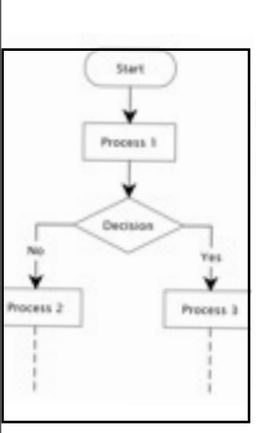
informational computation

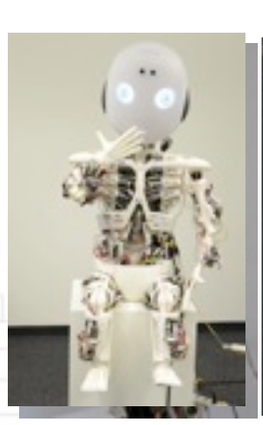
control and behavior less separable
increased reliance on self-organization

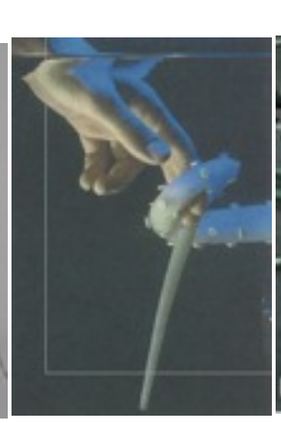
morphological computation

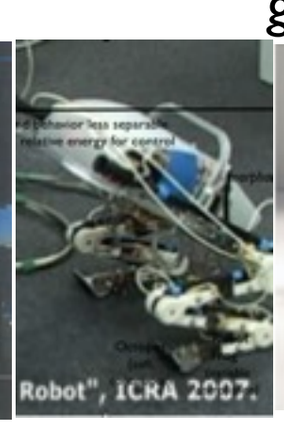
control dominant

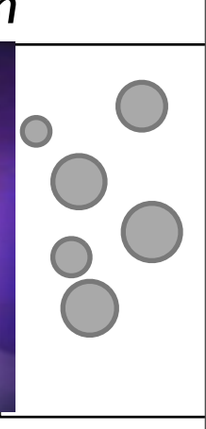
morphology and materials dominant
“guided self-organization”











pure algorithm

computer (running algorithm)

industrial robot (centralized control

Asimo (and similar robots)

Roboy (compliant, tendon-driven)

Octopus (soft, continuous)

“Robot Frog” (variable compliance)

Jaeger-Lipson coffee-balloon gripper

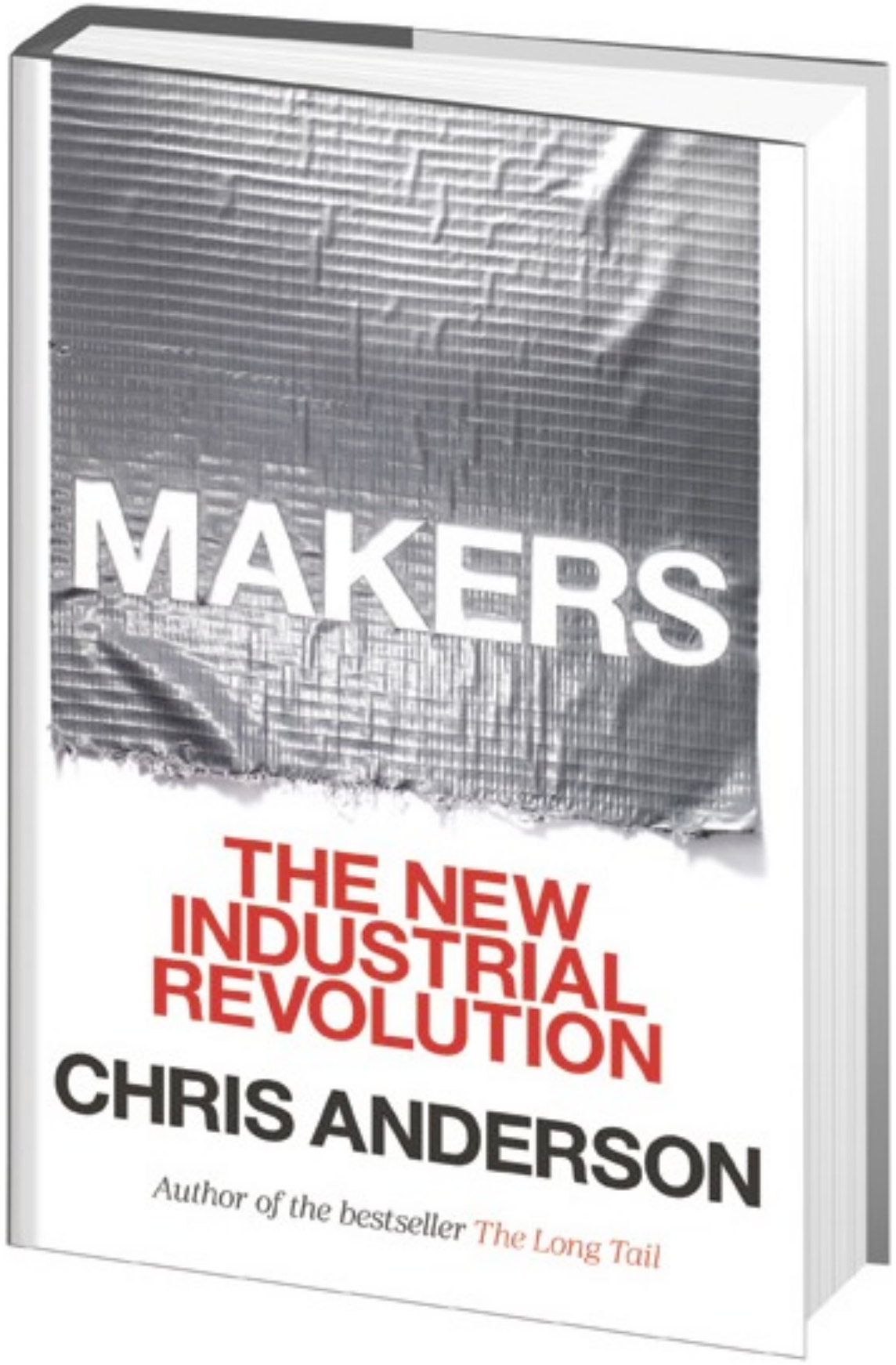
PDW (exploiting morphology)

cells molecules “Tribolons”

control dominant

morphology and materials dominant

“from bits to atoms”



A note on “guided self-organization”

at what level to apply control?

cockroaches: configuration of shoulder joint

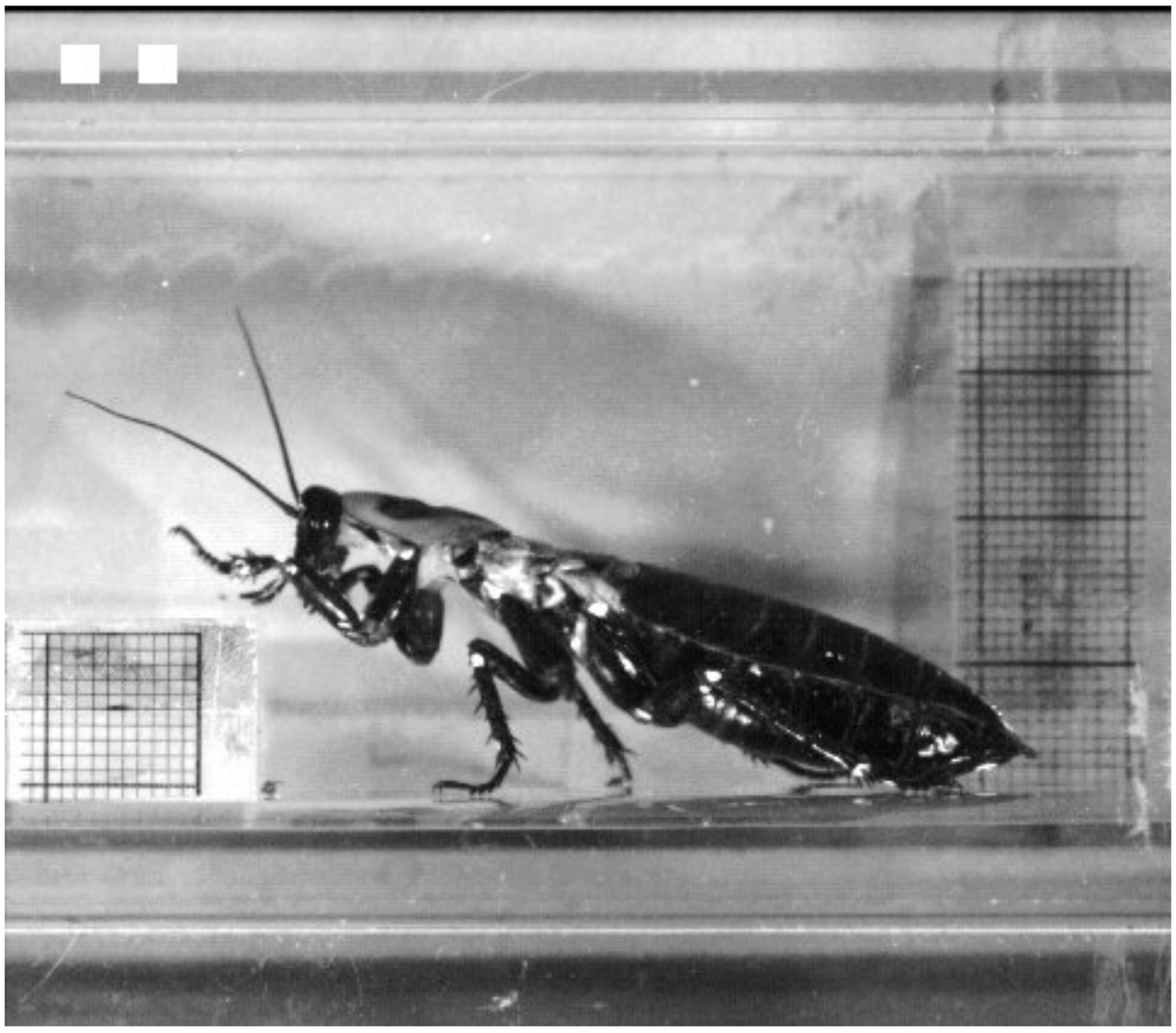
the Octopus robot: a paradigmatic case study

human movement and locomotion

Shuhei Miyashita’s “Tribolons”

Jürg Germann’s soft self-assembling

Exploiting morphology: managing complex bodies



pictures and ideas:
courtesy Roy Ritzmann
Case Western Reserve University

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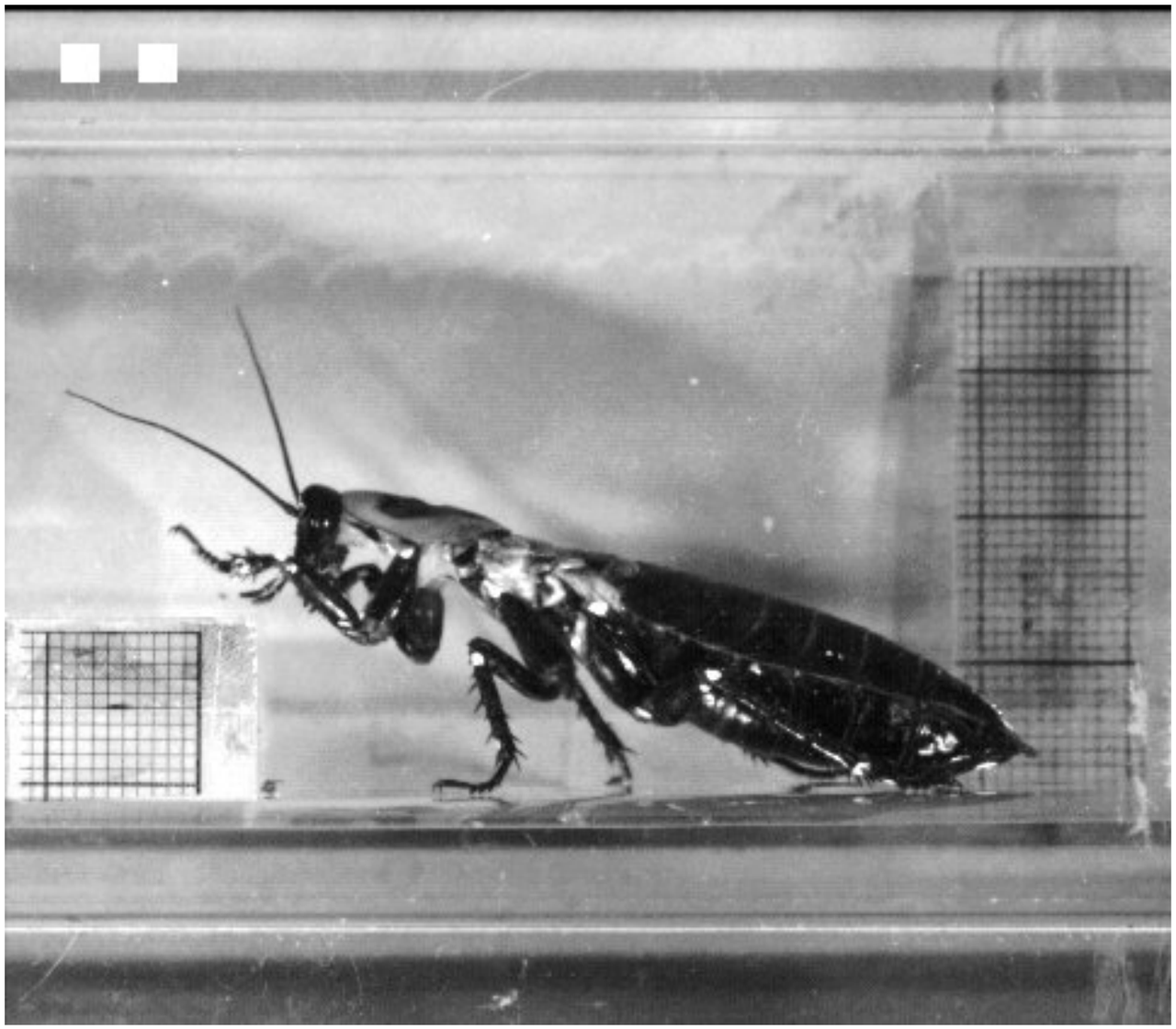

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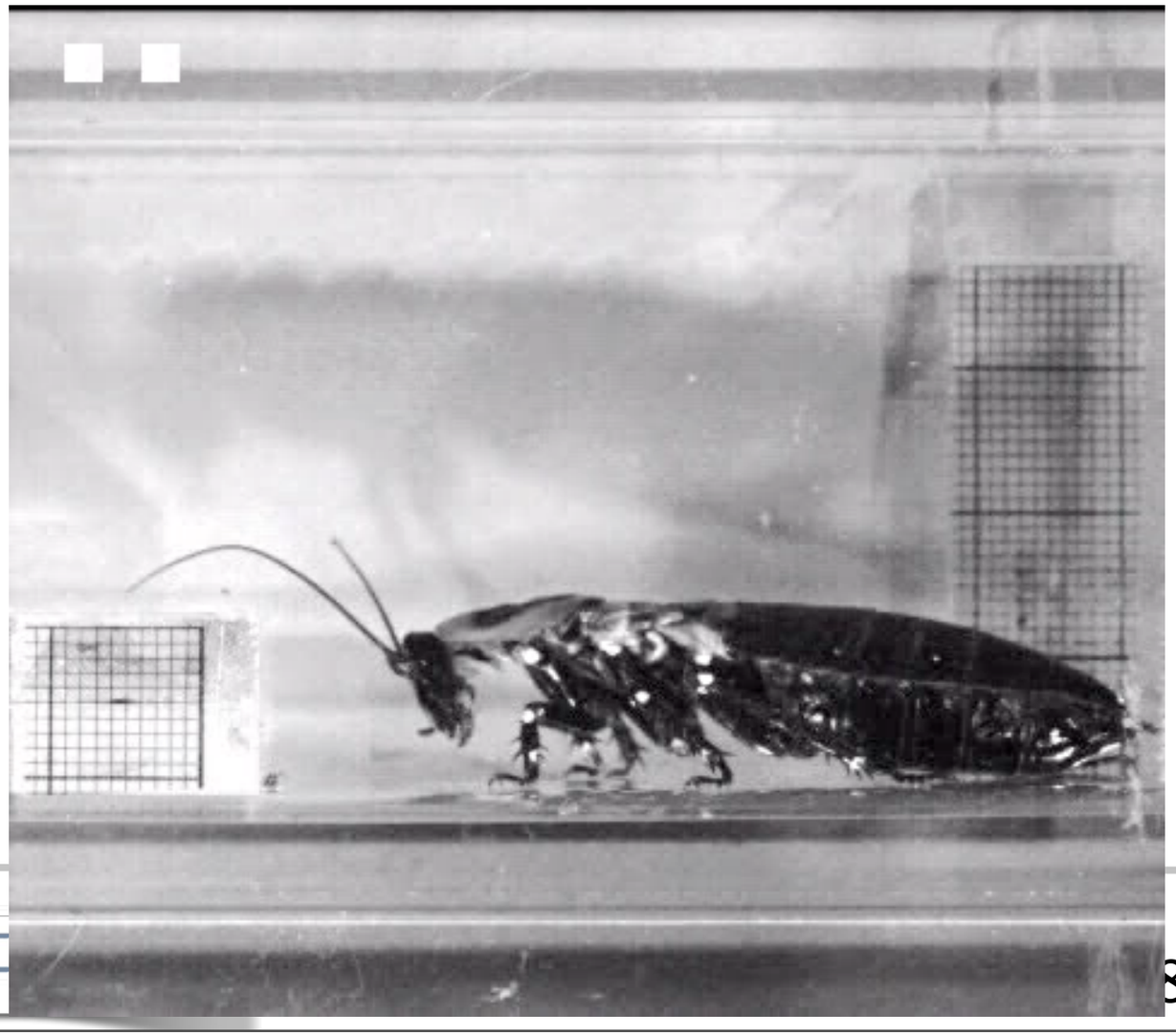
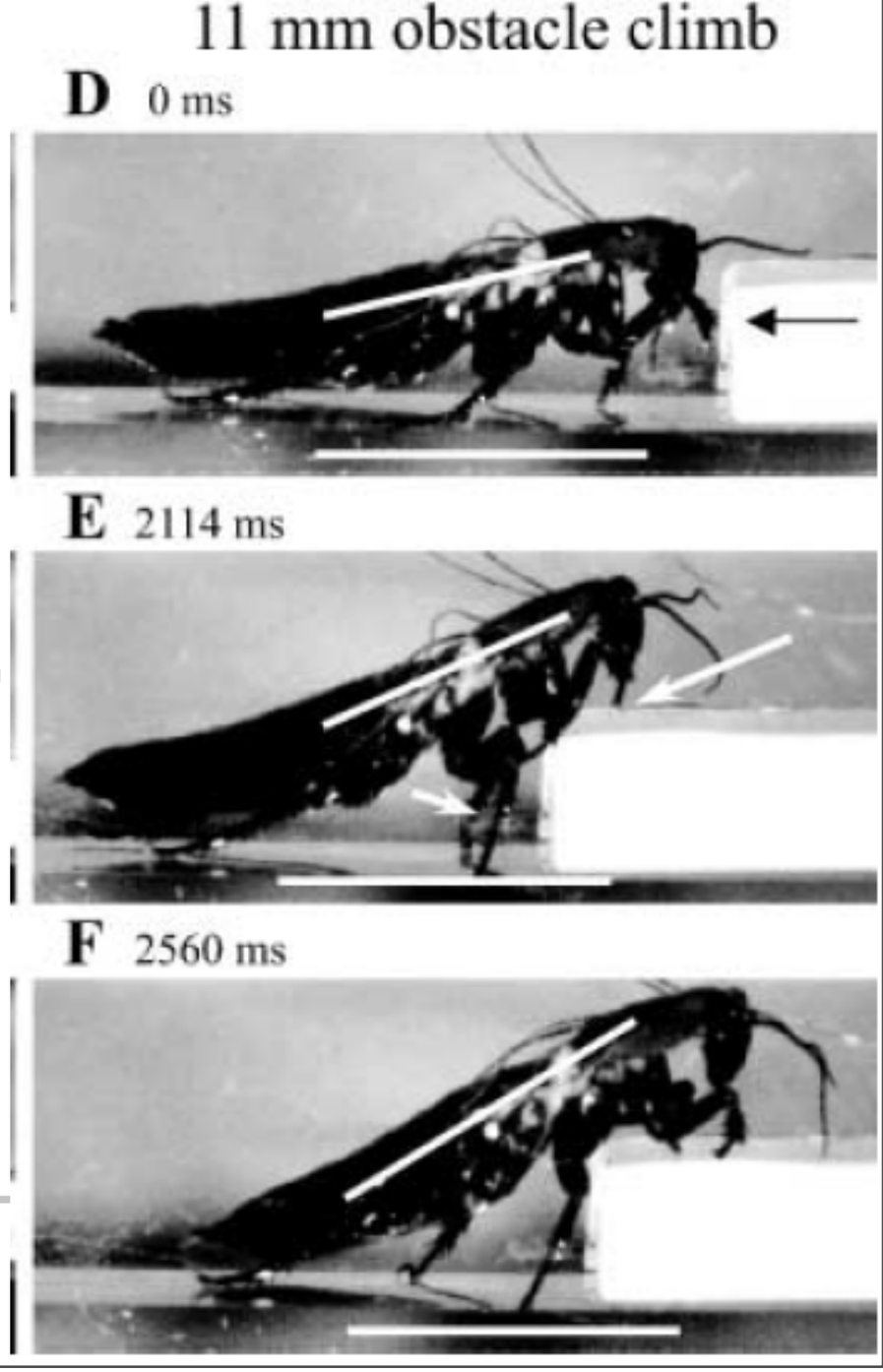


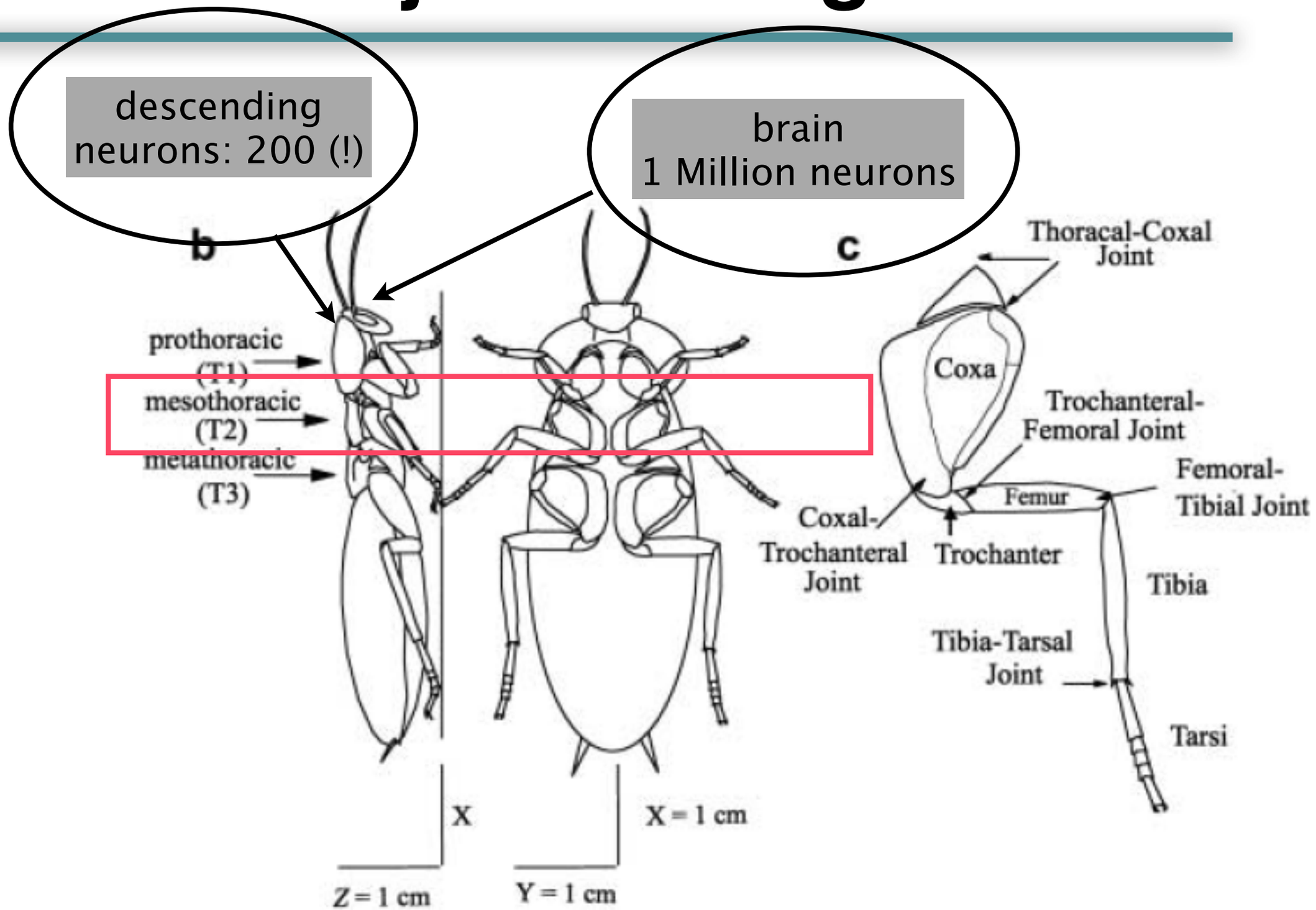
“Outsourcing” functionality: exploiting morphology

- **brain: 1 Million neurons (rough estimate)**
- **descending neurons: 200 (!)**
- brain:
  - **cooperation with local circuits**
  - **morphological changes (shoulder joint)**



- **Watson, Ritzmann, Zill & Pollack, 2002, J Comp Physiol A**

Effects of morphology change shoulder joint configuration



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

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morphological computation

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Octopus arm movements

Octopus Arm
Design and construction:

Matteo Cianchetti (SSSA)
Cecilia Laschi (SSSA)
Tao Li (UZH)
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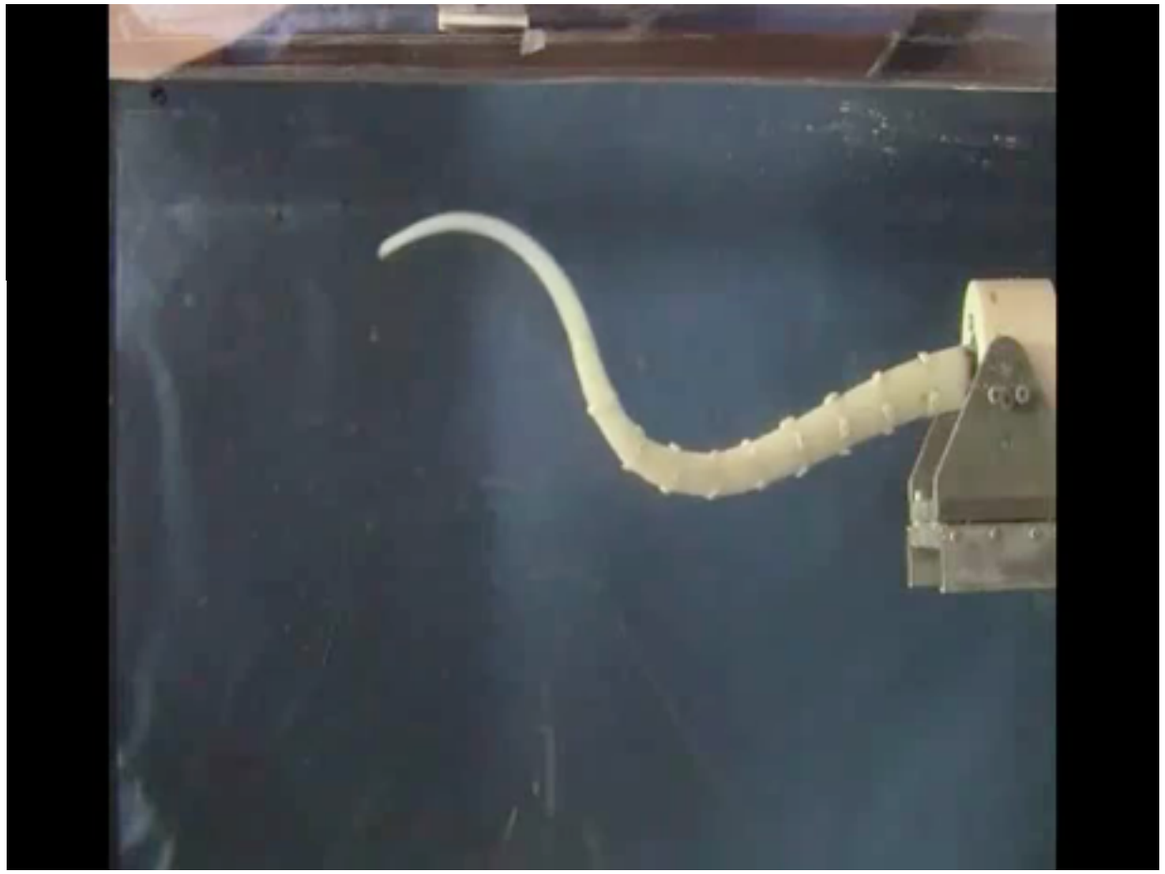

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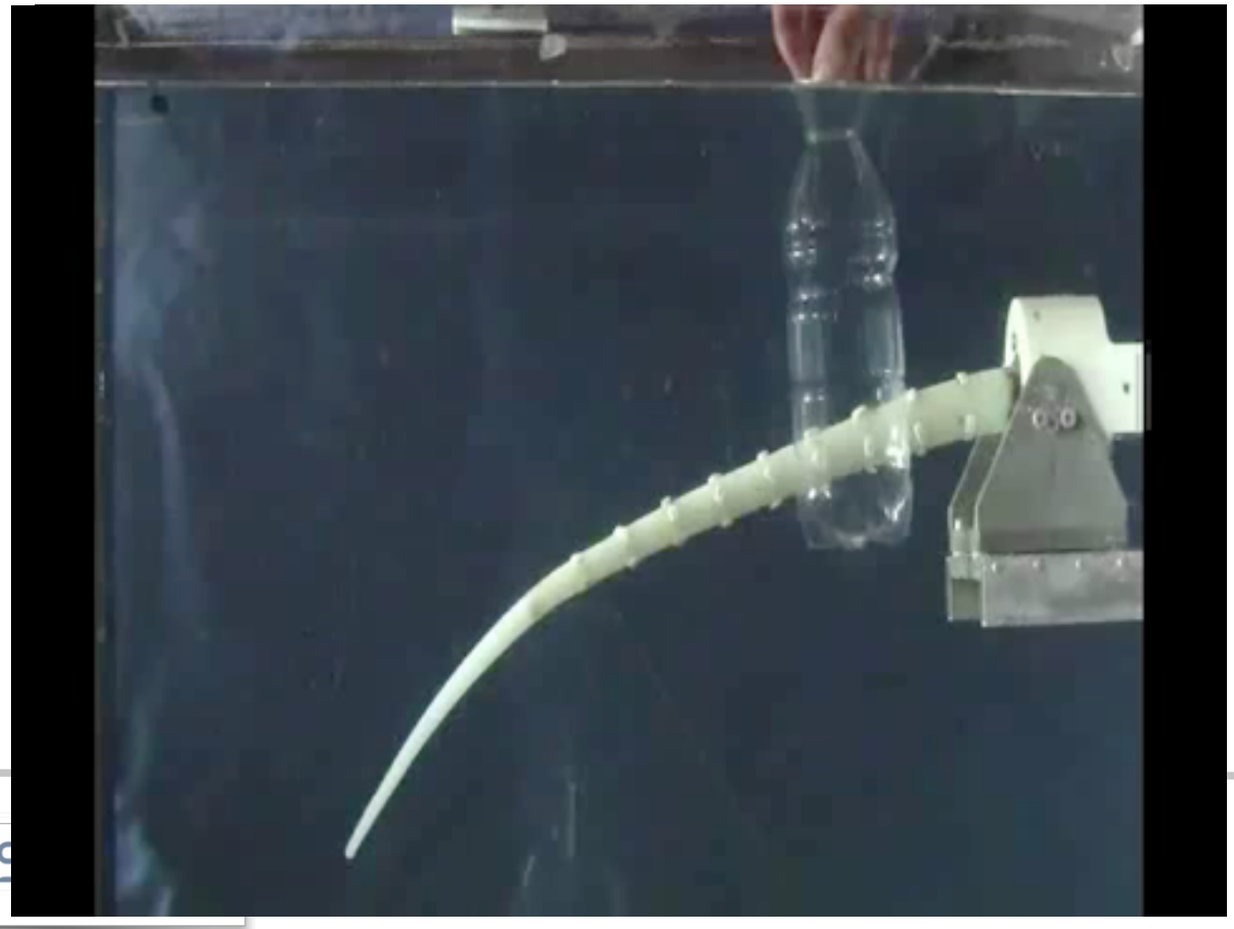

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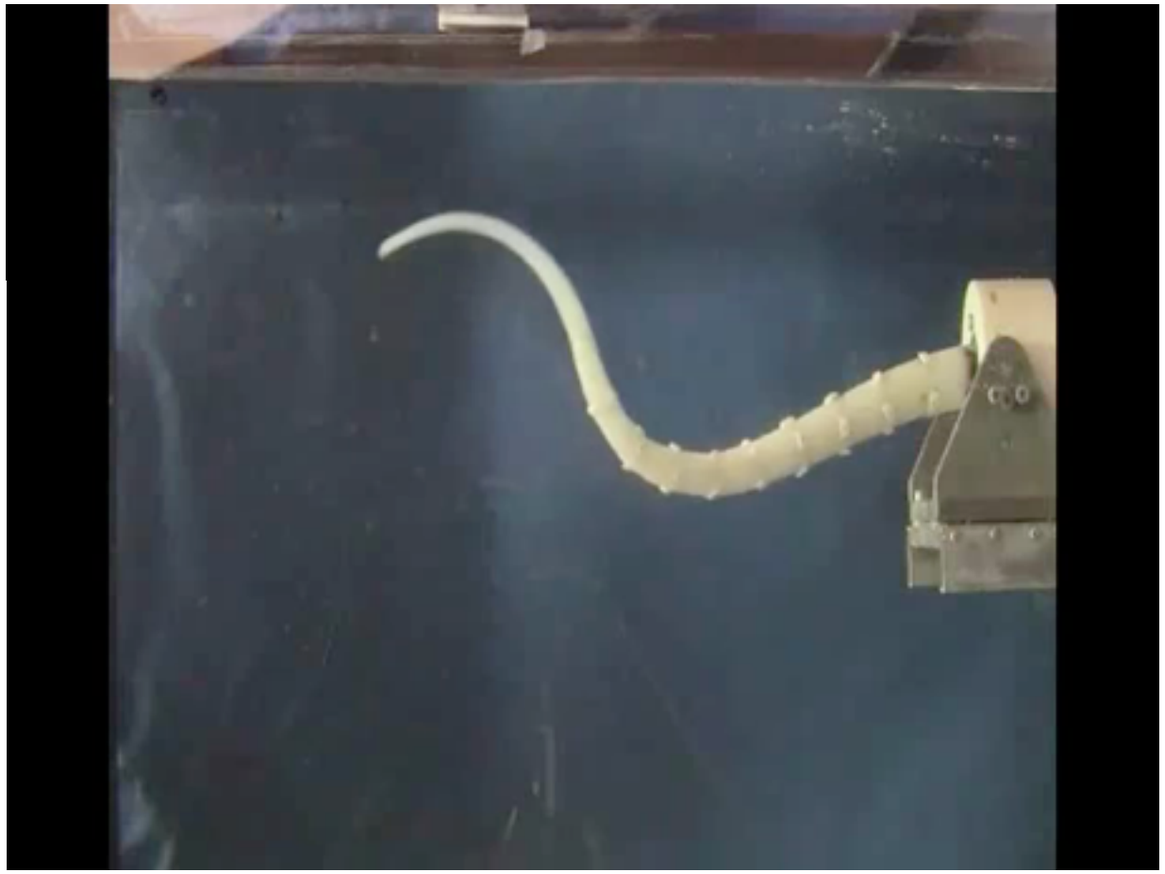

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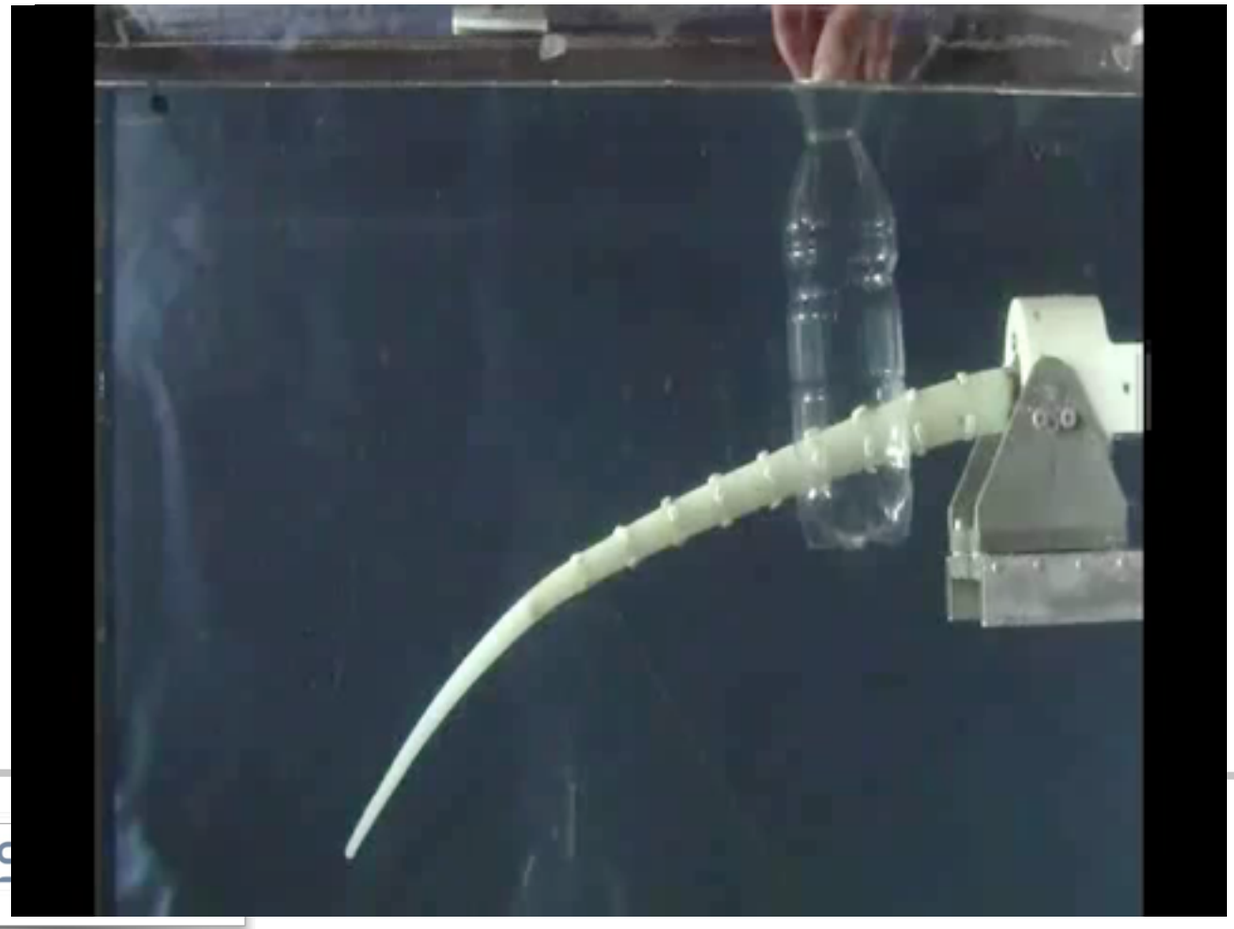

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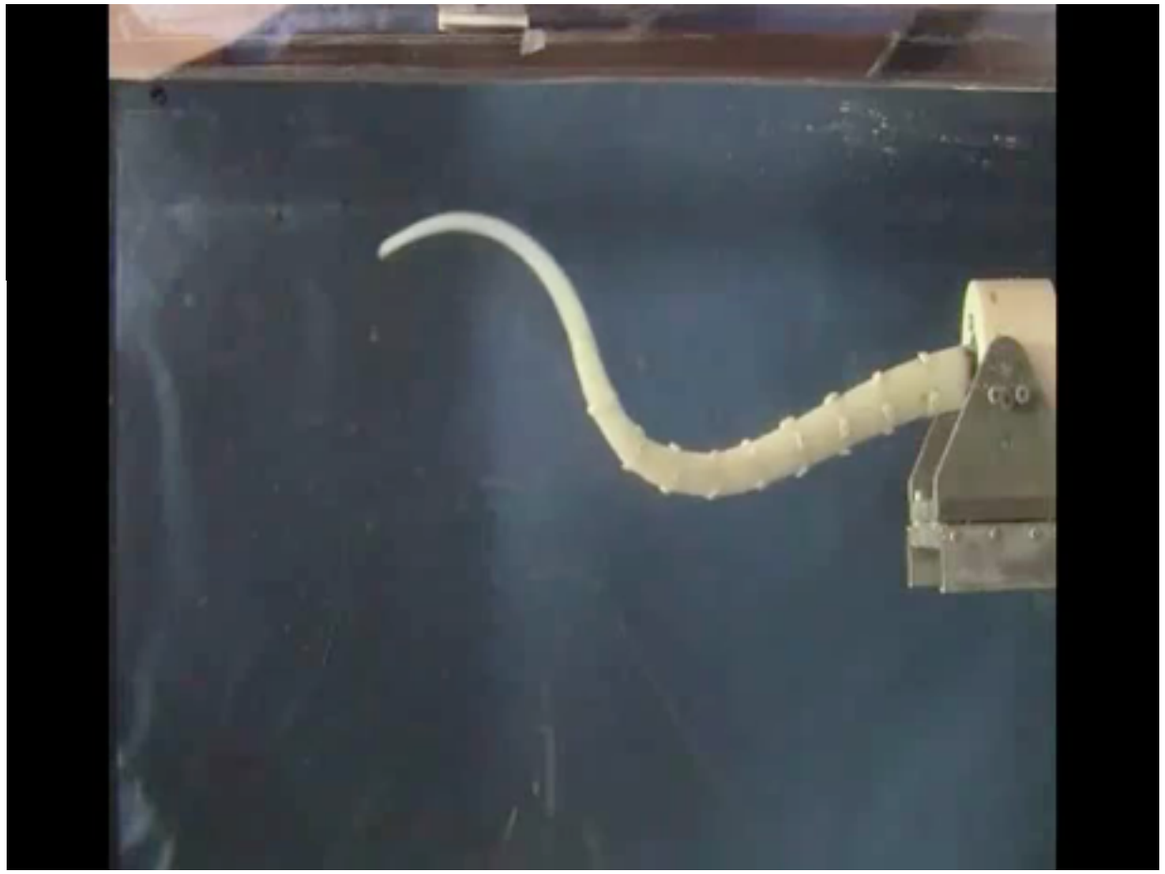

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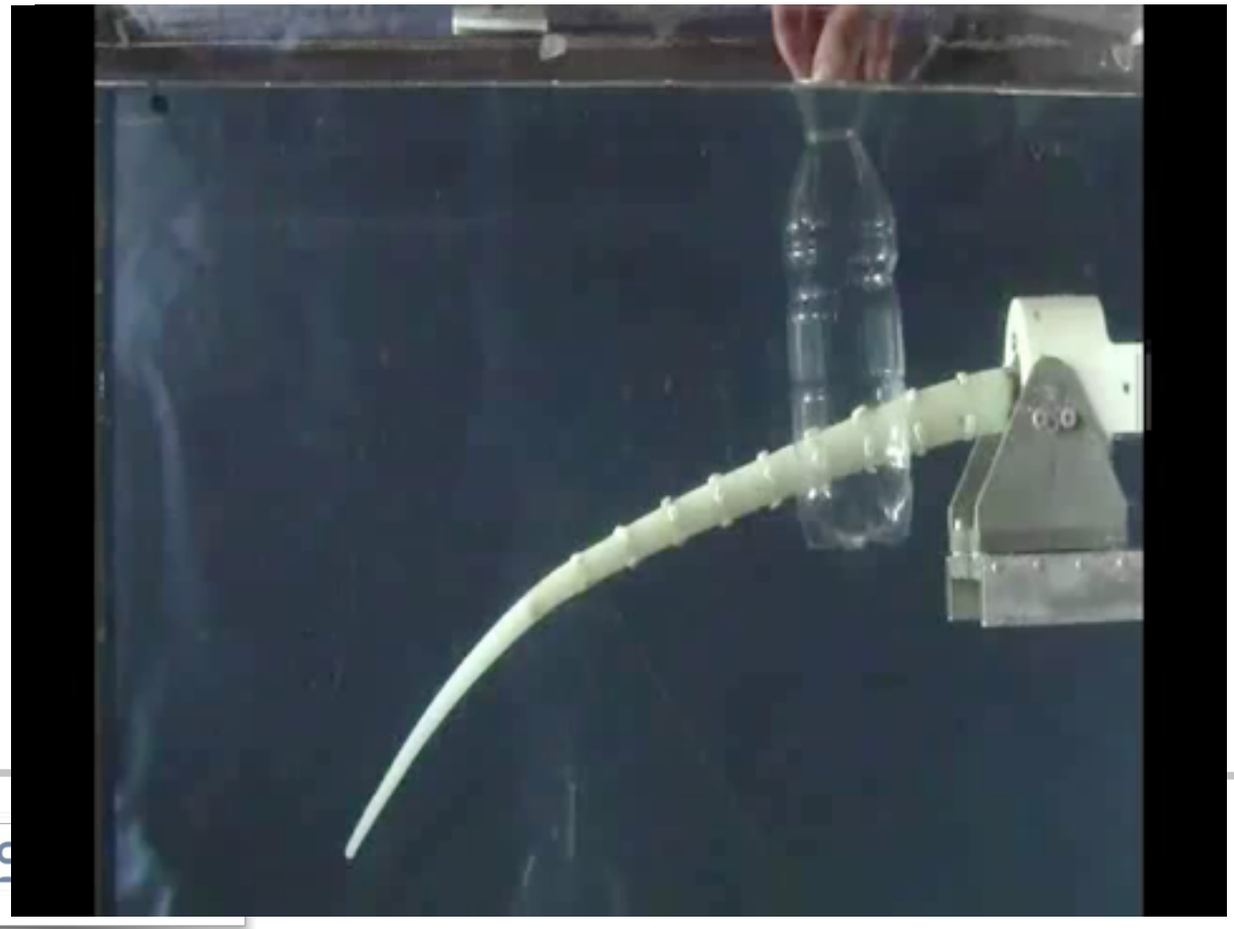
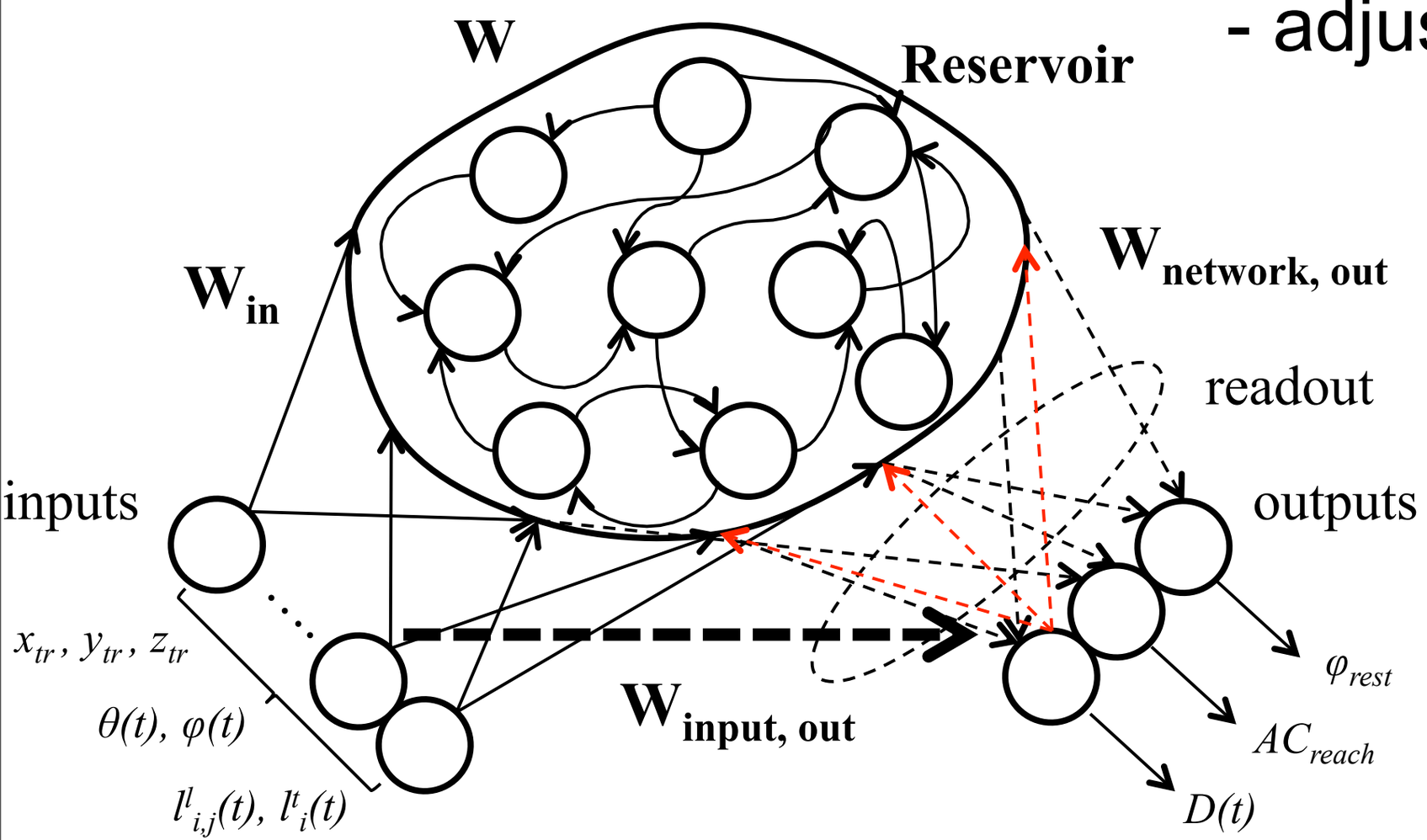


“Orchestrating” an Octopus arm



Reservoir computing:

- adjust only linear readout

$$\mathbf{W_{out}X = O}$$

$$\mathbf{W_{out} = O_{target}X^*}$$

Design and simulation:
Kohei Nakajima et al.

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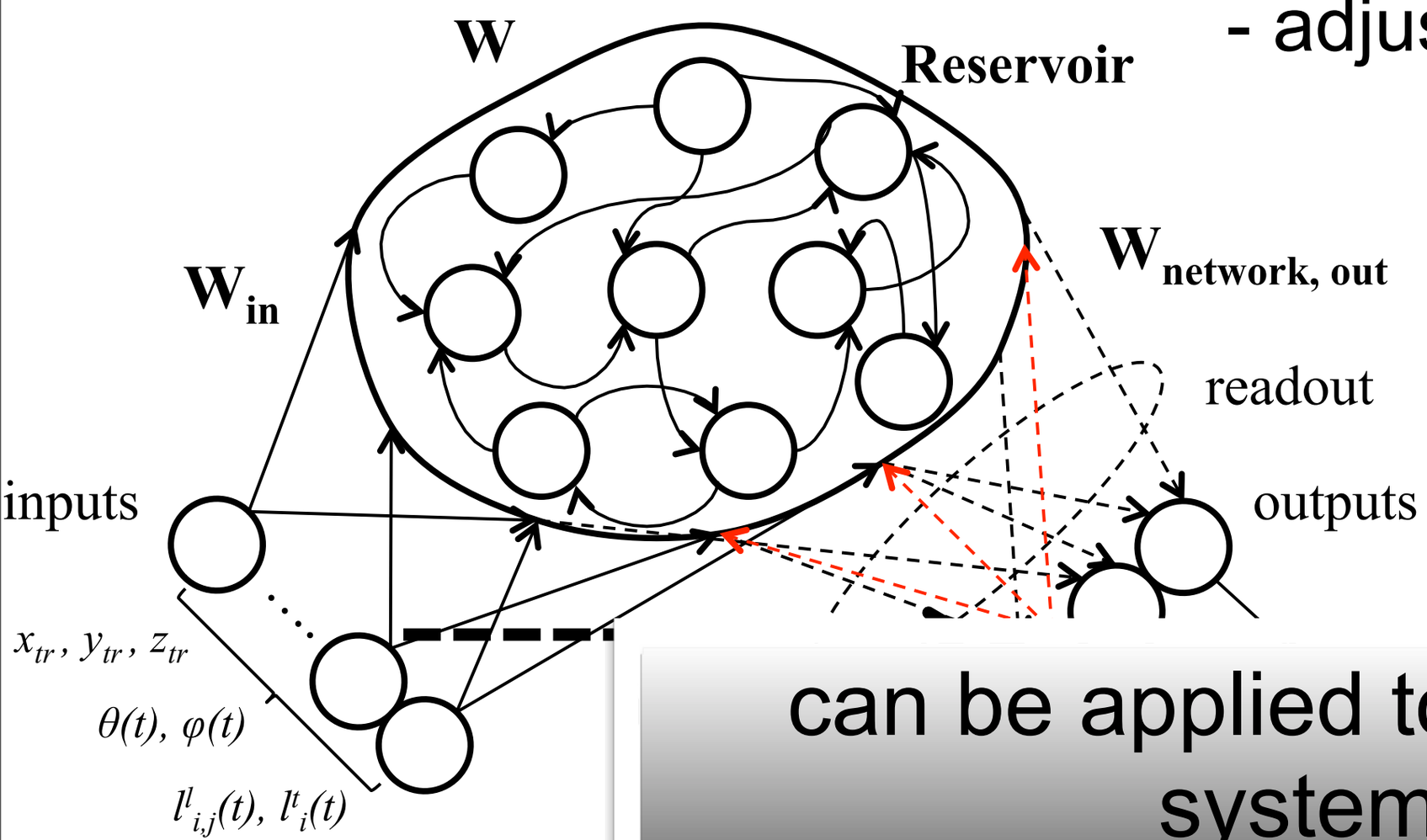


Reservoir computing:

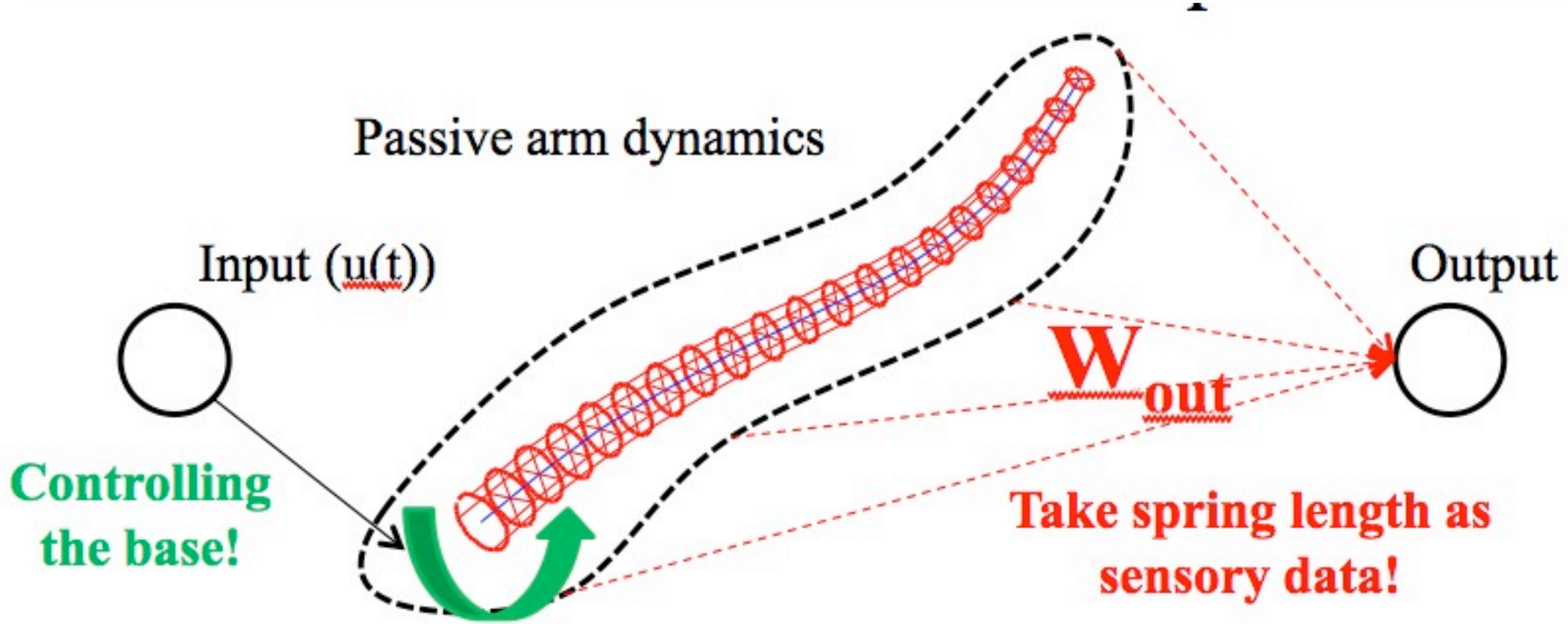
- adjust only linear readout

$$W_{out}X = O$$

$$W_{out} = O_{target}X^{*}$$

can be applied to physical system

Benchmark tasks: simulation setup



—> use for function approximation!

University of Zurich[UZH]

robotics Swiss National Centre of Competence in Research

ai lab

Simulated arm approximating benchmark tasks (Kohei Nakajima)

Task (Benchmark task) (Hauser et al. 2012)

- **2nd order nonlinear dynamical systems**

$$y(t+1) = 0.4y(t) + 0.4y(t)y(t-1) + 0.0048u^3(t) + 0.1$$

- **10th order nonlinear dynamical systems**

$$y(t+1) = 0.3y(t) + 0.05y(t)\left(\sum_{i=0}^{9} y(t-i)\right) + 0.06u(t-9)u(t) + 0.1$$

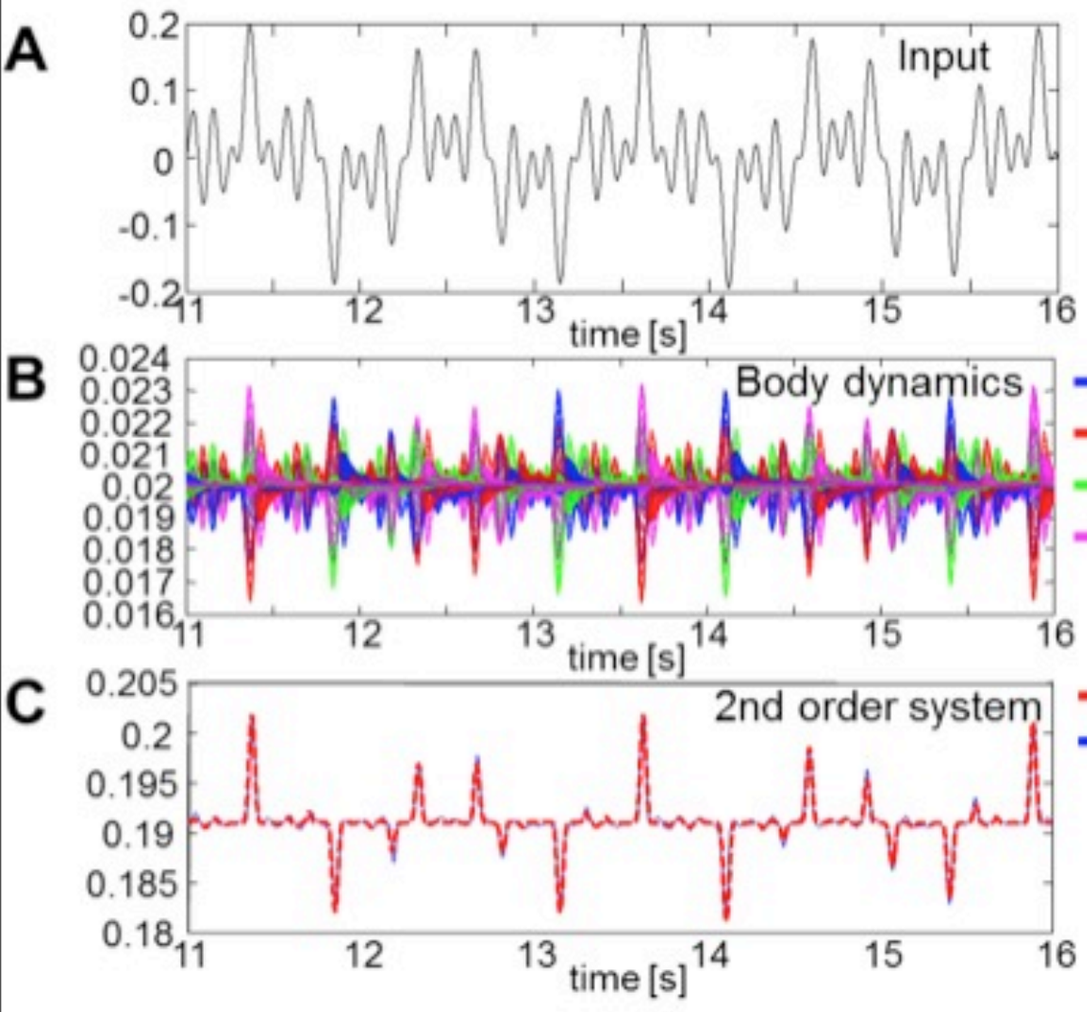
- **Volterra series**

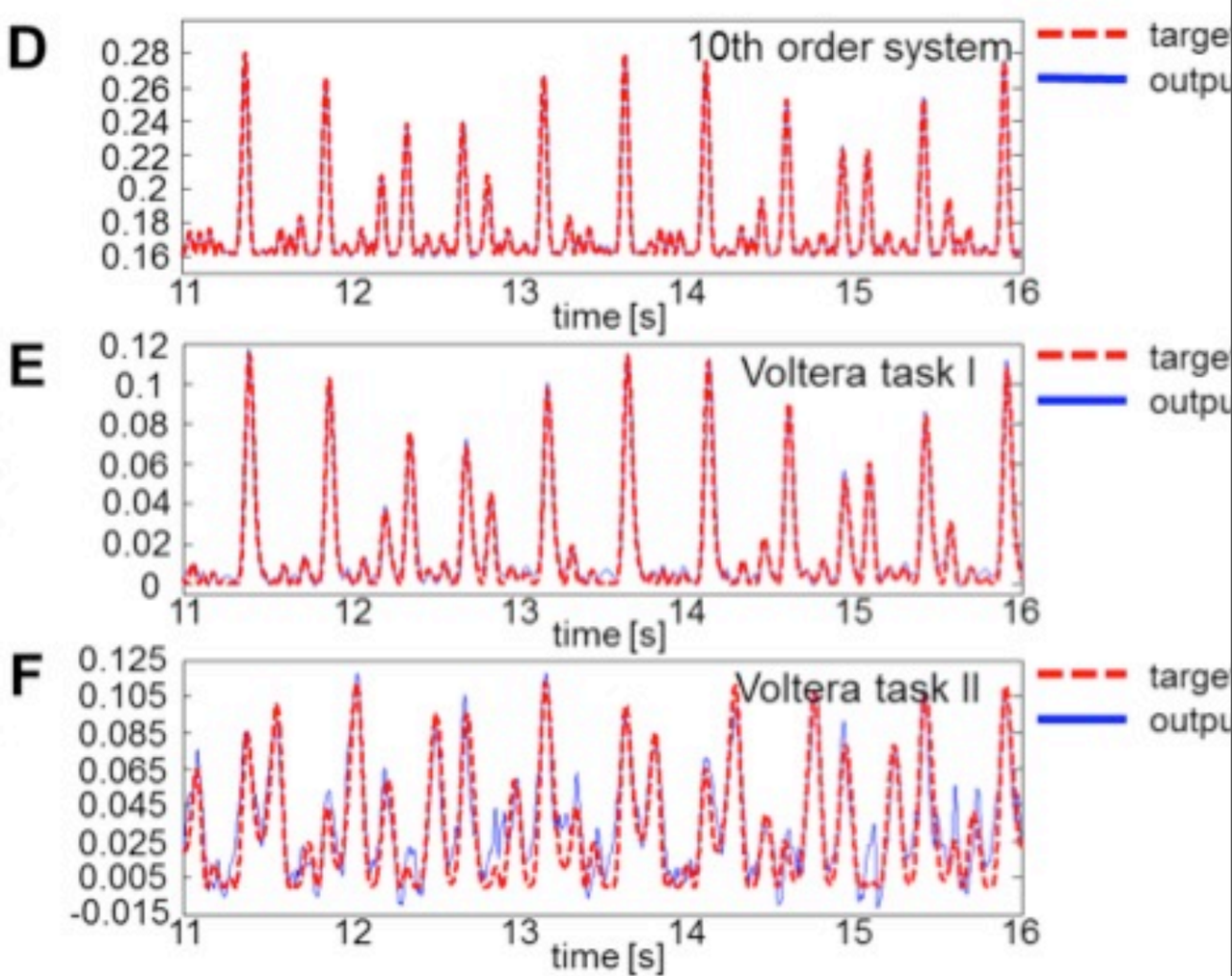
$$y(t) = Vu(t) = \iint_{\tau 1,\tau 2 \in R_0^+} h_2(\tau 1, \tau 2)u(t-\tau 1)u(t-\tau 2)d\tau 1 d\tau 2,$$

where h2 is a Gaussian kernel with $\mu_1 = \mu_2 = 0.1$ and $\sigma_1 = \sigma_2 = 0.05$, i.e., $h_2(\tau_1, \tau_2) = \exp((\tau_1 - \mu_1)^2/2{\sigma_1}^2 + (\tau_2 - \mu_2)^2/2{\sigma_2}^2)$, which is defined for $\tau_1, \tau_2 \in [0, 0.2]$.

K. Nakajima, H. Hauser, et al.,(in preparation) : Confident

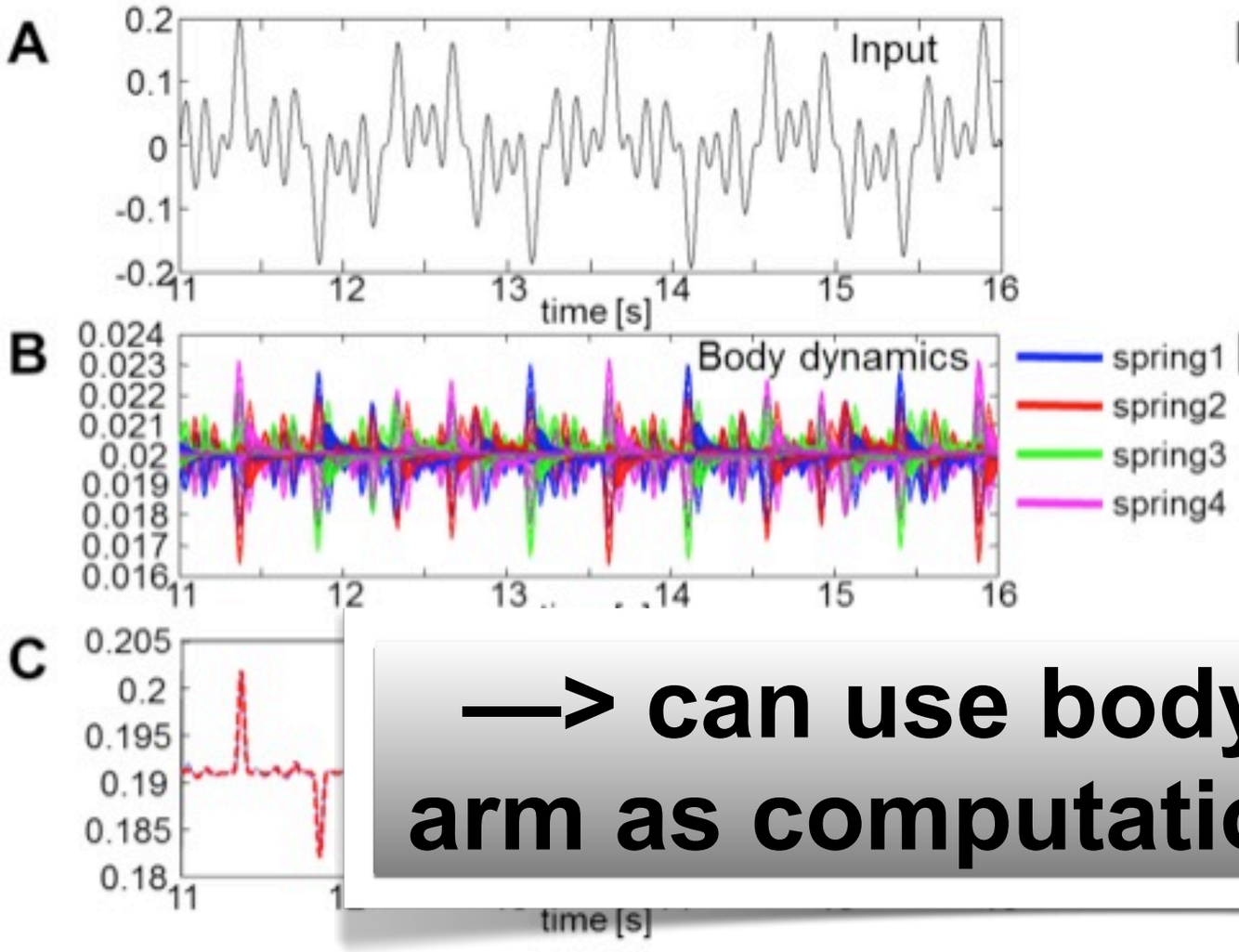
Task performance





- **2nd order non-linear dynamical system:** almost perfect
- **10th order non-linear dynamical system:** almost perfect
- **Volterra series (constrained to 100 steps):** almost perfect

Task performance



—> can use body dynamics of arm as computational resource!!

- **2nd order non-linear dynamical system:** almost perfect
- **10th order non-linear dynamical system:** almost perfect
- **Volterra series (constrained to 100 steps):** almost perfect

Body as reservoir

soft robots:

extremely rich dynamics

—> can be exploited:

- use body directly as reservoir
- non-linearity required

Body as reservoir

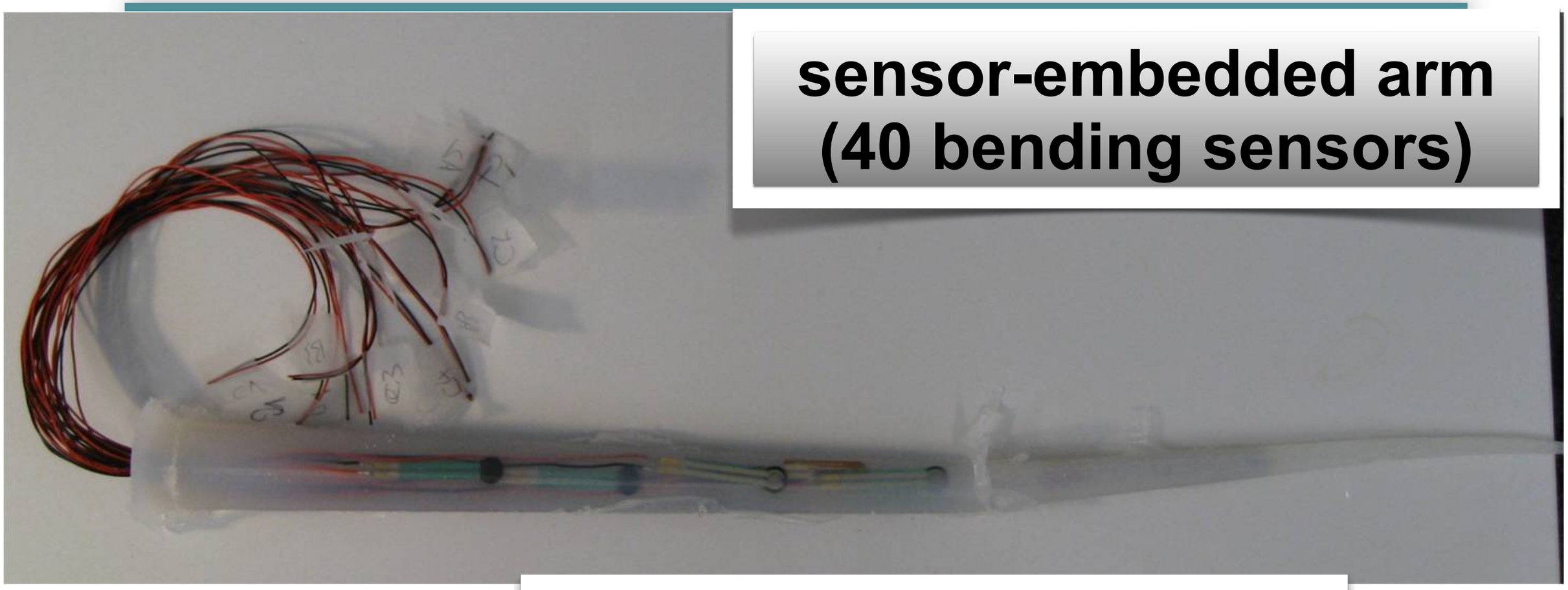
soft robots:

extremely rich dynamics

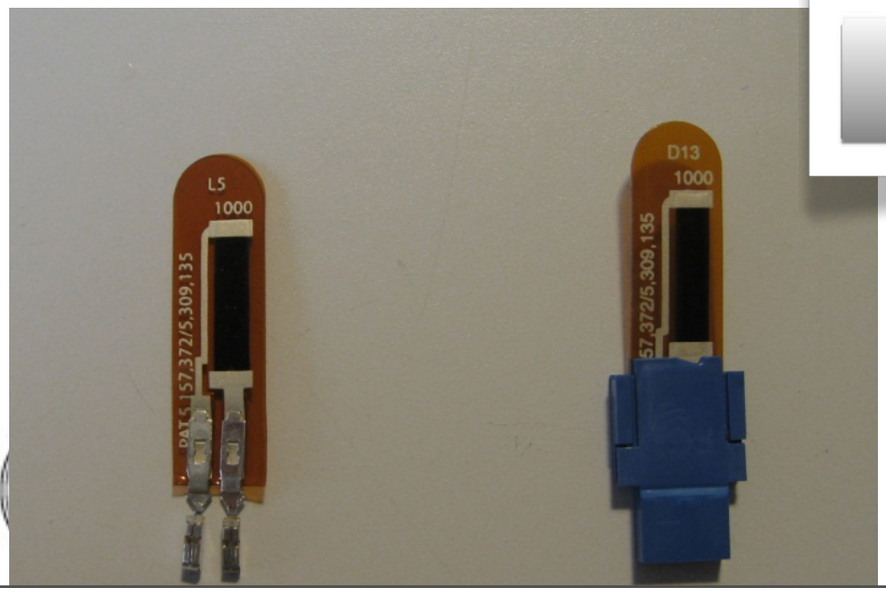
—> can be exploited:

- use body directly as reservoir
- non-linearity required

Sensorized physical arm



sensor-embedded arm (40 bending sensors)



bending sensors

robotics Swiss National Centre of Competence in Research

ai lab

The STIFF-FLOP project

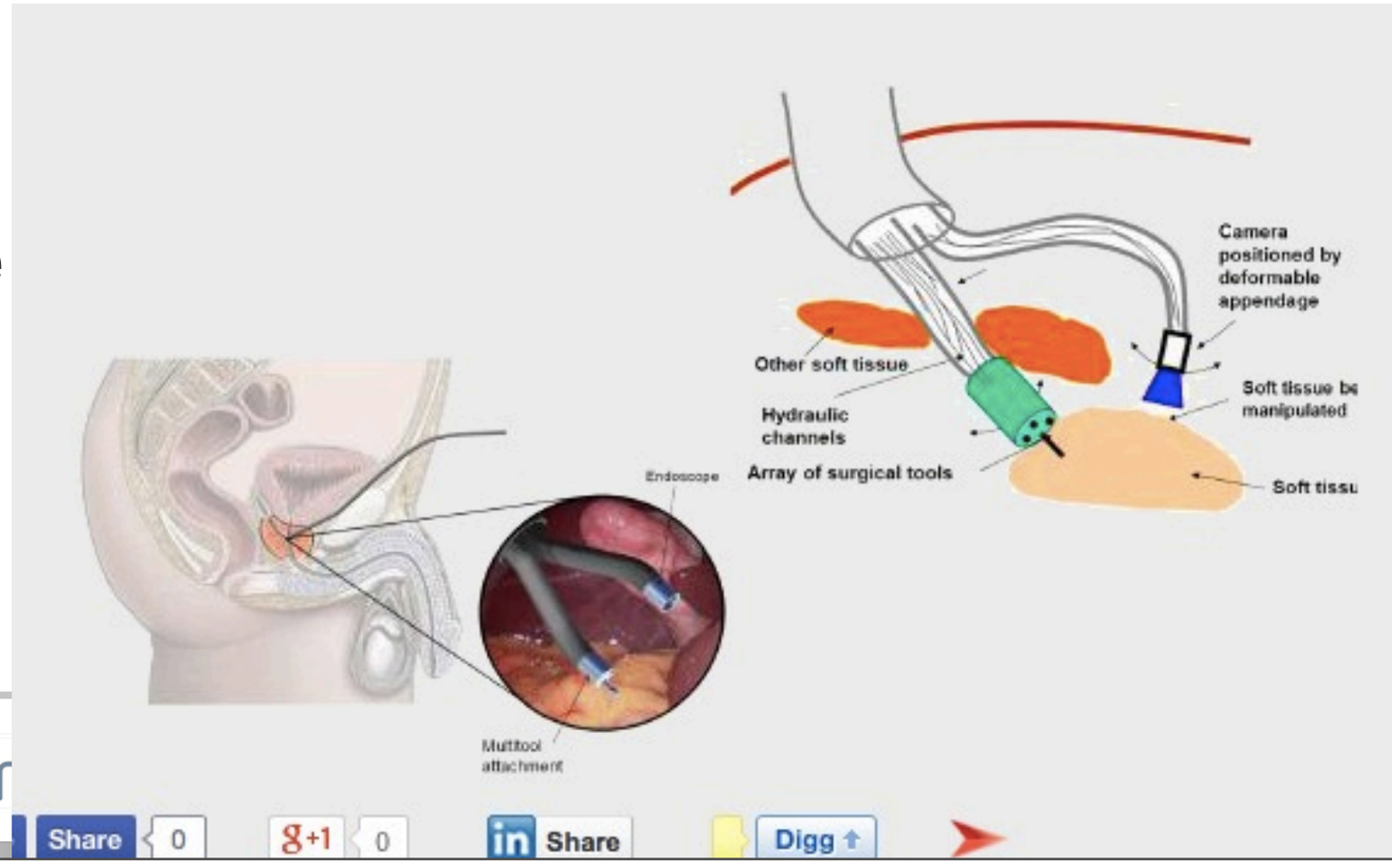
“spinout” of Octopus project

Use biological inspiration to create novel, flexible manipulator structures that are inherently capable of morphing their state from completely soft to entirely articulated

manipulation of stiffness (global dynamics)

application to minimally invasive surgery

learning from physical inter-action with envrionment



University of Zurich[UZH]

A note on “guided self-organization”

at what level to apply control?

cockroaches: configuration of shoulder joint

the Octopus robot: a paradigmatic case study

human movement and locomotion

Shuhei Miyashita’s “Tribolons”

Jürg Germann’s soft self-assembling

Morphology and computation: “trading spaces”

increasing dominance of morphology and materials
decreasing dominance of control

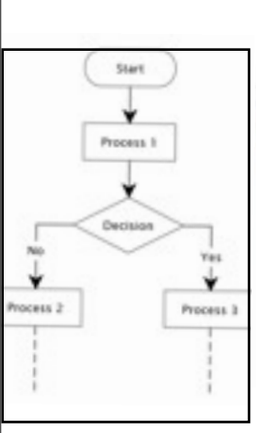
informational computation

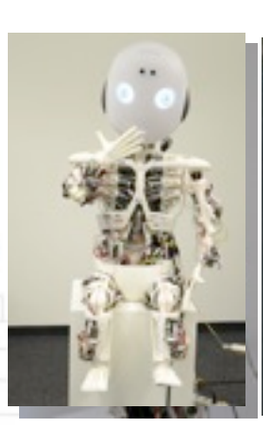
control and behavior less separable
increased reliance on self-organization

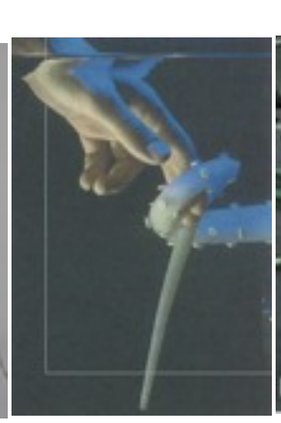
morphological computation

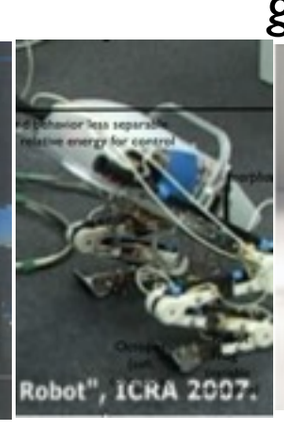
control dominant

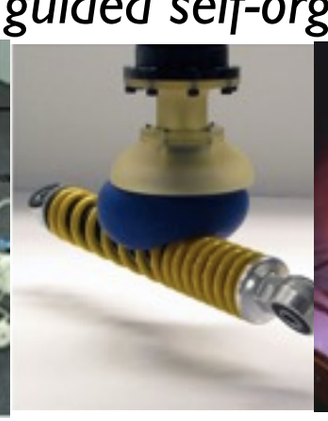
morphology and materials dominant
“guided self-organization”

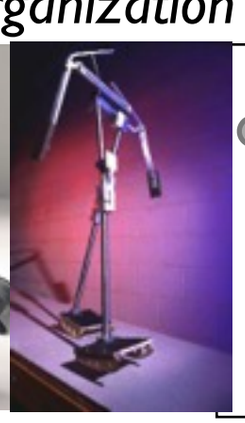


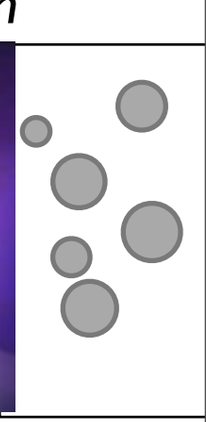












pure algorithm

computer (running algorithm)

industrial robot (centralized control

Asimo (and similar robots)

Roboy (compliant, tendon-driven)

Octopus (soft, continuous)

“Robot Frog” (variable compliance)

Jaeger-Lipson coffee-balloon gripper

PDW (exploiting morphology)

cells molecules “Tribolons”

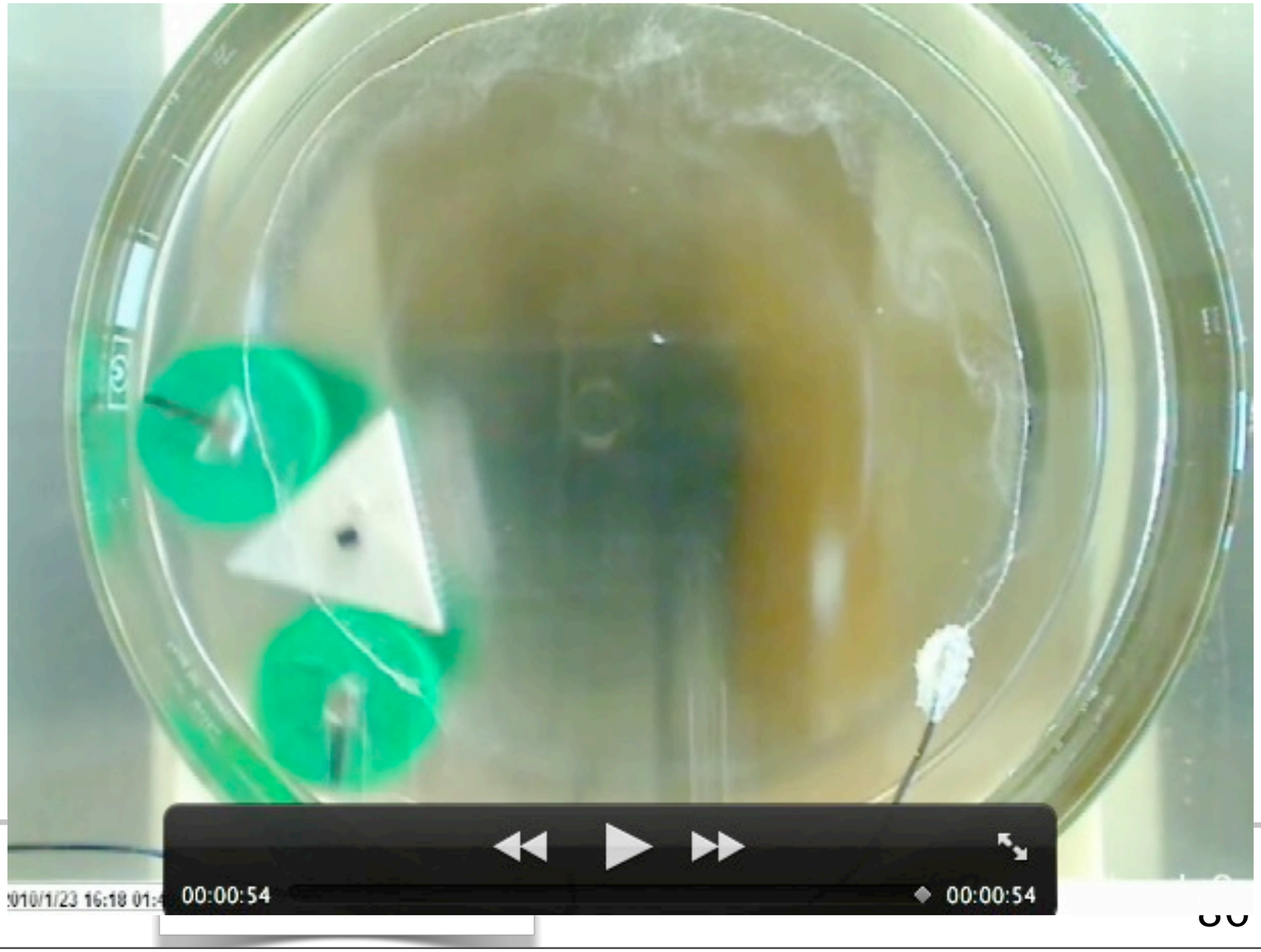
control dominant

morphology and materials dominant

Morphological Computation: self-assembly and emergent functionality

“The self-assembled, emergent bicycle”

Design and construction:
Shuhei Miyashita (previously AI Lab, now MIT)



Morphological Computation: self-assembly and emergent functionality

“The self-assembled, emergent bicylce”

morphological computation:
no control (vibration motor)
only morphology

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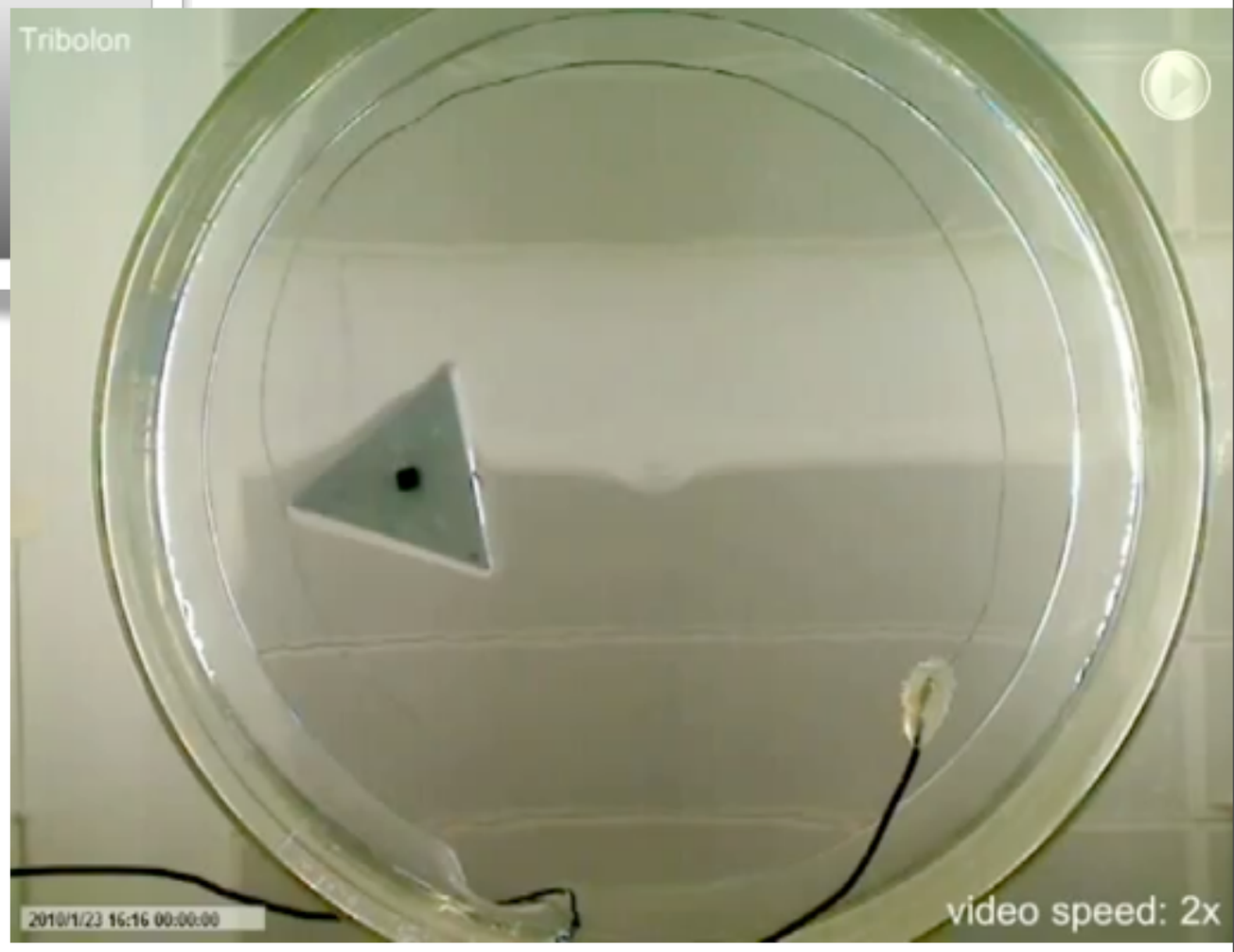

Changing the dynamics

- shape
- edges
- strength of magnet
- energy input (vibration) - dynamic

A note on “guided self-organization”

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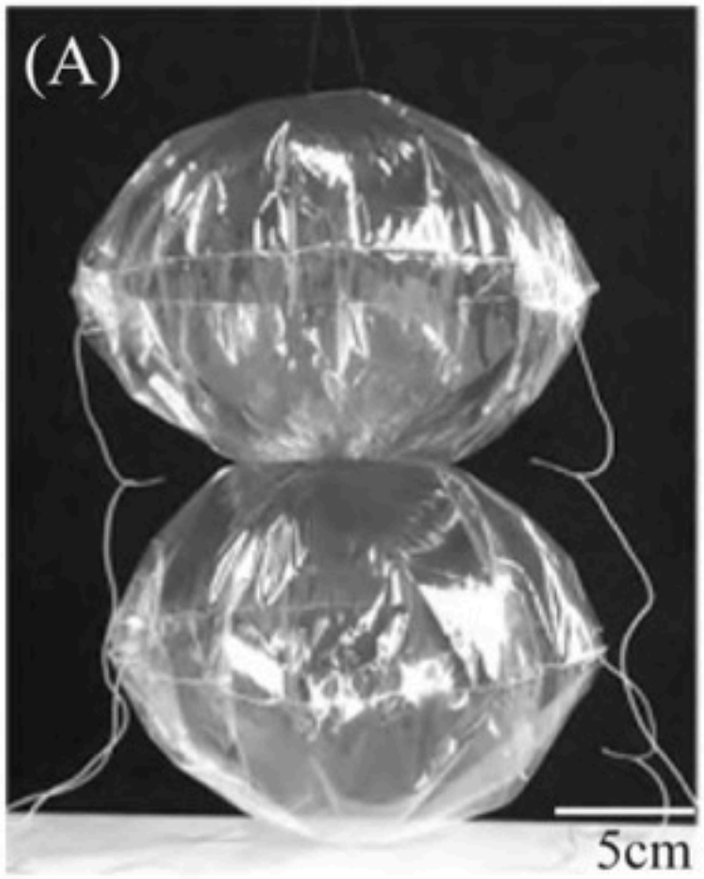
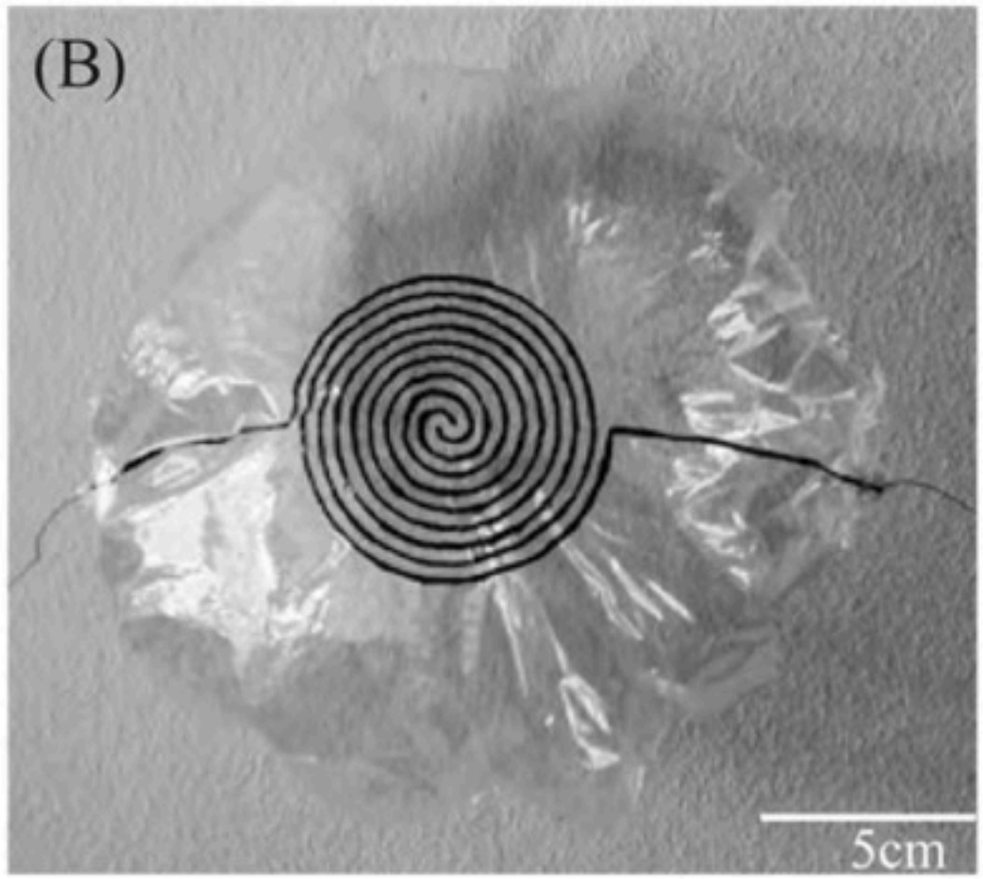
Jürg Germann’s soft self-assembling

Jürg Germann's soft cells for modular robots



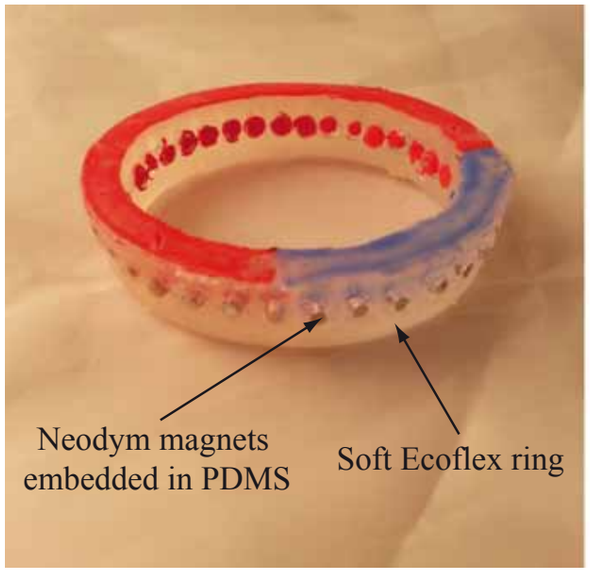


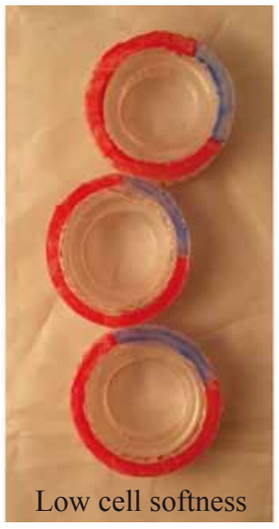
<u>soft connection mechanism</u>

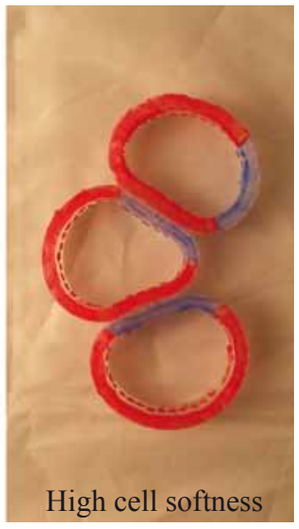
- based on electroadhesion
- reversible
- very soft
- compliance
- fault tolerance
- robustness

Figure 3.3: Fabricated prototype: (A) two modules connected together, (B) the module has a diameter of 18 cm and weighs 1.5 g, the pad has a radius of 3.9 cm and the electrode and gap width are 2 mm.

Jürg Germann's soft cells for modular robots



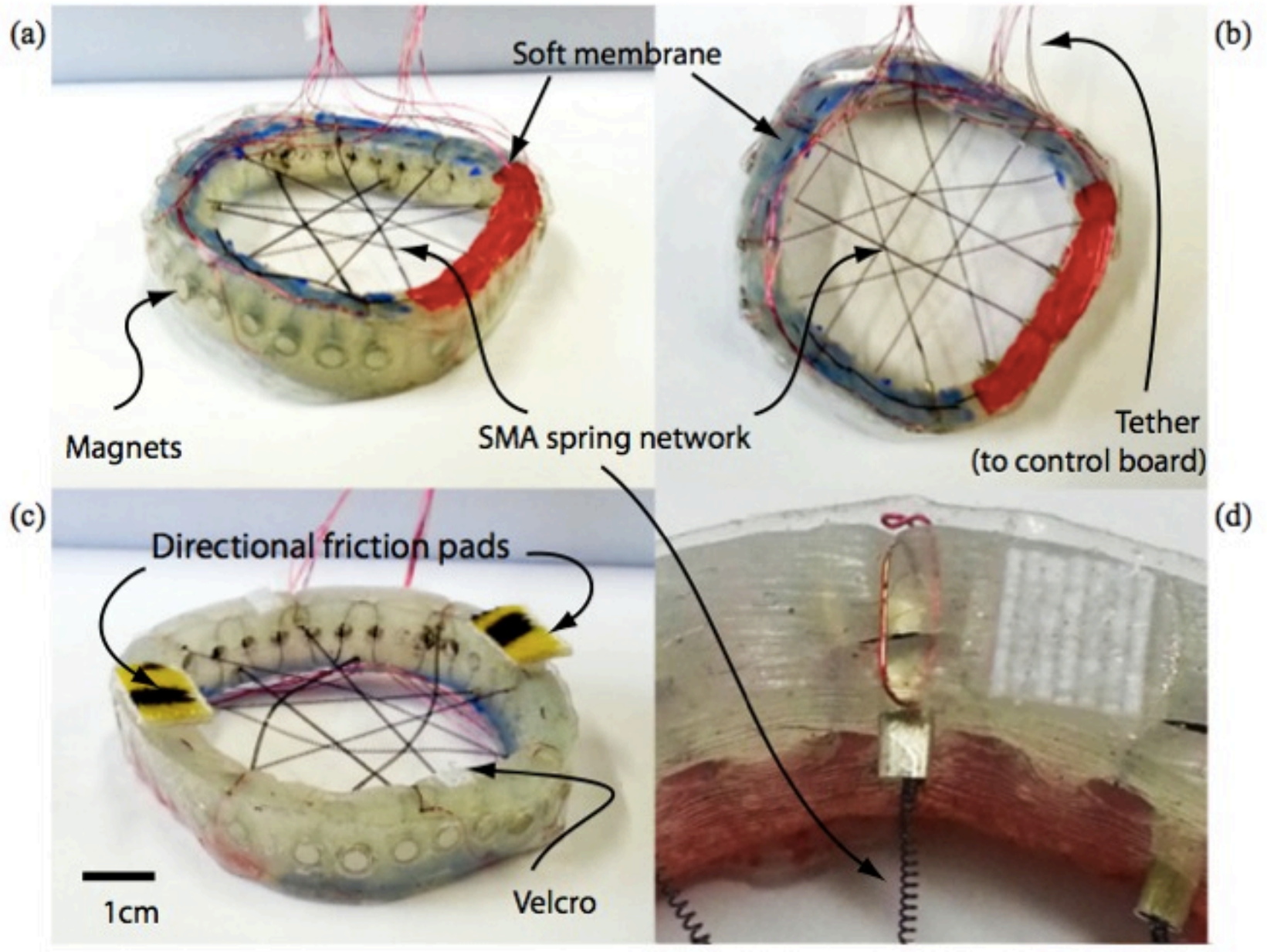




hardware cell

chain of soft cells folding into EPFL logo

Morphing mechanism

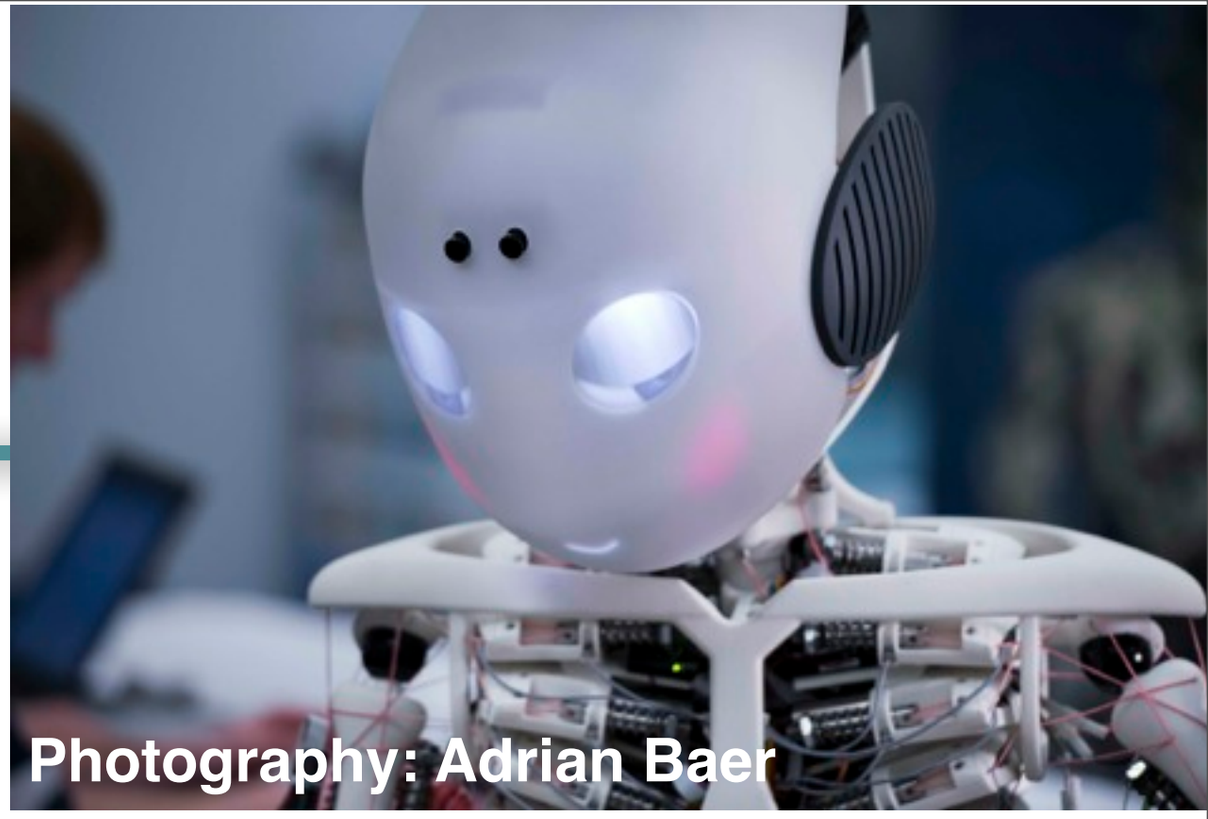


design and implementation of “morpho-functional machines”:
Juerg Germann, EPFL

Contents

- introduction and background
- principles of embodied intelligence
- the “power of materials”
- guided self-organization
- **the “Roboy” project**
- **summary and conclusions**

Roboy as research platform



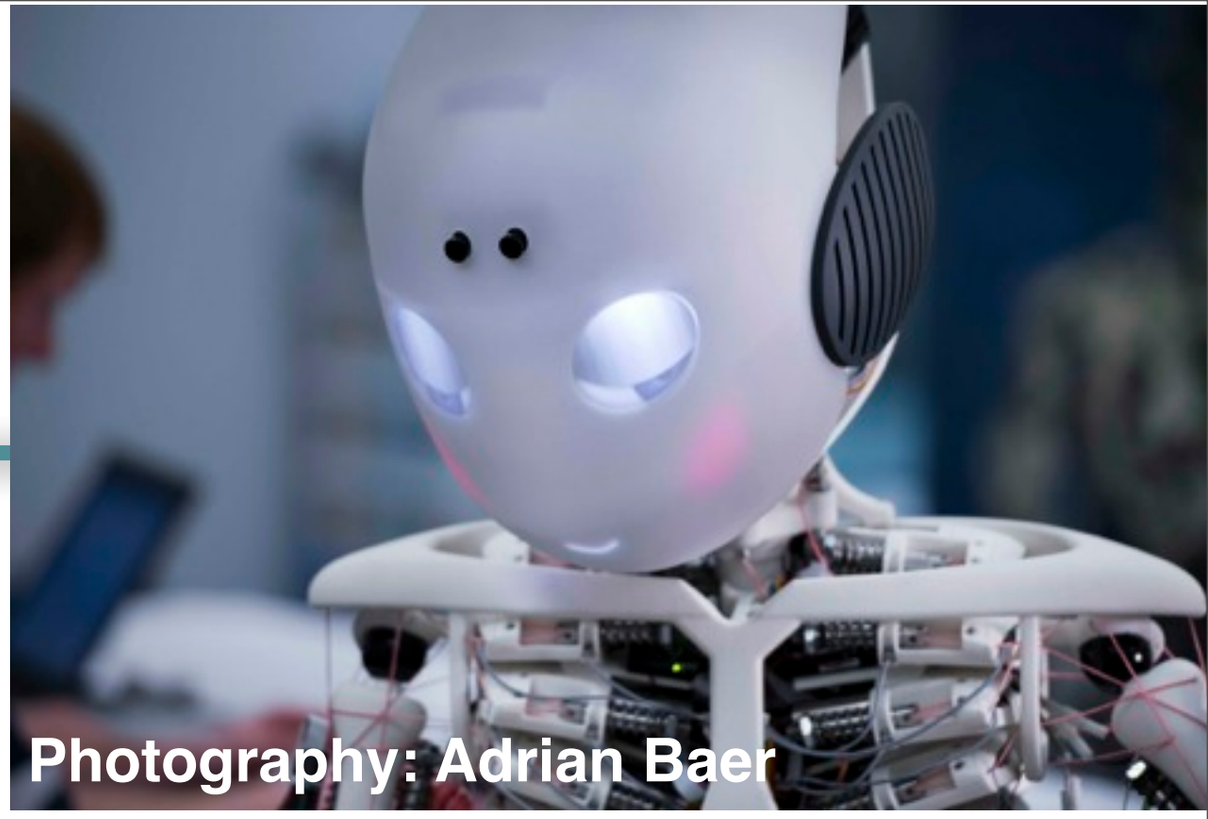
investigation of:

functioning of muscle-tendon system

relation intelligence/thinking -- sensory-motor processes

human-robot interaction

... and



ambassador of new generation of robots

share their living space with ours

friendly, useful, fun to be with

open source, community formation

ROBOTS ON TOUR

World Congress and Exhibition of Robots, Humanoids, Cyborgs and more

START BESUCHER ROBOTER PROGRAMM REFERENTEN ORT TICKETS KONTAKT ENGLISH

9. MÄRZ 2013 | 09.00–20.00 Uhr

PULS 5 | Giessereistrasse 18 | 8005 Zürich

Roboter für Jung und Alt in Zürich – reservieren Sie sich Ihr Ticket

***** Ausverkauft *****

AUSVERKAUFT

Robots on Tour ist ausverkauft. Leider gibt es auch keine Tickets mehr an der Tageskasse.

25 Jahre AI Lab Zürich:

20 Sekunden

Profis diskutieren

ZÜRICH. Wie werden Mensch und Maschine zusammen leben? Das diskutieren Forscher am Kongress «Robots on Tour» im Café Sphères in Zürich. In einer Podiumsdebatte geht es unter anderem darum, ob Roboter die Altenpflege übernehmen werden. Eintritt frei.
Fr, 8.3., 8.45–17 Uhr, Sphères, Hardturmstrasse 66, Zürich.
www.robotsontour.com

Roboter für alle

ZÜRICH. Roboter aus der ganzen Welt können Besucher an der Robotershow im Puls 5 in Zürich erleben. Ein Laufroboter will mit einer Batterieladung 65 Kilometer marschieren, Quadrokopter bieten eine Flugshow und Roboter aus Hollywoodfilmen lassen sich bestaunen. **Sa, 9.3., 9–20 Uhr, Puls 5, Giessereistrasse 18, Zürich.**
www.robotsontour.com

VERLOSUNG

«Wissen in 20 Minuten» verlost 5 Tickets für die Robotershow am 9.3. in Zürich. Teilnahme per Mail, Betreff «Roboter» an, win@scitec-media.ch. Einsendeschluss ist Dienstag, 5.3.

Invasion in Zürich – die Androiden kommen

ZÜRICH. Die besten dem Menschen nachempfundenen Roboter versammeln sich am 8. und 9. März in Zürich. Forscher aus aller Welt zeigen, warum sie Maschinen menschliche Züge geben wollen.

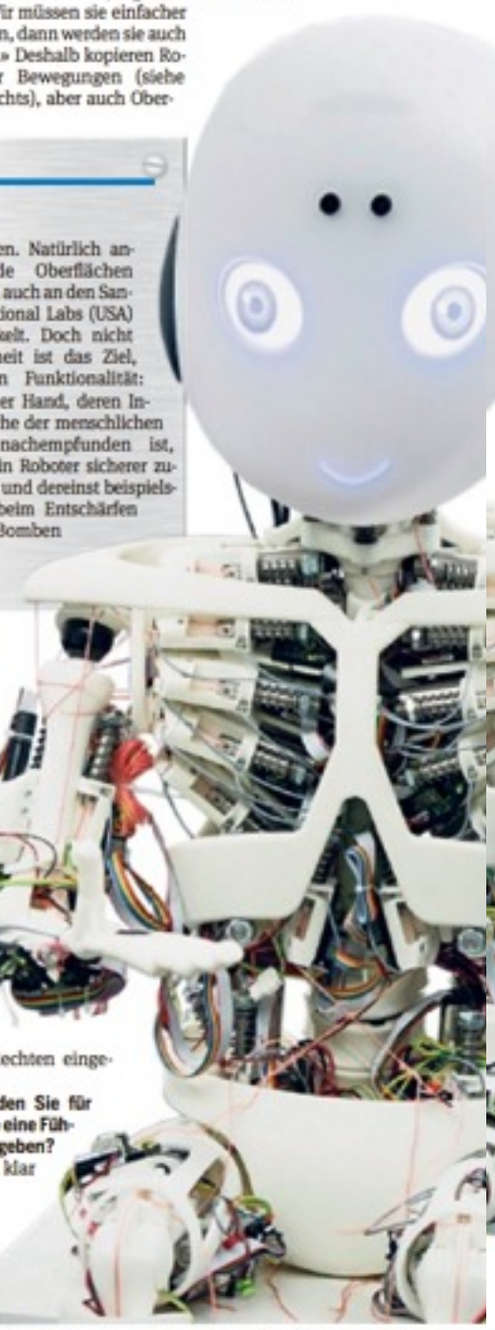
Aufgerufen zum Kongress «Robots on Tour» hat Rolf Pfeifer, der Direktor des Labors für Künstliche Intelligenz der Uni Zürich. Seit 25 Jahren forscht er an so genannten humanoiden Robotern, deren Bauweise und Funktionen denen des Menschen abgeschaut sind. Dies hat seinen guten Grund. «Die Roboter von früher waren zu schwer und zu sehr wie Maschinen konstruiert», sagt Pfeifer. «Wir müssen sie einfacher machen, dann werden sie auch besser.» Deshalb kopieren Robotiker Bewegungen (siehe Box rechts), aber auch Oberflächen und sogar Gesichtsausdrücke des Menschen. Denn die Natur ist immer noch das beste Vorbild.
BEAT GLOGGER

Oberflächen

Der Mensch dient als Vorbild

OSAKA/ALBUQUERQUE. Wie ähnlich sich Mensch und Maschine sein können, zeigt Hiroshi Ishiguro von der Uni Osaka (JPN). Sein Geminoid HI-1 ist ihm wie aus dem Gesicht geschnitten. Natürlich anmutende Oberflächen werden auch an den Sandia National Labs (USA) entwickelt. Doch nicht Schönheit ist das Ziel, sondern Funktionalität: Mit einer Hand, deren Innenfläche der menschlichen Haut nachempfunden ist, kann ein Roboter sicherer zugreifen und dereinst beispielsweise beim Entschärfen von Bomben helfen.
FEE


Geminoid HI-1 (links) und sein Schöpfer Hiroshi Ishiguro. KEY


Roboy ist das jüngste Familienmitglied der menschenähnlichen Roboter

Roboy – ganz natürlich

Am Kongress stellt das Labor für Künstliche Intelligenz den Roboter Roboy vor, den jüngsten Spross in der Familie der Humanoiden. Seine Anatomie ist der des Menschen nachempfunden. So hat er zum Beispiel auch künstliche Sehnen. Dadurch bewegt er sich menschenähnlicher als eine Maschine aus Stangen und Kugellagern. Denn natürliche Bewegungen entstehen nicht nur durch Muskelkraft, sondern auch passiv durch den Einfluss der Schwerkraft. Zum Beispiel, wenn man den Arm hebt und wieder fallen lässt. Roboy wurde in nur neun Monaten von einem internationalen Verbund von Forschern und Firmen erschaffen – finanziert durch Sponsoren und Crowdfunding. LO


aus Zürich. KEY

Gehirn

Steuern mit Gedankenkraft


Gedankengesteuerter Rollstuhl.

LAUSANNE/PITTSBURGH. Ein Rollstuhl, der sich nur mittels Gedanken steuern lässt, wurde an der ETH Lausanne gebaut. Der gelähmte Patient trägt eine Elektrodenkappe auf dem Kopf, die seine Hirnströme auffängt. Damit kann er das Gefährt steuern. Einen ähnlichen Erfolg erzielte eine Forschungsgruppe aus Pittsburgh (USA). Diese hatte einer Tetraplegikerin zwei Elektroden in die Grosshirnrinde implantiert. Mit der Hilfe dieser Neuroprothese gelang es der Patientin nach nur 13 Wochen Training, einen Roboterarm durch Gedankenkraft zu bewegen. LO

Helfende Hände

Dem Menschen stets zu Diensten

WINTERTHUR. Schon jetzt gibt es Roboter, die Staub saugen oder Rasen mähen. Doch künftig sollen Maschinen komplexere Dienstleistungen erbringen, zum Beispiel in der Altenpflege. Toyota hat bereits einen «Patienten-Transfer-Assistenten» entwickelt, der dem Pflegepersonal hilft, Patienten auf die Toilette und wieder zurück ins Bett zu bringen. In der Schweiz bereits getestet wurde Paro, eine Roboter-Robbe mit kuscheligem Fell, die Alten und Demenzkranken Gesellschaft leistet. Aber diese Entwicklung löst auch Unbehagen aus: «Viele Menschen befürchten, Maschinen könnten das Personal ersetzen», sagt Heidrun Becker vom Institut für Ergotherapie der ZHAW. Sie hat kürzlich eine Studie zu Robotern in der Gesundheitsversorgung durchgeführt.

Roboter können aber auch als Begleiter des Menschen und zur Unterhaltung dienen. Zum Beispiel RoboThespian, ein in England entwickelter interaktiver Roboter, der mehrere Sprachen spricht. Vorstellbar ist auch, dass Roboter bestimmte Jobs erledigen. So könnten sie zum Beispiel als Müllmänner, Kassiererinnen oder – laut einer Studie neuseeländischer Forscher – sogar als Prostituierte arbeiten. HO


RoboThespian steht als Begleiter zur Seite. ENGINEERED ARTS

Emotionen

Maschinen drücken Gefühle aus

OSAKA/BIELEFELD. Lächeln, die Stirn runzeln oder traurig schauen: Bereits jetzt können Roboter menschliche Emotionen nachahmen. Zum Beispiel der Roboter-Knabe Affetto, den Forscher der Uni Osaka (JPN) entwickelt haben.

«Echte Gefühle haben Roboter aber nicht», sagt Informatiker Ingo Lütkebohle von der Uni Bielefeld (D). Um das zu verdeutlichen und keine Ängste zu wecken, ähnelt der an seiner Uni entwickelte Roboter Flobi einer Comicfigur und nicht einem Menschen. Flobi könnte dereinst Astronauten auf der ISS oder Forschern in der Antarktis Gesellschaft leisten. HO


Affetto: menschliche Mimik. UNI OSAKA

Der Gast


Rolf Pfeifer. FOTO: D. LANDWE

Humanoide Zukunft?

«Intelligenz ist einer der meistgeschätzten Werte in unserer Gesellschaft. Darum wecken intelligente Roboter Ängste. Sie erinnern an Science-Fiction, Hollywood und «Terminator». Dabei haben intelligente Maschinen schon jetzt viele Tätigkeiten von Menschen übernommen: Sie rechnen, saugen Staub oder schweissen Motoren zusammen. Und sie sind uns in vielerlei Hinsicht überlegen, weil sie schneller, zuverlässiger und billiger sind. Das stört nicht, solange es sich um Einzeltätigkeiten und spezialisierte Geräte handelt. Doch je menschenähnlicher uns die Maschinen sind, desto mehr bereiten sie uns Sorgen. Sollen wir also solche humanoiden Roboter entwickeln? Mit Roboy haben wir uns bewusst für einen Androiden entschieden. Er ist Botschafter und Wegbereiter für eine neue Generation von Robotern, die künftig mit uns den Lebensraum teilen und nützliche Aufgaben erfüllen werden. Mit ihnen werden wir gerne zusammen sein. Roboy ist eine Forschungsplattform, von der wir lernen können, wie man intelligente Systeme baut. Die Prinzipien können wir anwenden, ohne dass das Endprodukt humanoid aussehen muss.

Rolf Pfeifer ist Direktor des Labors für künstliche Intelligenz der Uni Zürich. Neben menschenähnlichen Robotern erforscht er solche, die aussehen wie Fische oder Quallen.

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«Roboter als Teil der Gesellschaft»

ZÜRICH. Pascal Kaufmann ist einer der Väter des menschenähnlichen Roboters Roboy. Er arbeitet am Labor für Künstliche Intelligenz der Uni Zürich.

Pascal Kaufmann, warum muss ein Roboter aussehen wie ein Mensch?
Will man Roboter zum Beispiel im Gesundheitswesen einsetzen, dürfen sie nicht wie Gabelstapler aussehen. Wir wollen Roboter so bauen, dass sie in die Gesellschaft integriert werden könnten.


Neurobiologe Pascal Kaufmann. STAR'ANI

Wann werden Roboter intelligenter sein als der Mensch?
Es kommt drauf an, wie man Intelligenz definiert. Wenn man einen Schachspieler als intelligent bezeichnet, dann gibt es schon lange Roboter, die dem Menschen überlegen sind. Aber das sind sie eben nur in einem ganz bestimmten Bereich.

Schürt man mit Maschinen wie Roboy nicht die Angst, dass Roboter den Menschen unterwerfen oder ihn ersetzen?
Nein, mit dem herzigen Roboter wirken wir dieser Angst entgegen. Die Leute sehen an seinem Beispiel, wie weit die Forschung derzeit ist. Und sie verstehen, dass es noch einiges braucht, bis die Roboter gleich viel können wie der Mensch.

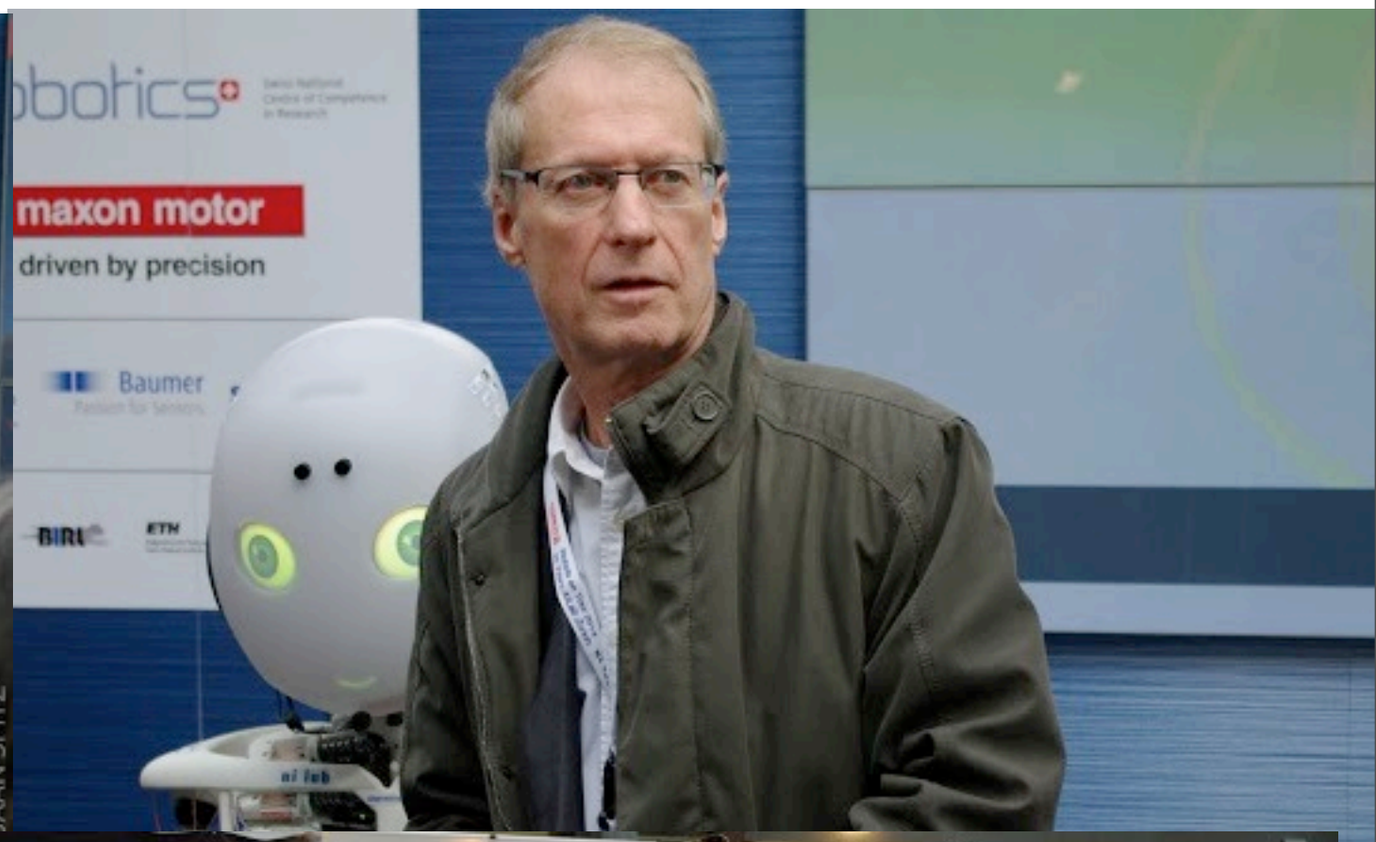
Mit Ihrem Wissen kann man auch Kriegsroboter bauen.
Das ist in der Wissenschaft immer so. Wenn Sie eine Linse oder ein neues Material erfinden, kann das immer zum Guten wie zum Schlechten eingesetzt werden.

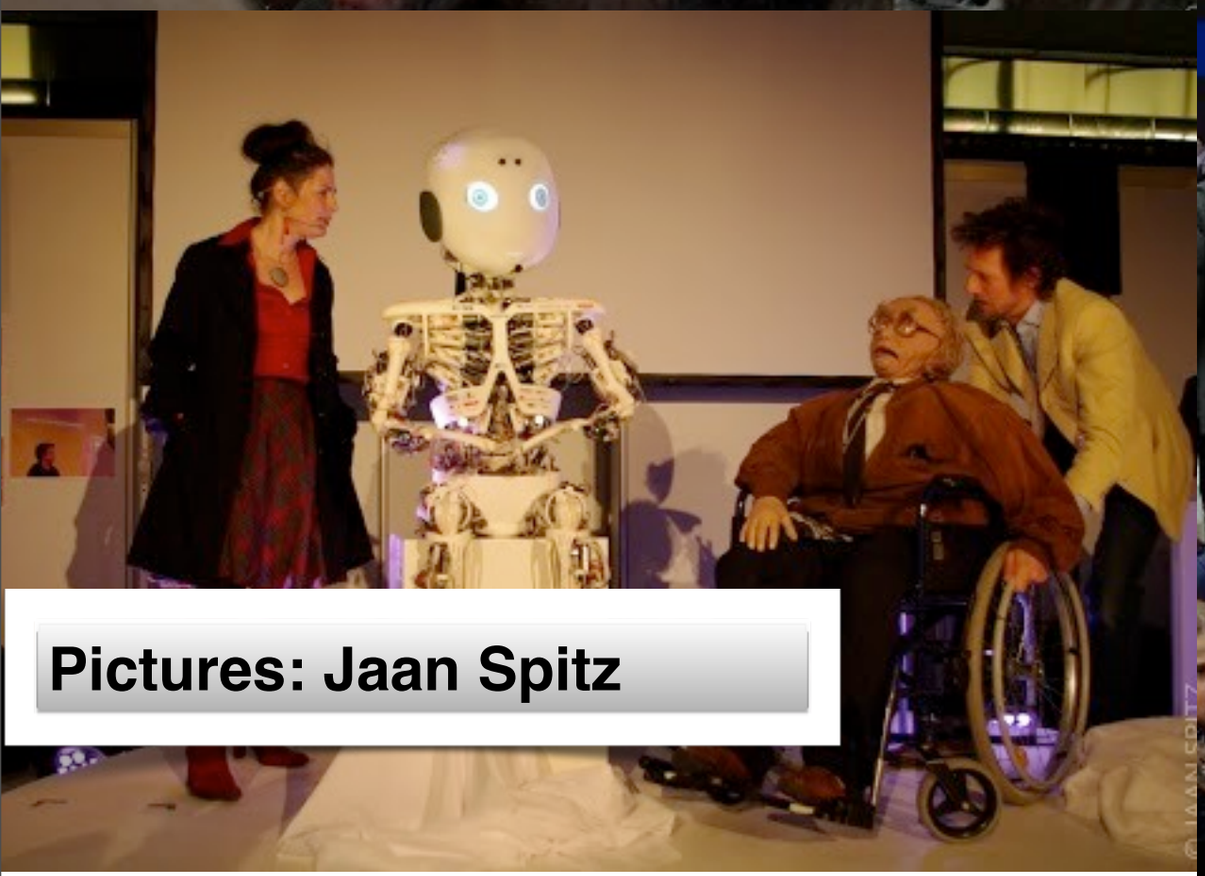
Anders gefragt: Würden Sie für die Rüstungsindustrie eine Führung durch Ihr Labor geben?
Das lässt sich ganz klar beantworten: nein.
BEAT GLOGGER

Pictures: Jaan Spitz

Zurich, Puls5
8/9 March 2013

Pictures: Jaan Spitz





Pictures: Jaan Spitz

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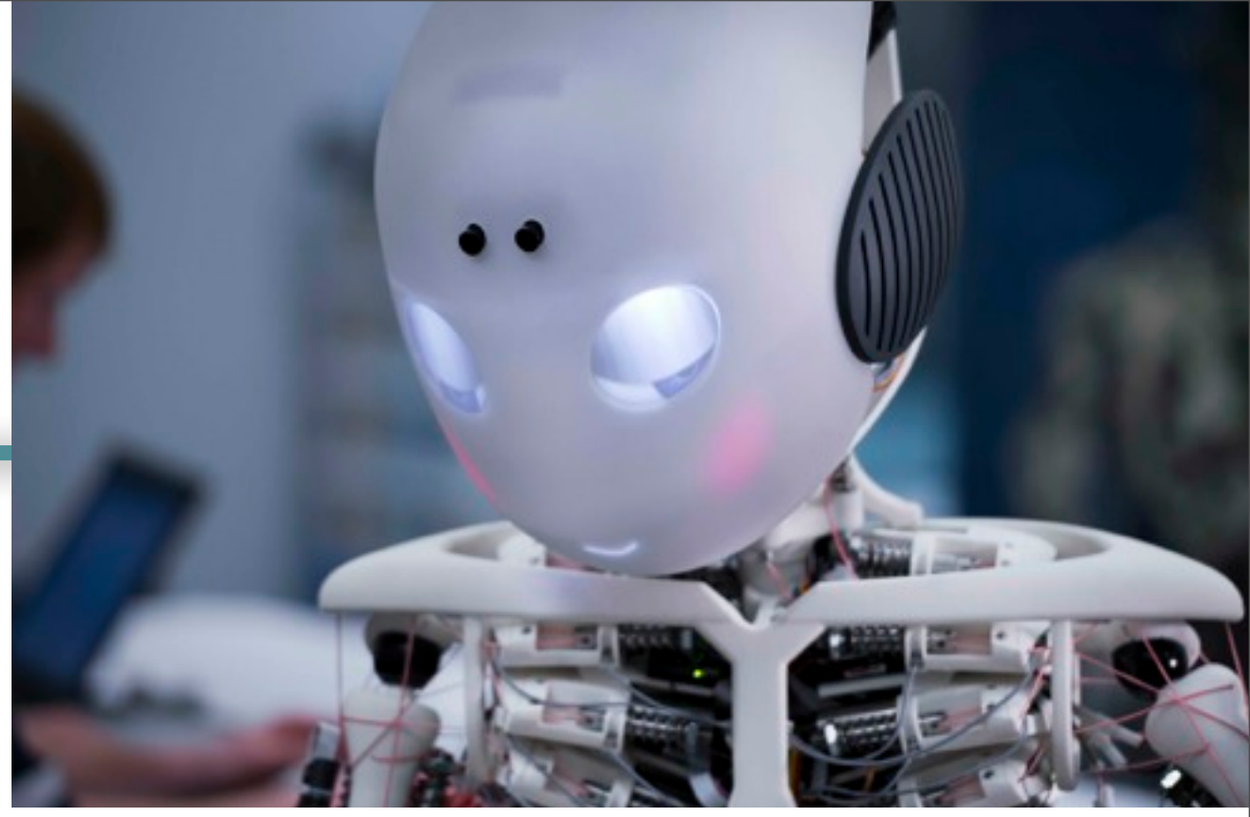
robotics Swiss National Centre of Competence in Research

ai lab

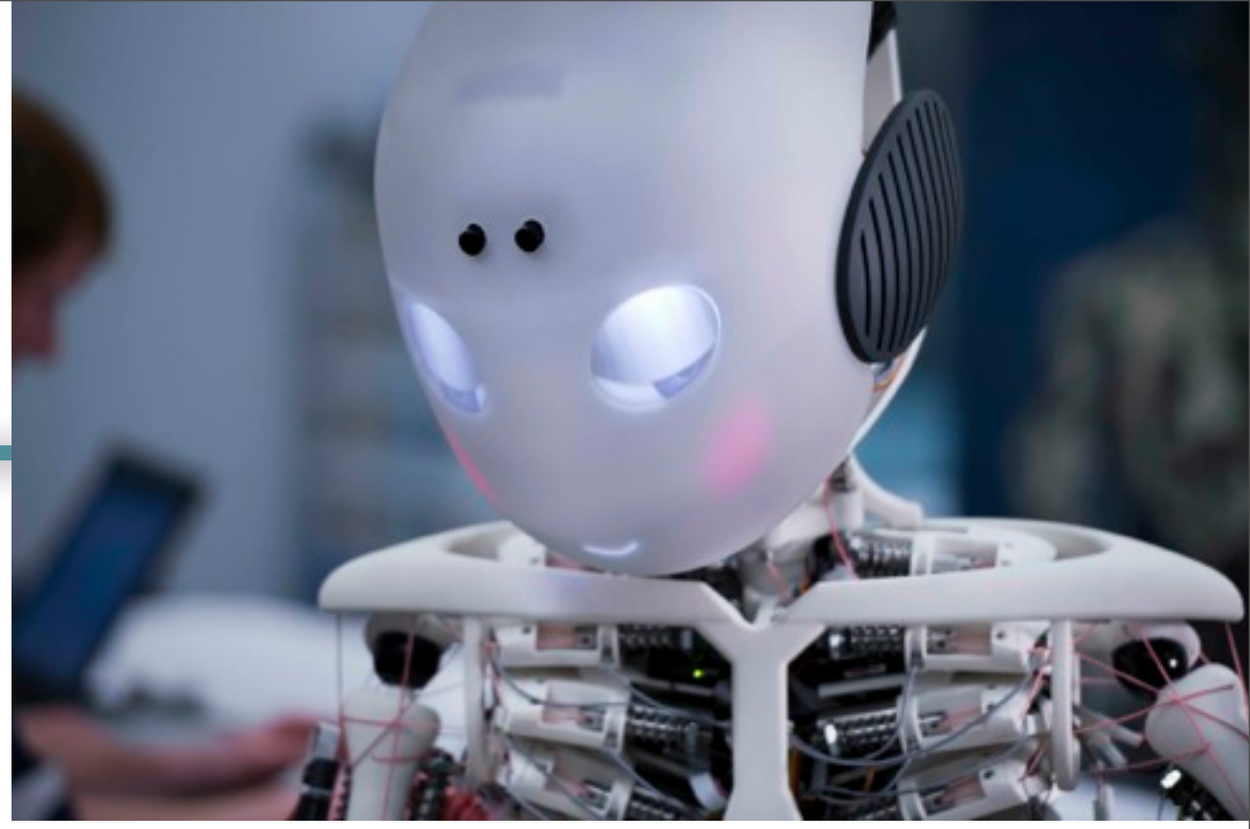
Media Coverage



BBC, Financial Times, Discovery Channel, Wired, Huffington Post, CNET, Science World Report Reuters, Keystone, National Geographic, ZDF, Bild, Welt, Süddeutsche Zeitung, Berliner Zeitung, 3SAT, Deutsche Welle, Daily Mail, SRF Tagesschau, NZZ, Tages Anzeiger, 20Minuten, Züricher Wirtschaftsmagazin, MIT Technology Review, ...

Switzerland, Germany, France, Spain, England, Sweden, Italy, Turkey, Irland, Greece, Japan, China, India, USA, Canada, Brasil, Chile, Argentina, Vietnam, Israel, Egypt, Mexico, Korea, Russia, ...

Roboy on Tour



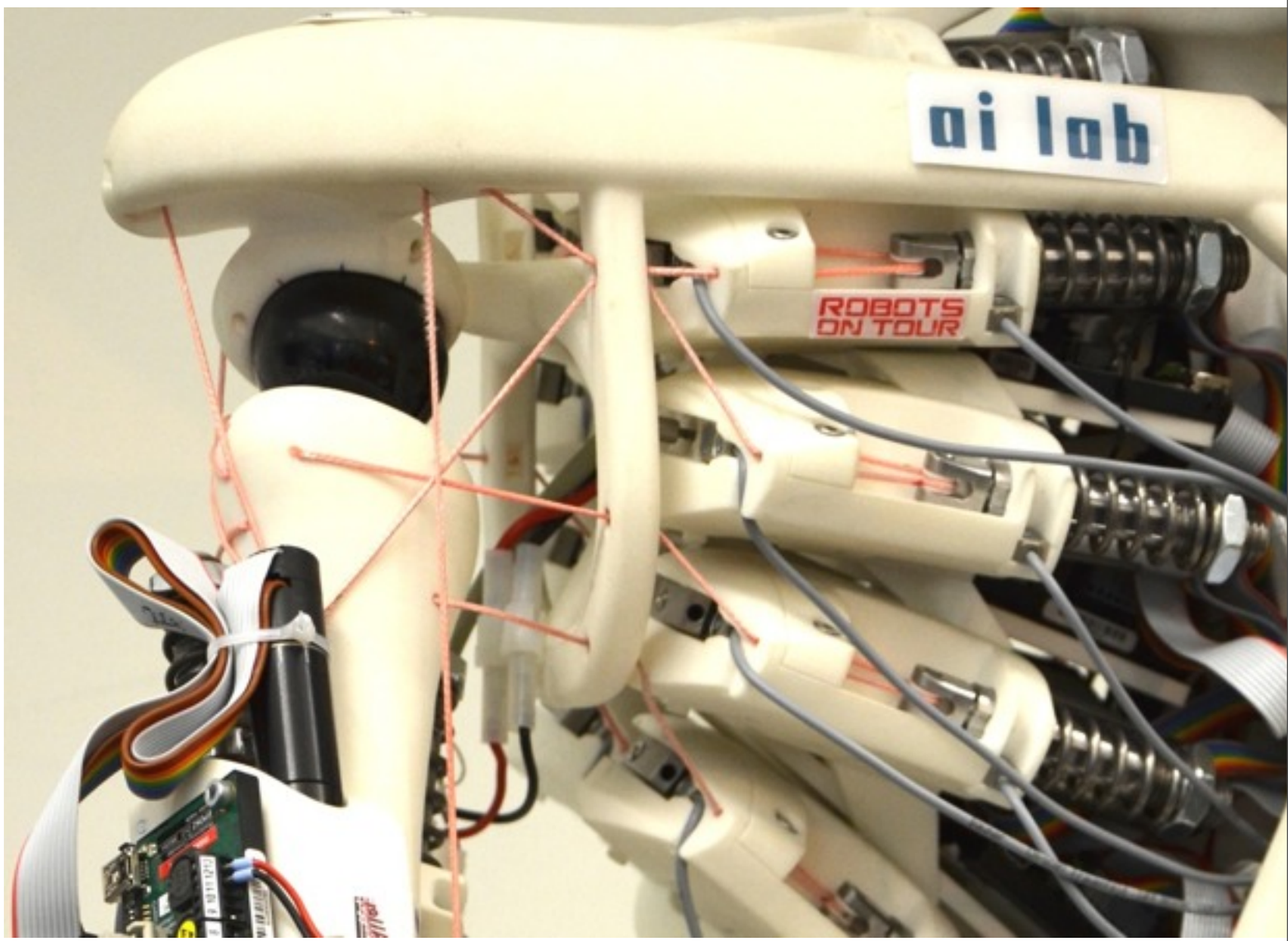
Itinerary:
ICRA (Karlsruhe), Swiss Innovation Fair (Zurich), Munich (TU), Beijing and Shanghai (China), Washington, D.C. (US), Zurich TEDx, Dornbirnd (Austria), Tokyo (Japan), Cebit - Hannover, London (UK) ...

Roboy as research platform

tendon-driven

48 “muscles”

shoulder joint:
8 “muscles”



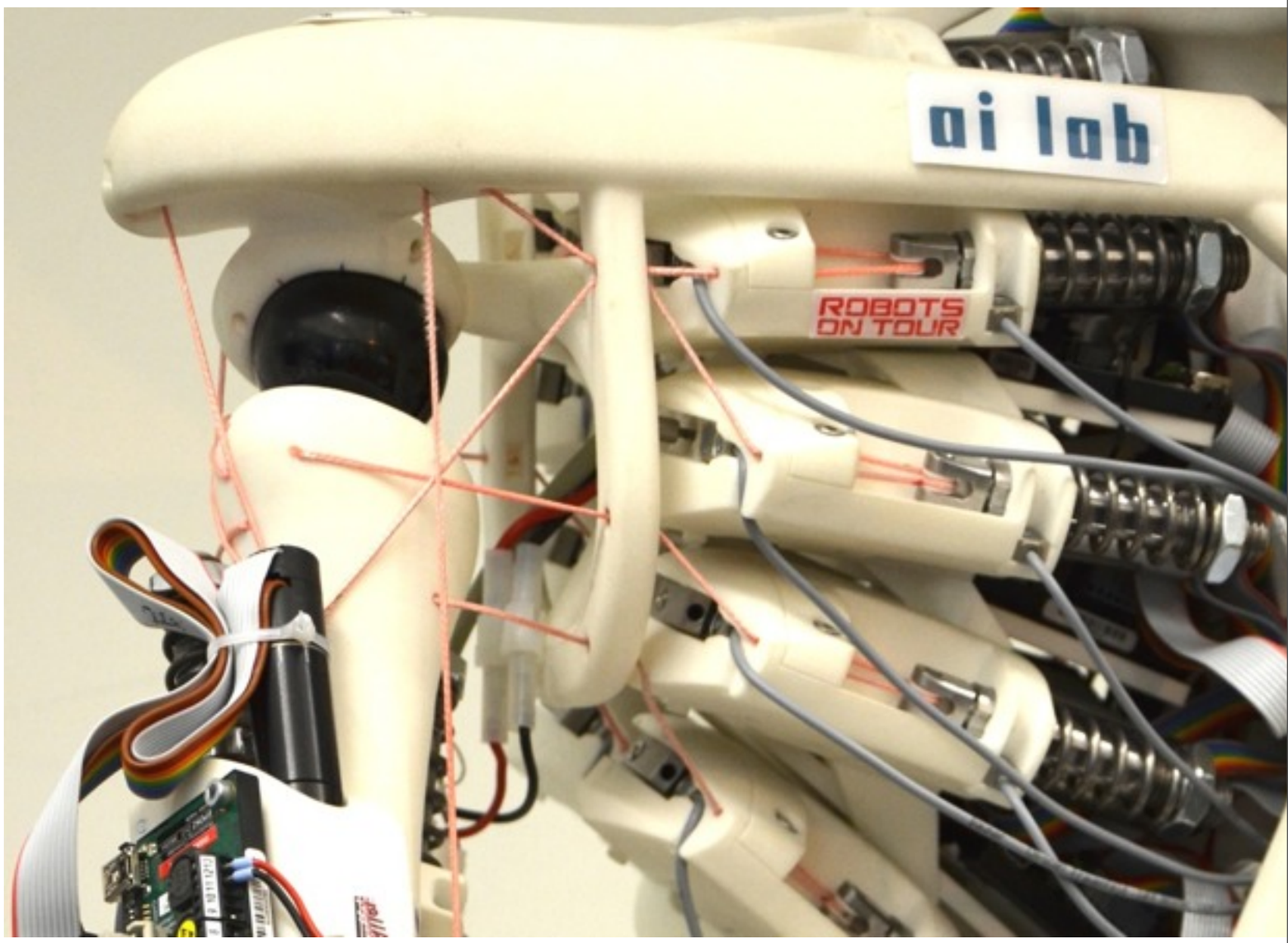
Roboy as research platform

tendon-driven

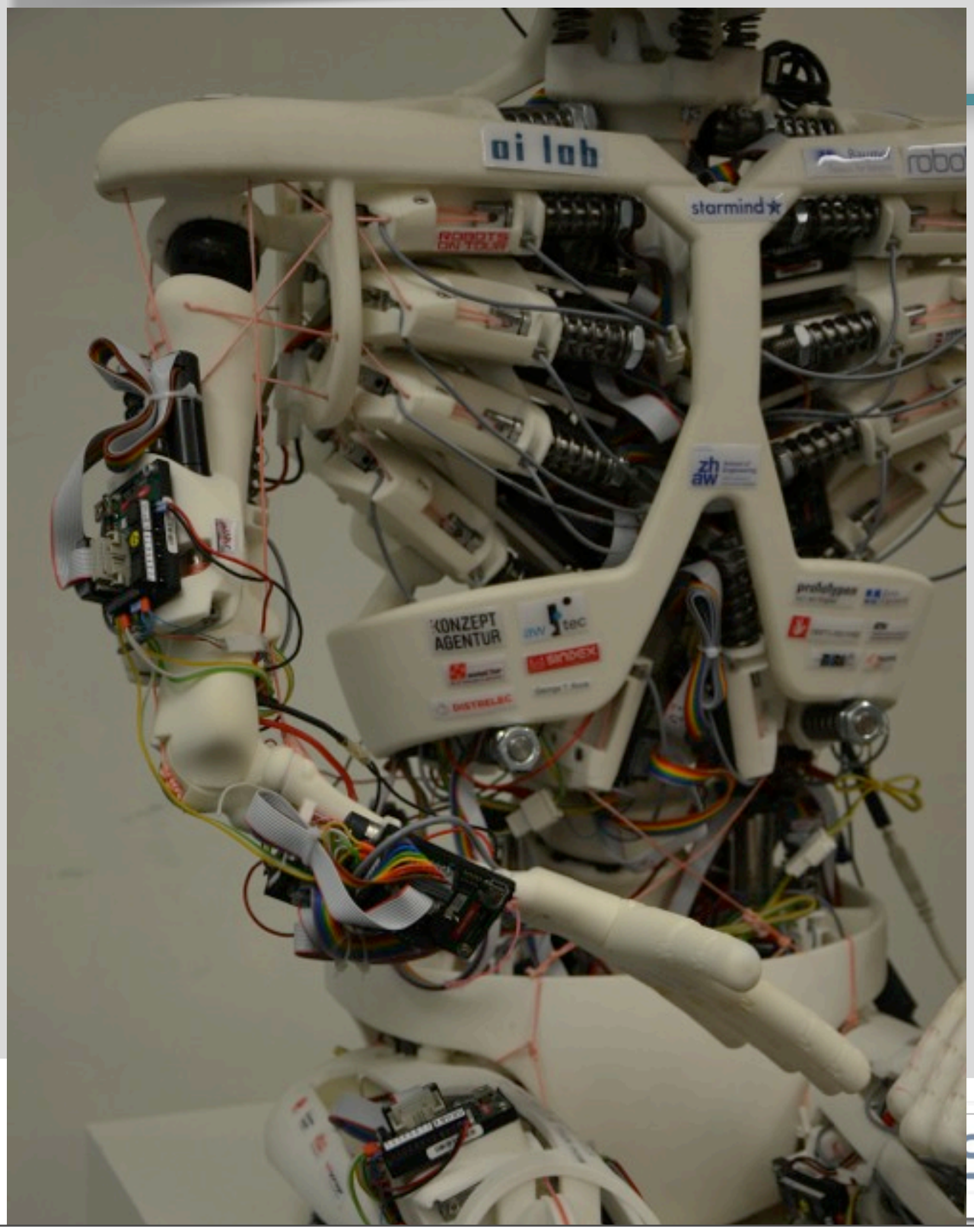
48 “muscles”

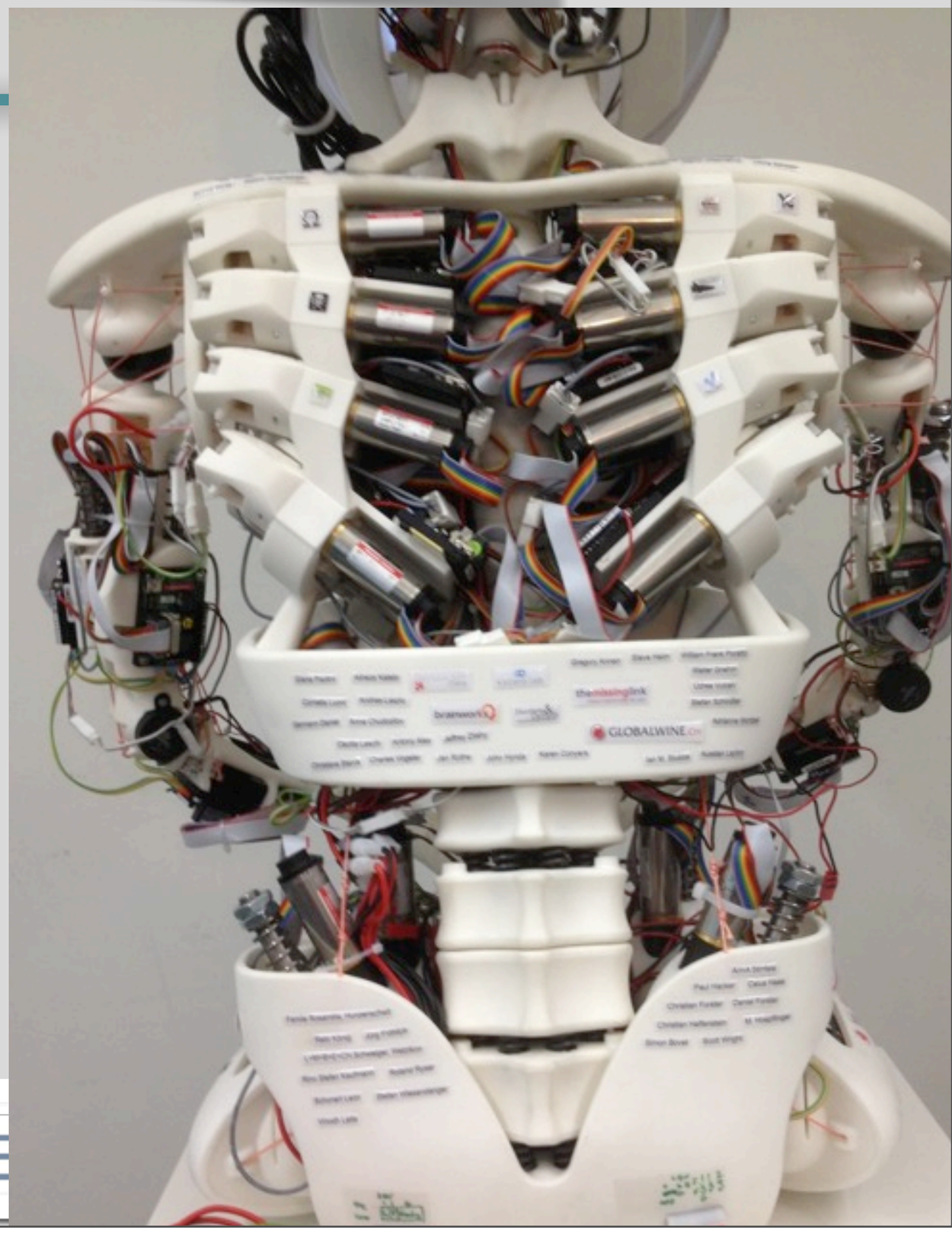
shoulder joint:
8 “muscles”:

--> learning not programming



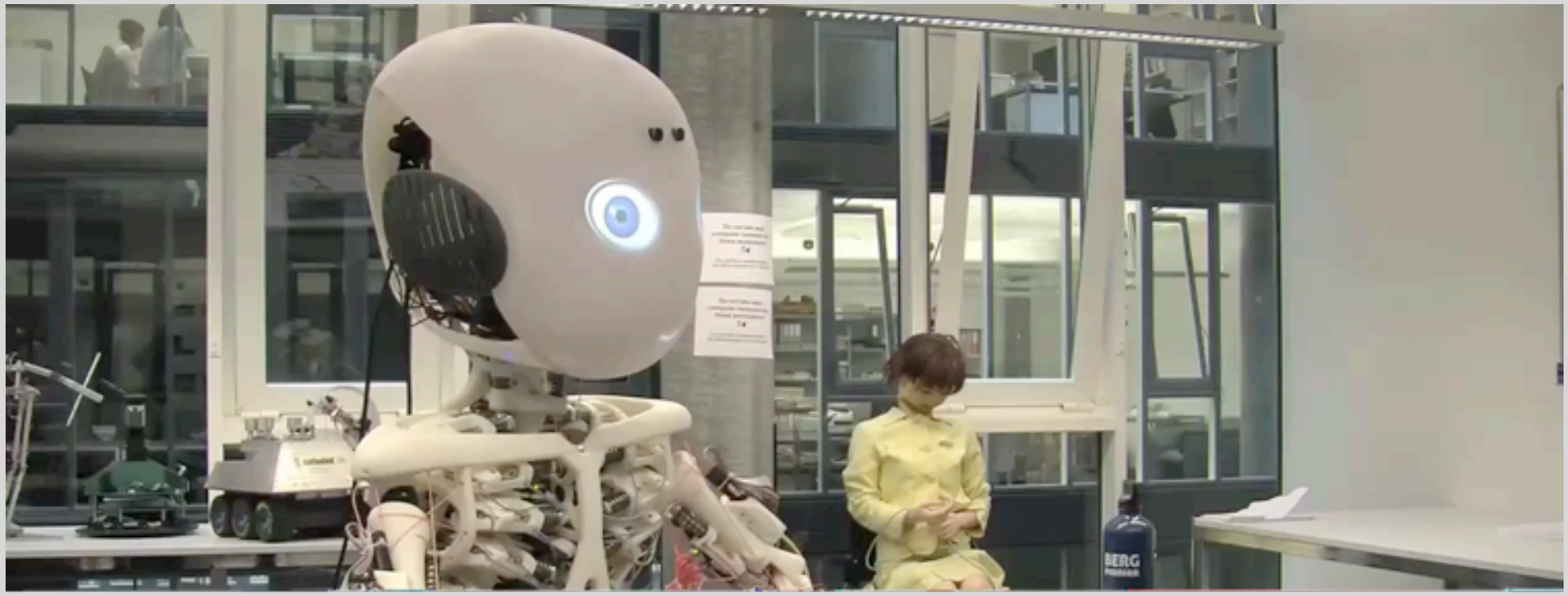
Sponsors - Logos on Roboy



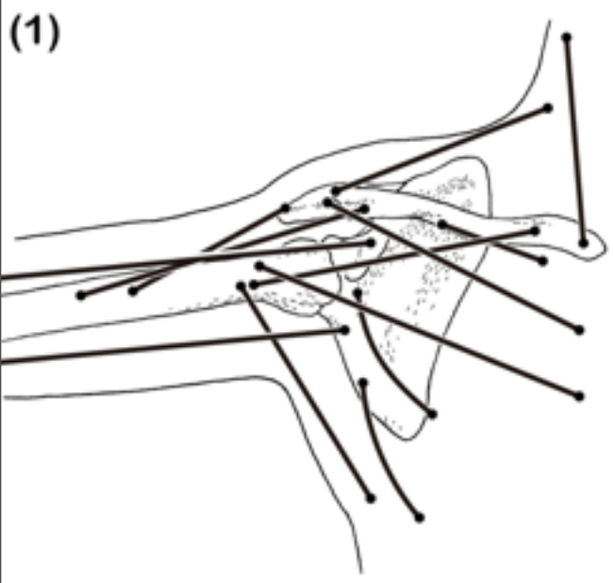


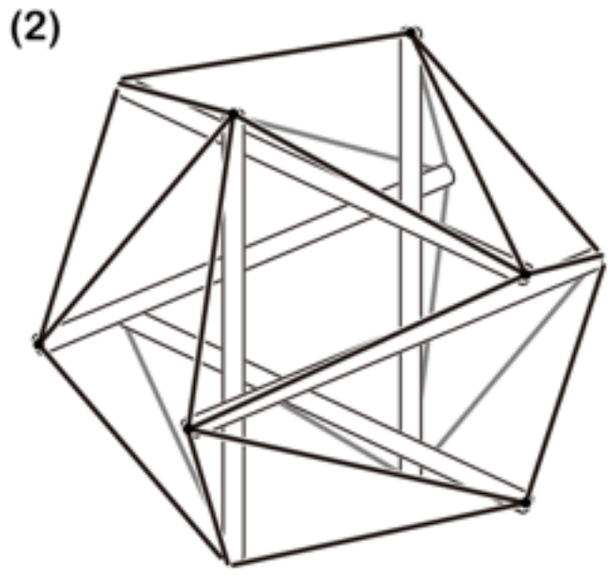
Various Youtube videos
March 2013

Various Youtube videos
March 2013



Humans, Roboy: tensegrity structures?



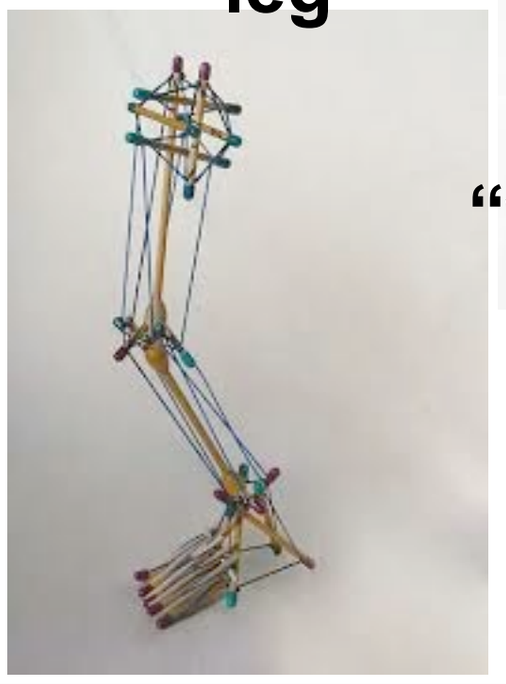


tensegrity and self-organization:

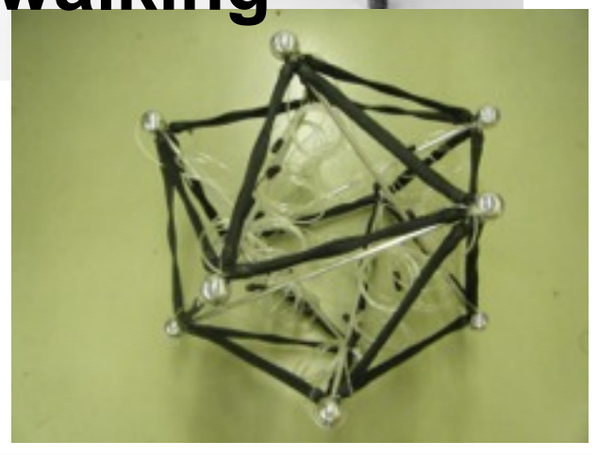
“orchestration” of movement, rather than control

“pelvis”

“leg”

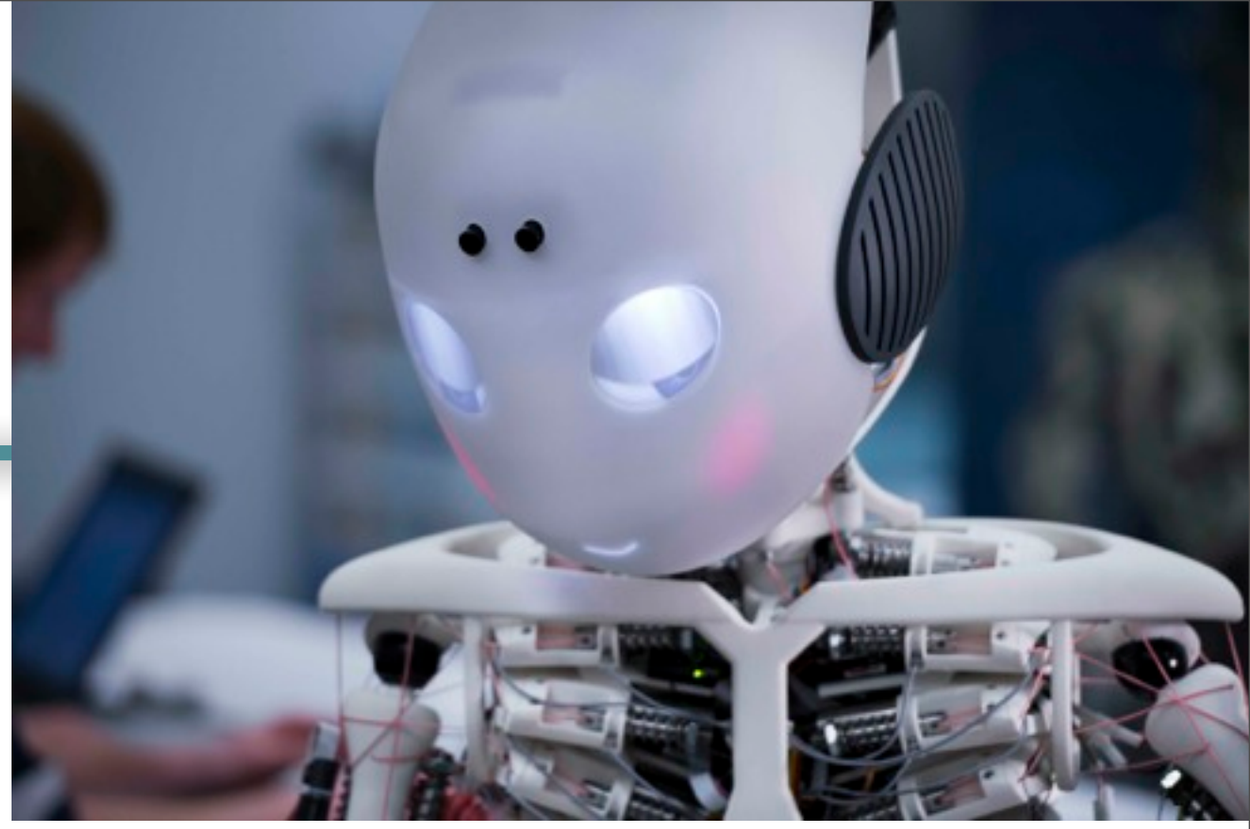


“walking”



Illustrations:
Shun Iwasawa, Studio Ghibli, Tokyo

Roboy on Tour



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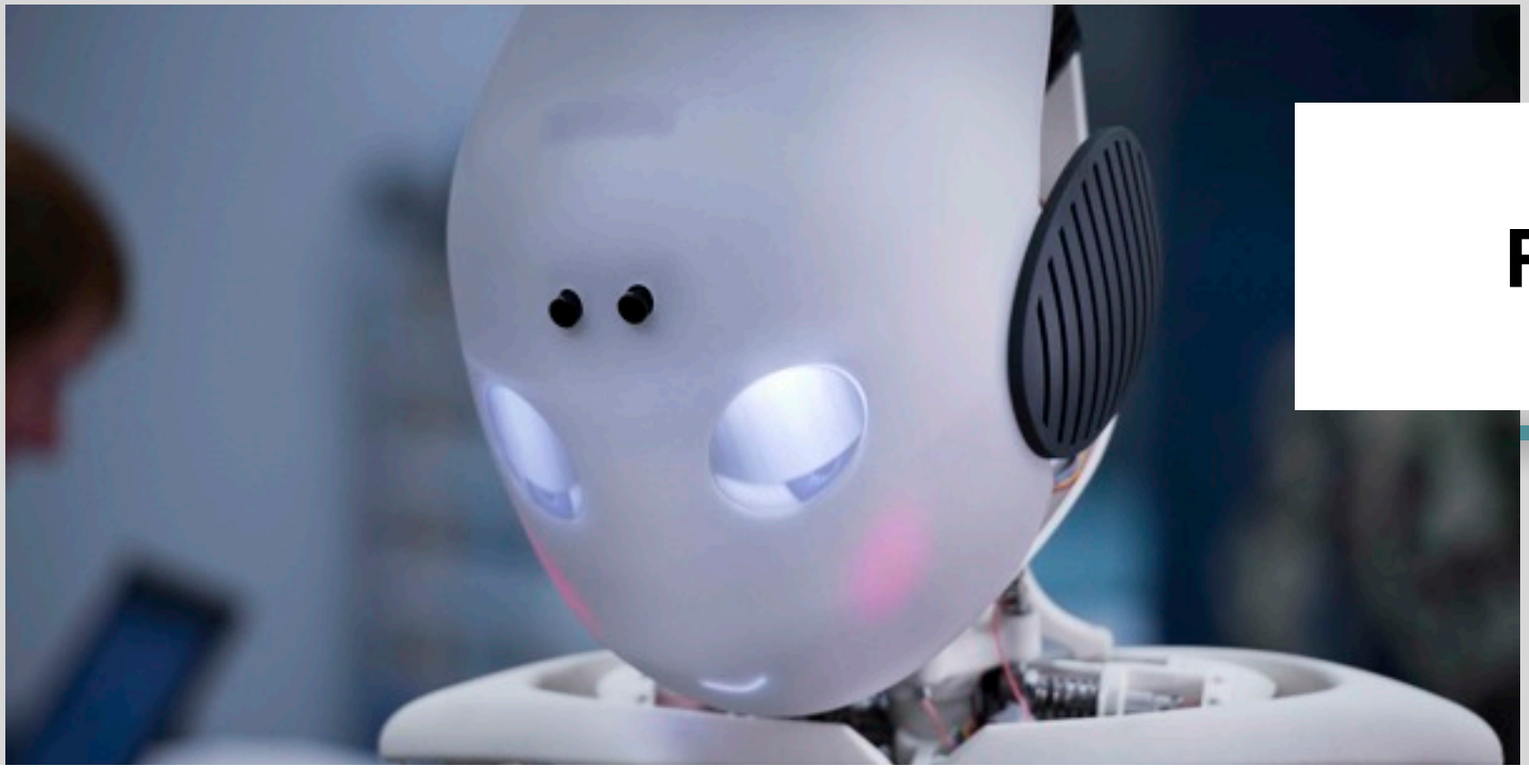

Roboy on Tour

Itinerary:

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IJCAI 2013 Beijing

University of Zurich[UZH]

robotics Swiss National Centre of Competence in Research

ai lab

Beijing

Roboy at Penghao Theater Beijing

Beijing

Roboy at Penghao Theater Beijing

Shanghai


中国瑞士机器人联合展演
Robot Show - A Meeting Point of Robots and Roboticists from Switzerland a
主办单位:
上海科技馆
瑞士
学
瑞士
化中心
活动时间:
2013年

Shanghai

with Rolf and Hesheng

Roboy in autonomous wheel chair

Roboy on Tour

Itinerary:
ICRA (Karlsruhe), Swiss Innovation Fair (Zurich), Munich (TU), Beijing and Shanghai (C), Tokyo (Japan), London (UK) ...

Washington D.C.

University of Zurich[UZH]

robotics Swiss National Centre of Competence in Research

ai lab

Washington D.C. (Swiss Embassy)

“Soiree Suisse” 18 September 2013

1.200 guests

“Soiree Suisse” 18 September 2013

Swiss taxpayer’s money??

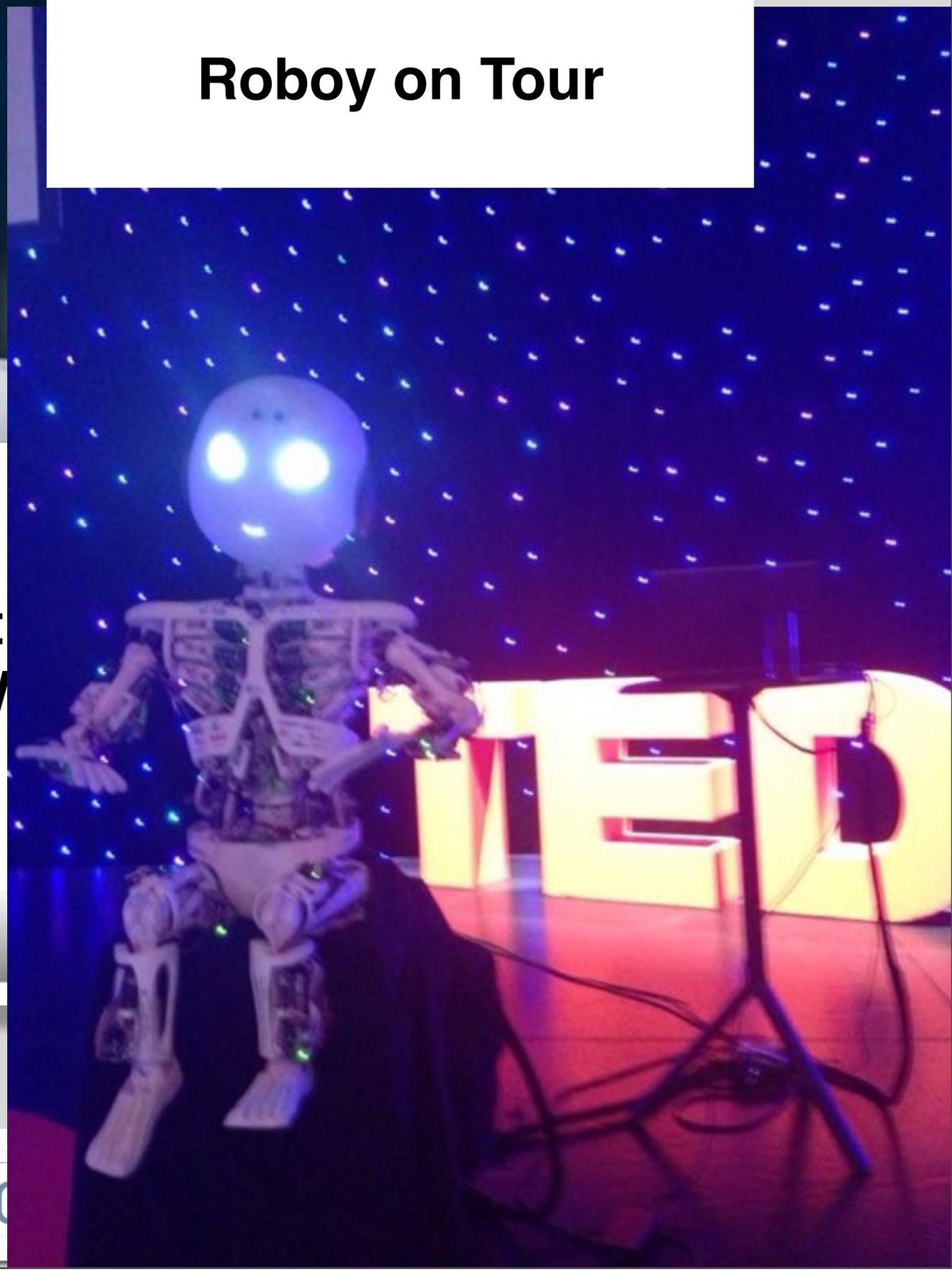
“Soiree Suisse” 18 September 2013

Washington D.C. (Swiss Embassy)

robotics Swiss National Centre of Competence in Research

ai lab

Roboy on Tour



Itinerary:

ICRA (Karlsruhe), Swiss Innovat
Zurich **Shanghai (China), W**
(Japan), London (UK) ...

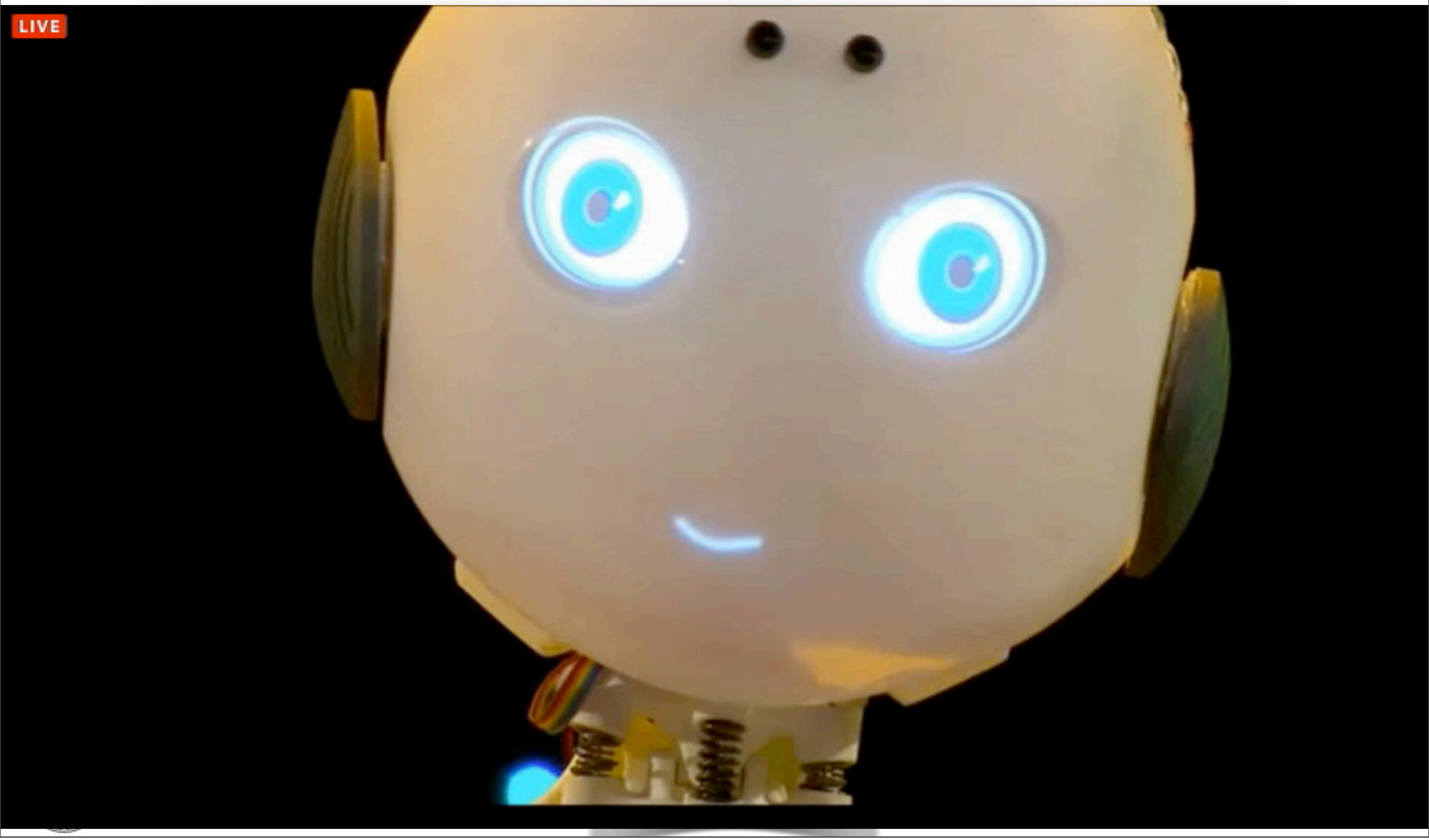
TEDx Zurich, Oct. 2013

University of Zurich[UZH]

robotic

Roboy at TEDx in Zurich

Roboy at TEDx in Zurich



Roboy at Cebit 2014, Hannover

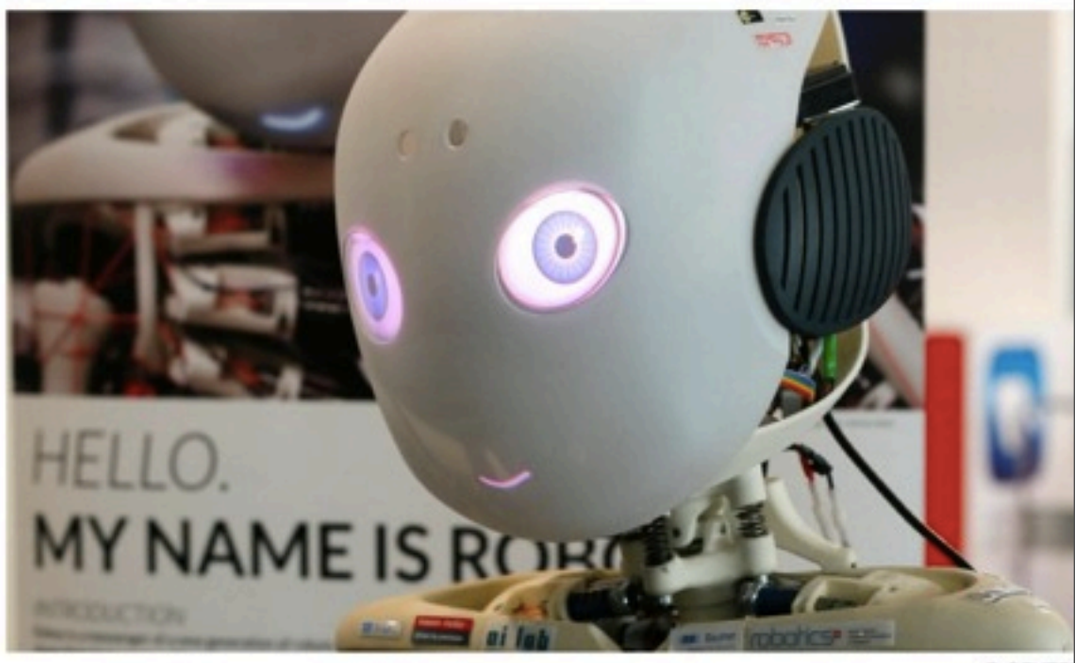
Cebit 2014

Ein Roboter mit himmelblauen Augen

12.03.2014 · Die Knochen sind aus Kunststoff, das Hirn ist ein Chip, das Herz eine Batterie. Auf der Computermesse Cebit marschiert eine neue Generation von Maschinenmenschen auf. Ein Blick in die Zukunft.

Von STEPHAN FINSTERBUSCH, HANNOVER

Artikel | Bilder (1) | Lesermeinungen (6)



Gestatten, meine Name ist Roboy

© REUTE

Hannover, 11. März. Die Knochen sind aus Kunststoff, das Hirn ist ein Chip,

Roboy at Cebit 2014, Hannover

CeBIT BLOG

Themen Über das Blog Netzwerk

Home » Consumer Electronics & Digital Lifestyle » Von Roboy zu RoboThespian: Roboter bevölkern die CeBIT

Von Roboy zu RoboThespian: Roboter bevölkern die CeBIT

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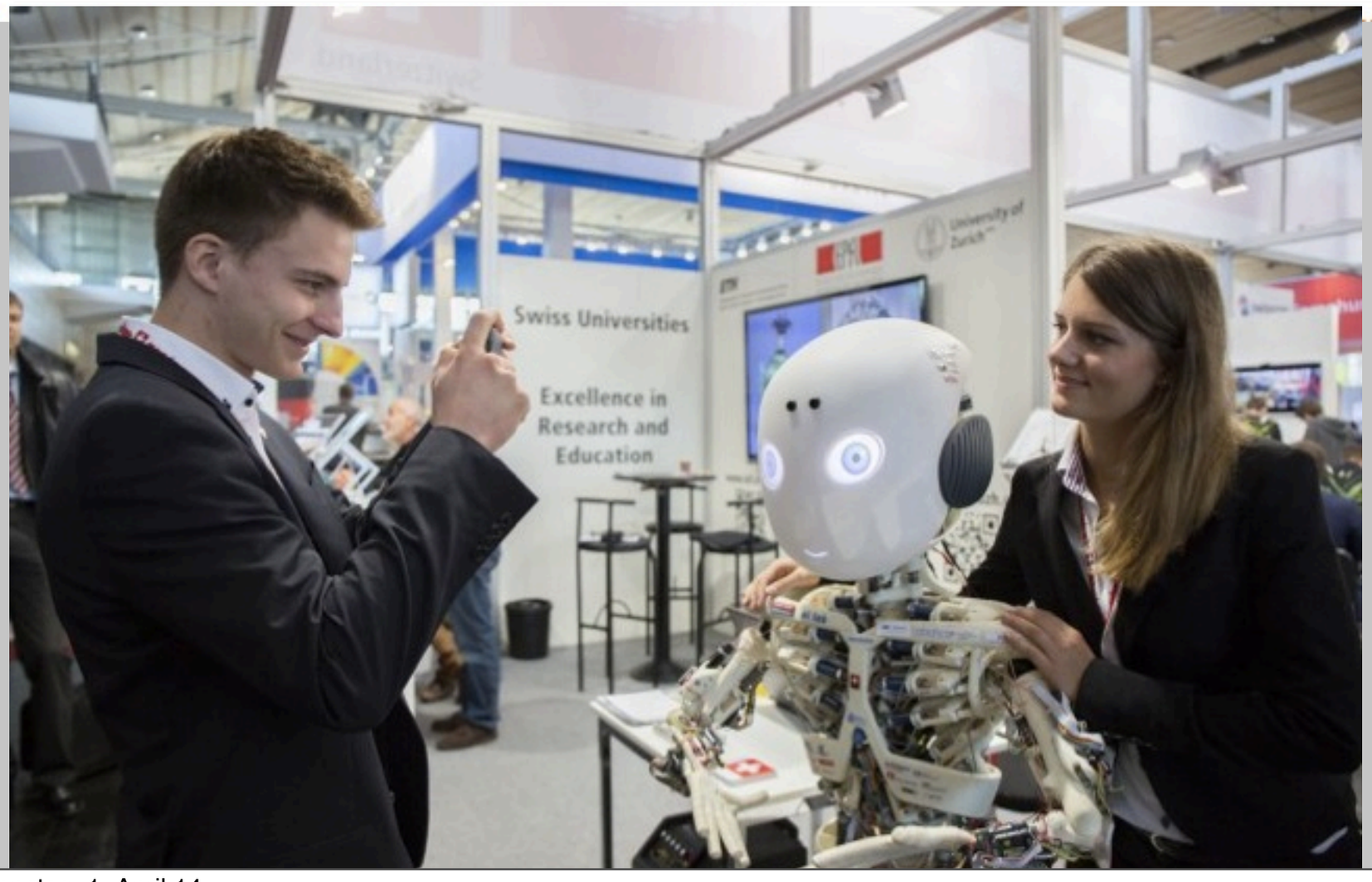

Robov at Cebit 2014, Hannover

CeBIT BLOG

Hot Topics: ETFs | Banking | Forex Education | Online Broker Center

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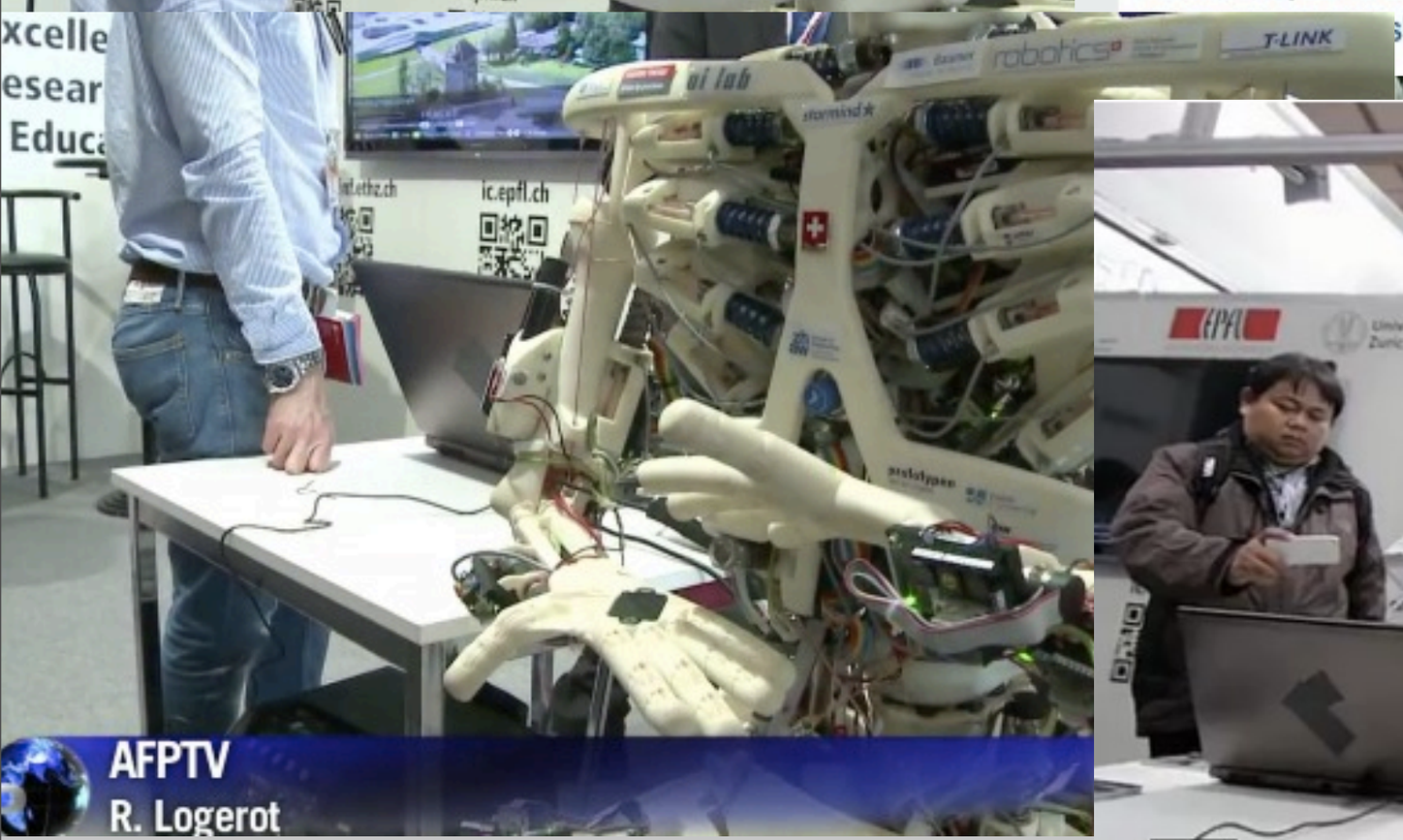
QUOTES | MARKETS | NEWS | INVESTING | ADVANCED INVESTING

Enter symbol, name or keyword

Home > Video > **Emotional Robots Have Tech Fair X-Factor**

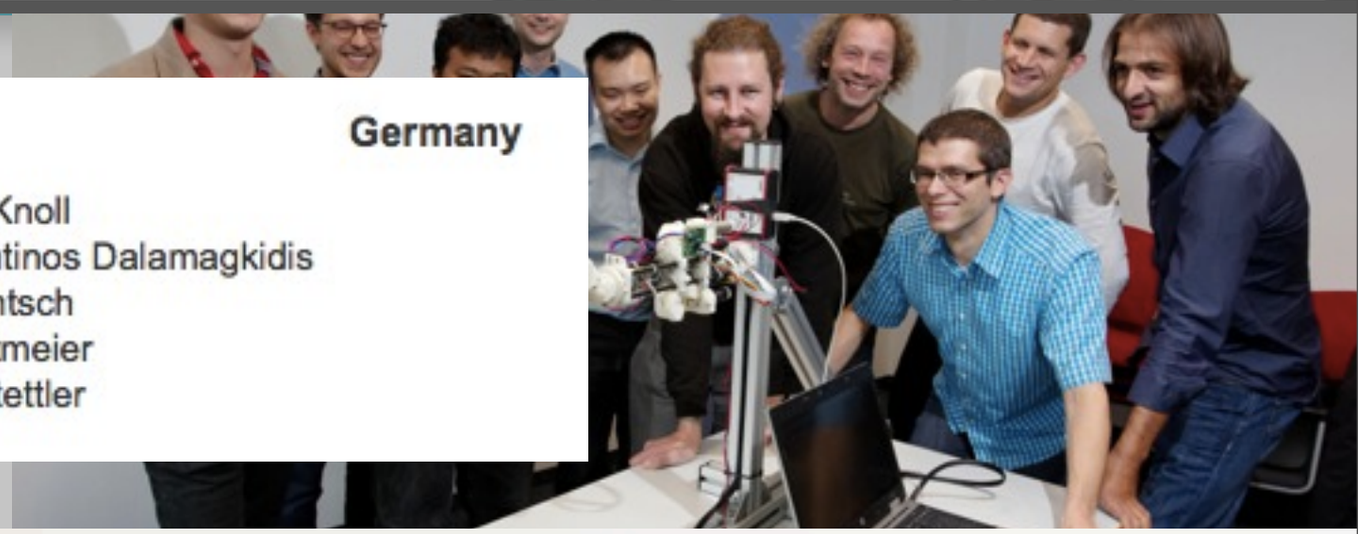
Emotional Robots Have Tech Fair X-Factor - Presented by: The Aol. On Network

He moves, he talks and likes to express his personality. Roboy is a so-called humanoid
show emotions.



Myorobotics

A framework for musculoskeletal robot development



Technische Univerität München (TUM) **Germany**

Robotics and
Embedded Systems

Prof. Alois Knoll
Dr. Konstantinos Dalamagkidis
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Rafael Hostettler

Myorobotics

A framework for musculoskeletal robot development

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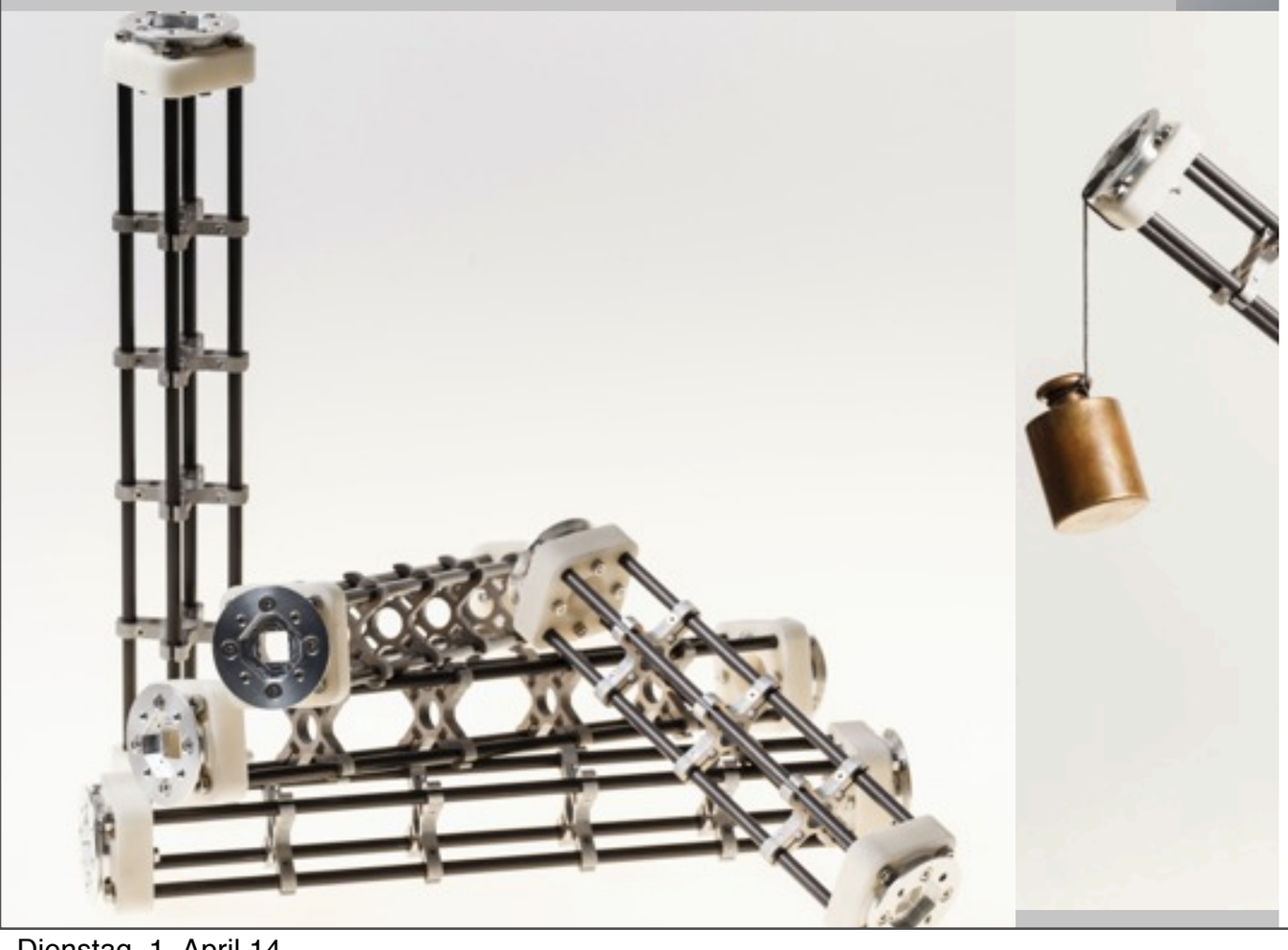
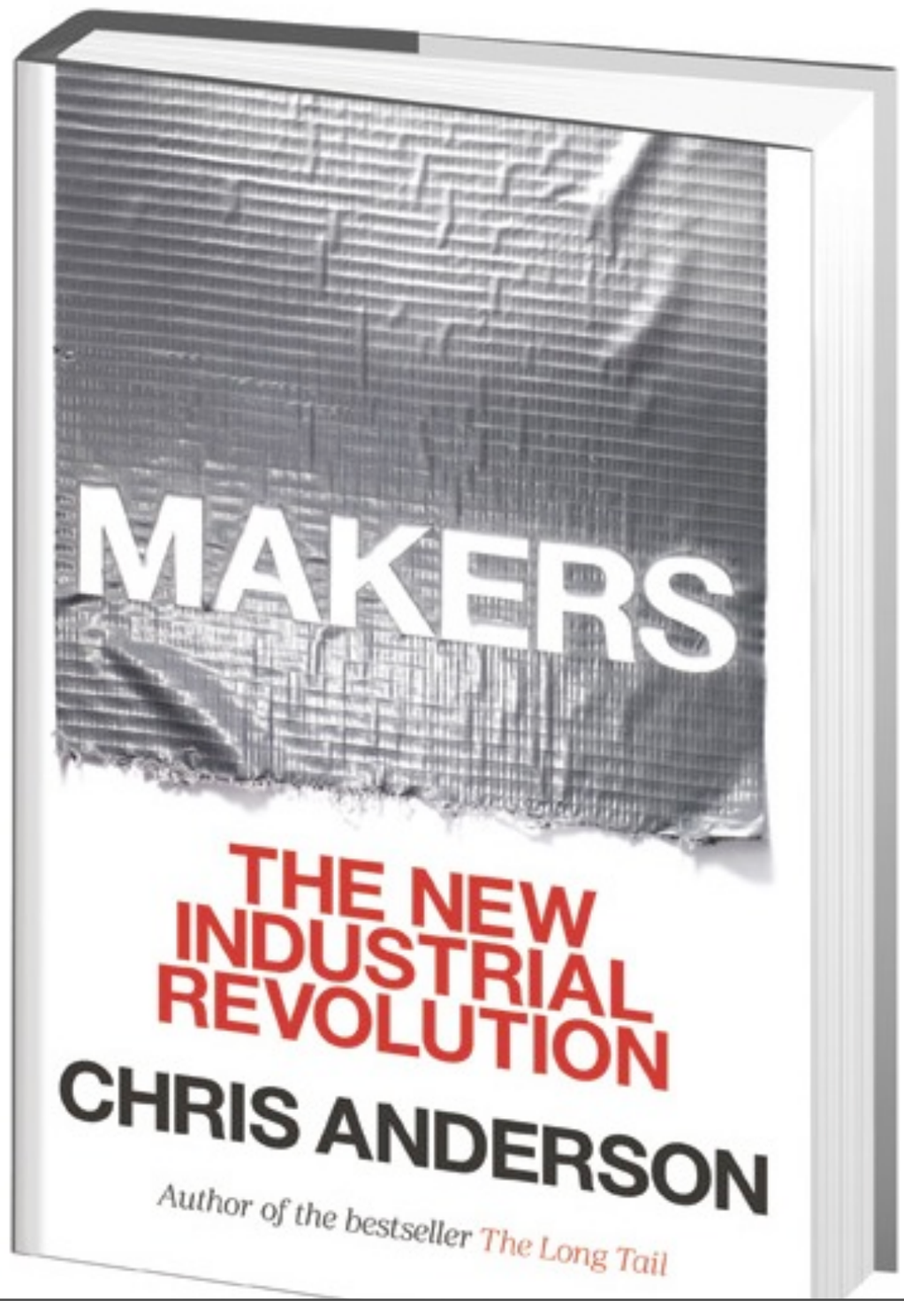
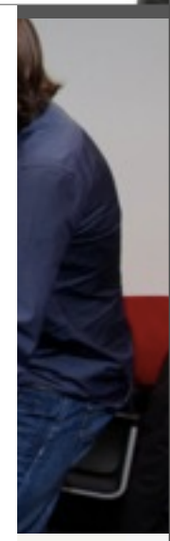
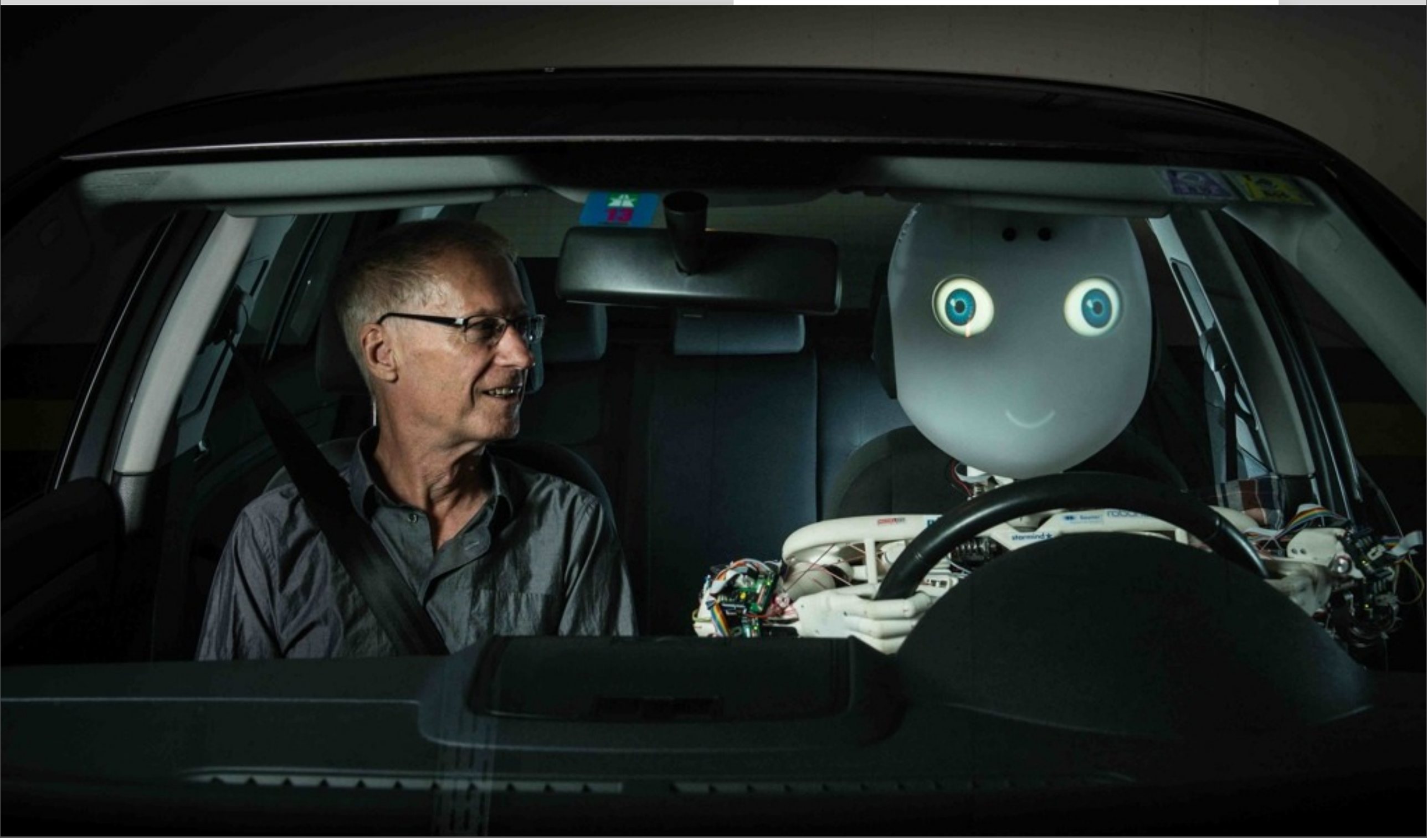






The future?



Contents

- introduction and background
- principles of embodied intelligence
- the “power of materials”
- the “Roboy” project
- **summary and conclusions**

“Soft robotics”

- central role of materials!
- no clear separation between controller and “controlled”
- new notion of control (morphological computation; “orchestration”)
- understanding the “design space”

Trends in AI/robotics

classical		*embodied*
centralized control	→	interplay of brain, body, and environment
top-down control	→	guided self-organization
algorithm	→	dynamical system
abstract symbol processing	→	sensory-motor coordination
top-down design	→	design for emergence
fixed morphology	→	morpho-functional machines

Trends in robotics/manufacturing

manufacturing, “hard”	→	service, “soft”
individual robots	→	robot “ecosystem”
isolated robots	→	the human/robot “cloud”
complete automation	→	human-robot cooperation
outsourcing production	→	re-insourcing
software, “bits”	→	physical system, “atoms”
centralized manufacturing	→	distributed “makers”
big industries, high invest-ments	→	SMEs, small investment

Epilogue

Sun I, son of a Chinese mother and American fighter pilot. Mother dies at birth, father returns to US. Sun I grows up in monastery, Wu, the chef (cook), is his mentor. One of the chores: carrying water in buckets from the river to the monastery, which was situated on a high rock. When they arrived at the top, Sun I's buckets were always empty (spilling), Wu's always full.

Listen to the following conversation:

It was true. By some extraordinary luck or skill Wu never seemed to lose a drop, though he hurried along the treacherous stair at twice my pace. (I tried to cut my losses by moving slowly, plotting my course in advance and picking each footrest with deliberate care.)

"I don't understand it," I confessed to him. "You must know some kind of trick. Explain your method." ...

"You haven't yet caught on. It's precisely this—excess of method—that confounds you, leaves the buckets nearly empty …"

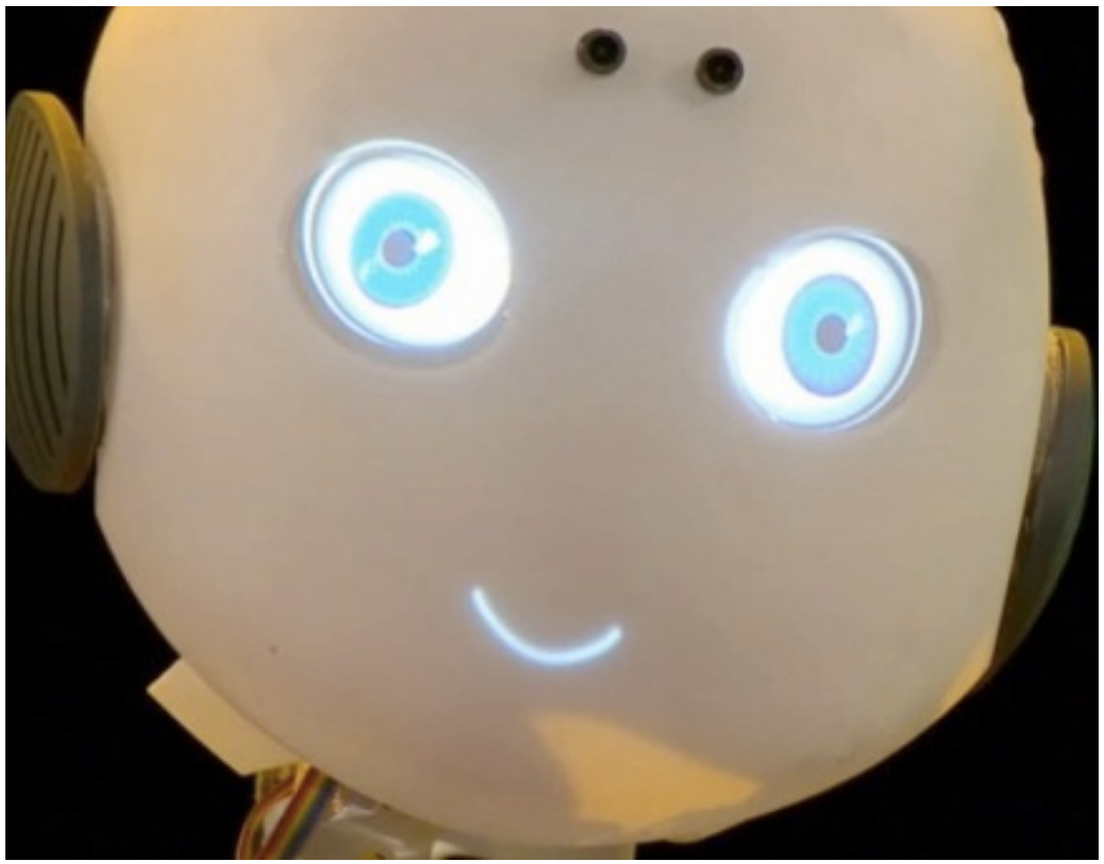
"How do I do it? ... I close my eyes and think of nothing. My mind is somewhere else. My legs find their way without me, even over the most uneven ground. How can I tell you how I do it? . . . I can't even remember myself!"

(David Payne, "Confessions of a Taoist on Wall Street", 1984, pp. 18–19)

Epilogue

Illustration:
Shun Iwasawa, Studio Ghibli, Tokyo

“Better robots - better life”



Thank you for your attention!