The Shanghai Lectures 2019

HeronRobots *Pathfinder Lectures*

Natural and Artificial Intelligence in Embodied Physical Agents

HeronRobots

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Inspired by nature,

we develop and implement advanced breakthrough solutions designed with a holistic approach.

The ShanghAI Lectures

An experiment in global teaching

Lecture 6-7
Grab Bag, Summary and topics to discuss

Fabio Bonsignorio

Welcome to the United Nations. It's your world

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World population projected to reach 9.7 billion by 2050

29 July 2015, New York

The current world population of 7.3 billion is expected to reach 8.5 billion by 2030, 9.7 billion in 2050 and 11.2 billion in 2100, according to a new UN DESA report, "World Population Prospects: The 2015 Revision", launched today.

"Understanding the demographic changes that are likely to unfold over the coming years, as well as the challenges and opportunities that they present for achieving sustainable development, is key to the design and implementation of the new development agenda," said Wu Hongbo, UN Under-Secretary-General for Economic and Social Affairs.

Most of the projected increase in the world's population can be attributed to a short list of high-fertility countrie mainly in Africa, or countries with already large populations. During 2015-2050, half of the world's population growth is expected to be concentrated in nine countries: India, Nigeria, Pakistan, Democratic Republic of the Congo, Ethiopia, United Republic of Tanzania, United States of America (USA), Indonesia and Uganda, listed according to the size of their contribution to the total growth.

NATIONAL GEOGRAPHIC

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MAGAZINE | JANUARY 2016

See for Yourself: How Arctic Ice Is Disappearing

Since satellites began regularl
declined sharply in extent and thic
is thin stuff that doesn't survive t
entire Arctic ecosystem, from pla
think that, by altering the jet stre
around the

Graphics and maps by **Lauren Ja**
Esteban,

UK world sport football opinion culture business lifestyle fashion environment tech

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Sydney
Dispatch

Australia's new normal ... as city temperatures hit 47C people shelter from the deadly heat

In Sydney's baking suburbs, fans have sold out – and fears about the effects of climate change are mounting

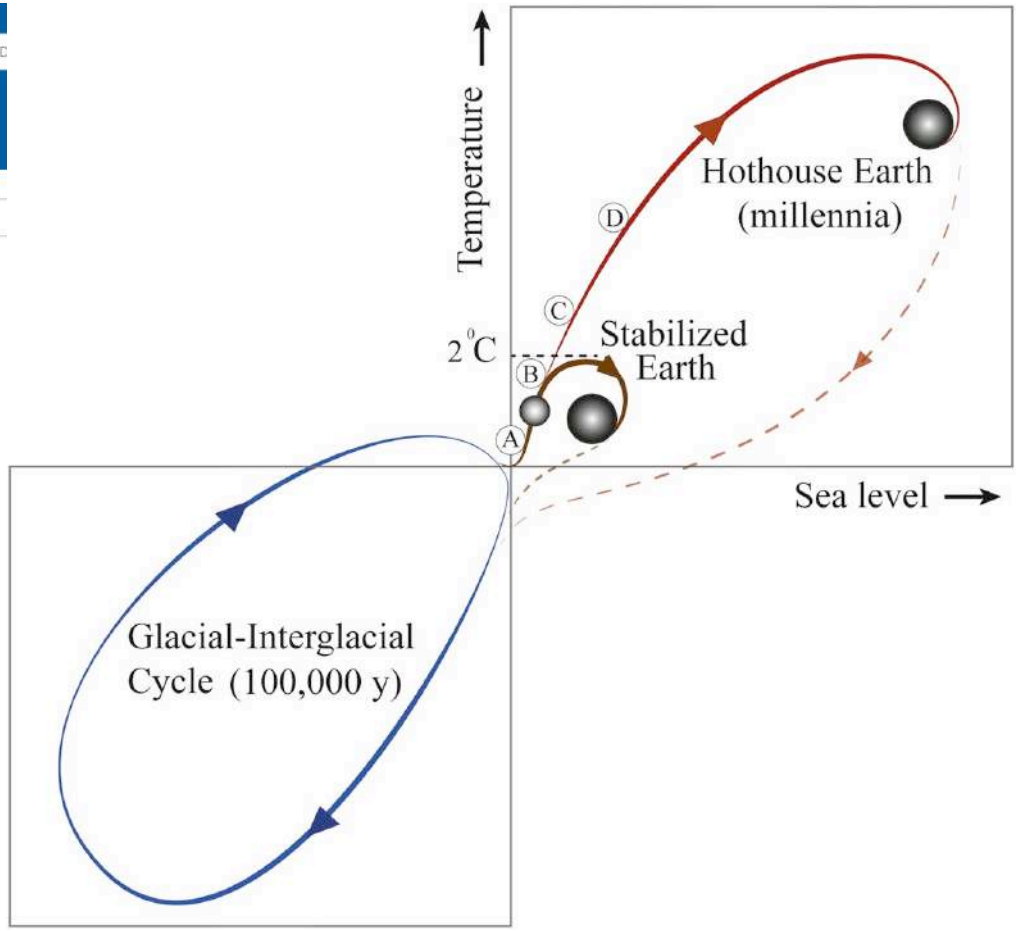
PNAS
Proceedings of the National Academy of Sciences of the United States of America

Trajectories of the Earth System in the Anthropocene

Will Steffen, Johan Rockström, Katherine Richardson, Timothy M. Lenton, Carl Folke, Diana Liverman, Colin P. Summerhayes, Anthony D. Barnosky, Sarah E. Cornell, Michel Crucifix, Jonathan F. Donges, Ingo Fetzer, Steven J. Lade, Marten Scheffer, Ricarda Winkelmann, and Hans Joachim Schellnhuber

PNAS August 14, 2018 115 (33) 8252-8259; published ahead of print August 6, 2018 https://doi.org/10.1073/pnas.1810141115

Edited by William C. Clark, Harvard University, Cambridge, MA, and approved July 6, 2018 (received for review June 19, 2018)



Older and newer attempts

Juanelo Torriano alias Gianello della Torre, (XVI century) a craftsman from Cremona, built for Emperor Charles V a mechanical young lady who was able to walk and play music by picking the strings of a real lute.

Hiroshi Ishiguro, early XXI century

Director of the Intelligent Robotics Laboratory, part of the Department of Adaptive Machine Systems at Osaka University, Japan

Not everything worked as expected!

The second wave: the current approach shows some limitations

On the other hand the debriefing of DARPA DRC shows clearly that humanoid robots are **still far from the required level of capabilities in fact many metrics**, **such as time-to-completion, are highly application or task specific.**

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

The “frame problem” (1)

From: Dennett*, D.C. 1987. “Cognitive Wheels: The Frame Problem in AI”, in Pylyshyn, Z.W., ed., The Robot’s Dilemma: The Frame Problem in Artificial Intelligence. Norwood, NJ: Ablex, pp. 41–64.

R1: (naive ☺) robot

INSIDE(R1,ROOM)
ON(BATTERY,WAGON)
PULLOUT(WAGON, ROOM)

***Daniel Dennett, American philosopher (philosophy of mind)**

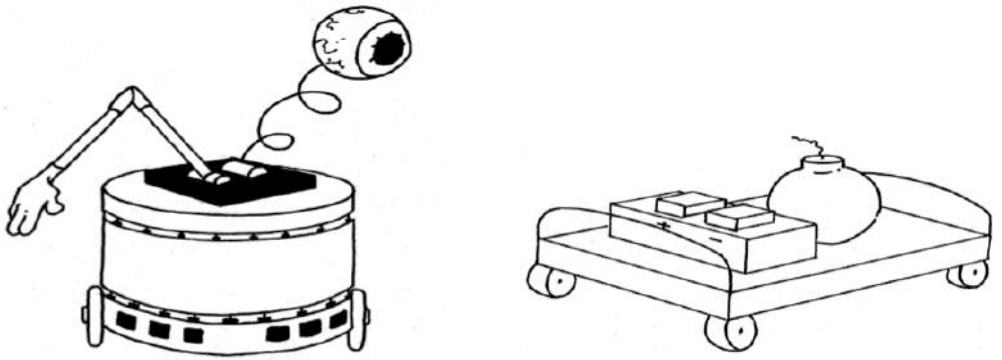


Illustration: (adapted from) **Isabelle Follath**

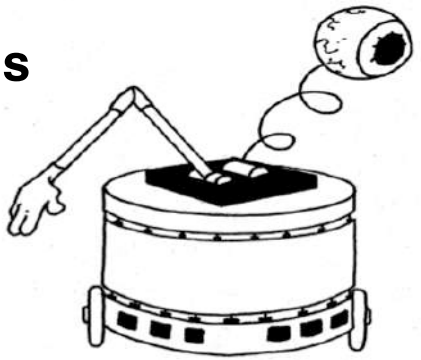
Not as expected

The “frame problem” (2)

From: Dennett*, D.C. 1987. “Cognitive Wheels: The Frame Problem in AI”, in Pylyshyn, Z.W., ed., The Robot’s Dilemma: The Frame Problem in Artificial Intelligence. Norwood, NJ: Ablex, pp. 41–64.

R1D1:
Robot Deducer
(it deduces the implications of its own acts)

***Daniel Dennett,**
American philosopher
(philosophy of mind)



INSIDE(R1D1,ROOM)
ON(BATTERY,WAGON)
COLOUR(PULLOUT(WAGON, ROOM))
=UNCHANGED
…
…
WHEELS(REVOLUTIONS, PULLOUT(.))=..

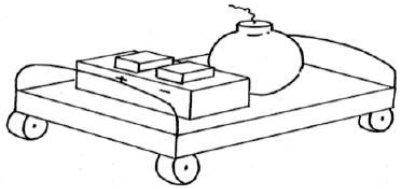


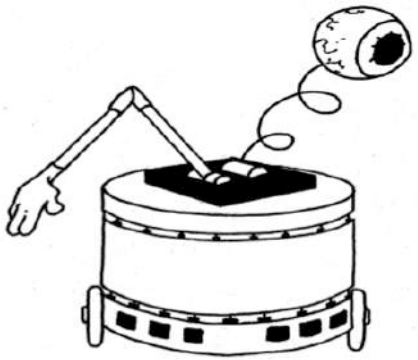
Illustration: (adapted from) **Isabelle Follath**

In the meantime…

The “frame problem” (3)

From: Dennett*, D.C. 1987. “Cognitive Wheels: The Frame Problem in AI”, in Pylyshyn, Z.W., ed., The Robot’s Dilemma: The Frame Problem in Artificial Intelligence. Norwood, NJ: Ablex, pp. 41–64.

R2D1(aka ‘Hamlet’
Robot Relevant
•Deducer
(it discards not relevar
implications
of its own acts)



INSIDE(R2D1,ROOM)
ON(BATTERY,WAGON)
COLOUR(PULLOUT(WAGON, ROOM))
=NotRelevant
…
…
WHEELS(REVOLUTIONS, PULLOUT(.))=
NotRelevant
…
Not Relevant…Not Relevant…
Not Relevant….

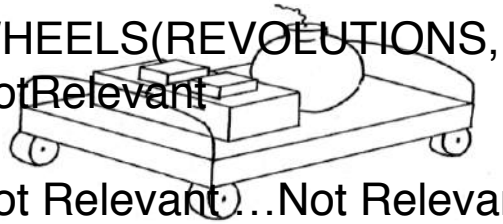


Illustration: (adapted from) **Isabelle Follath**

You know the story…

Summary of Dennett's points

- **obvious to humans, not obvious to (GOFAI) robots (robot only has symbolic model/representation of world)**

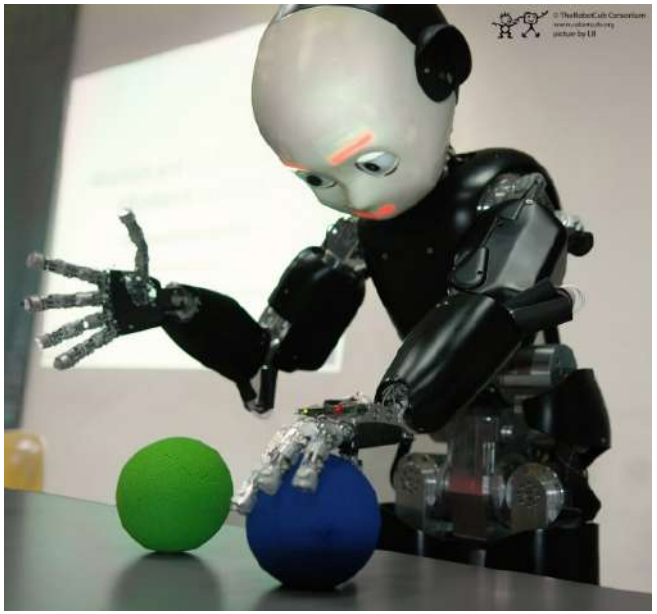
- **vast number of potential side effects, mostly irrelevant**

distinction between relevant and irrelevant inferences

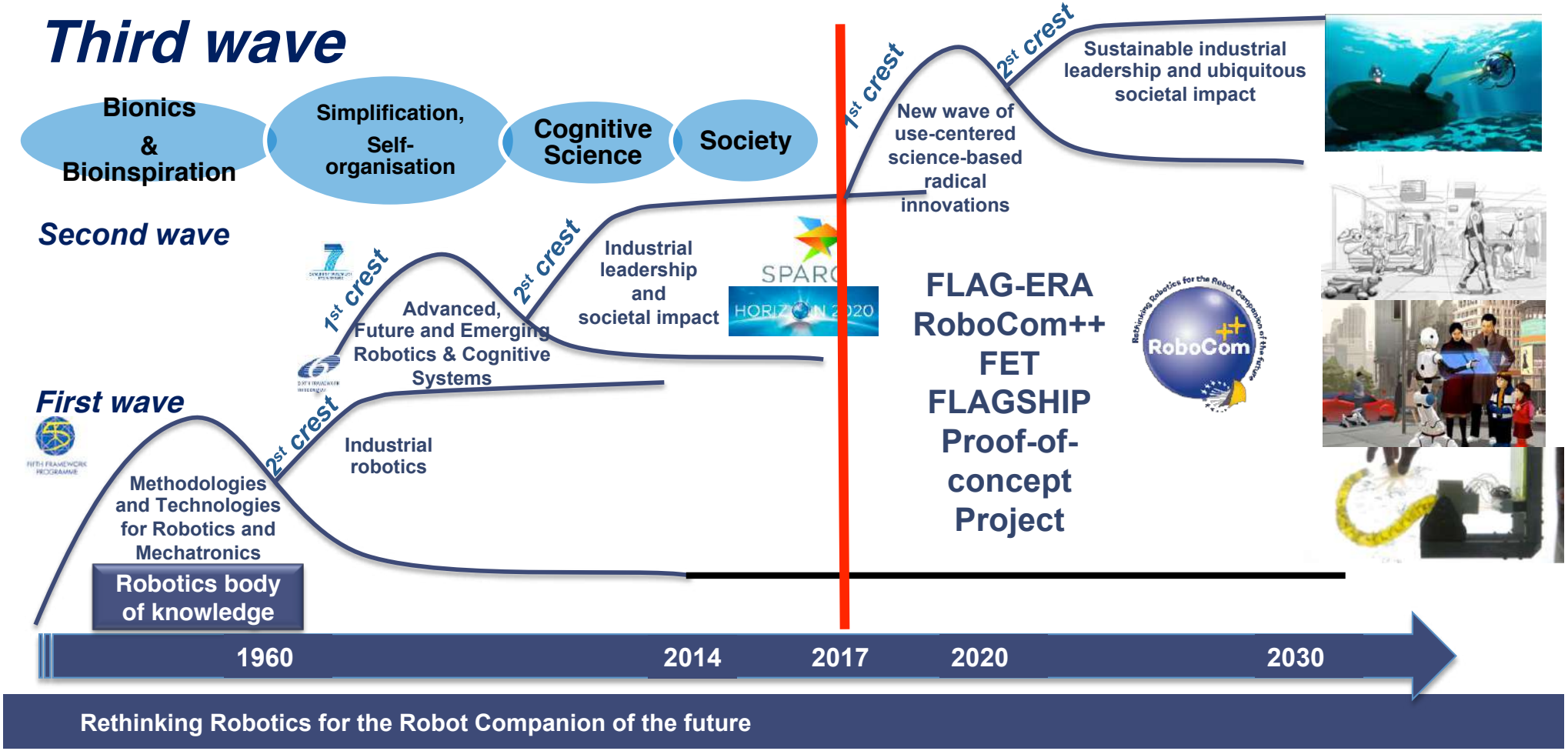
Pursuing new frontiers:
The robotics bottleneck

Today, more functionality means:

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

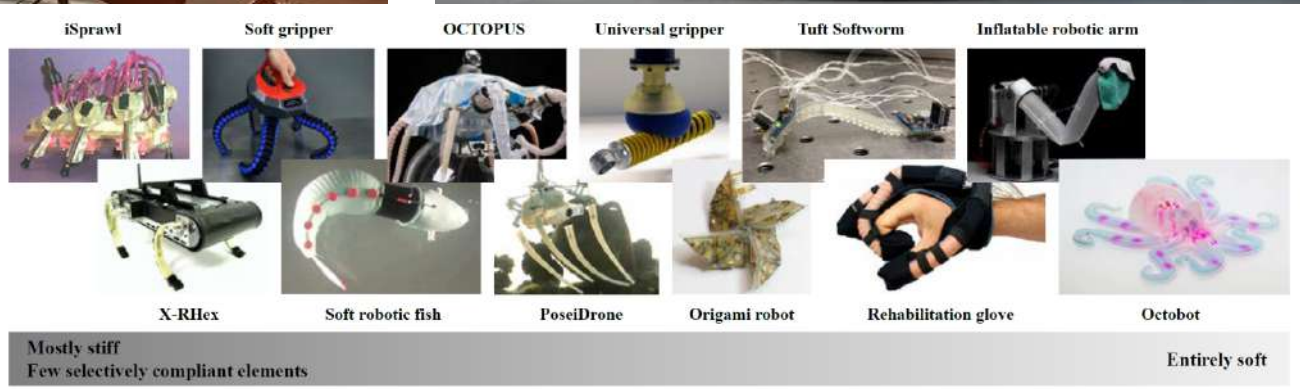


The Robotics waves

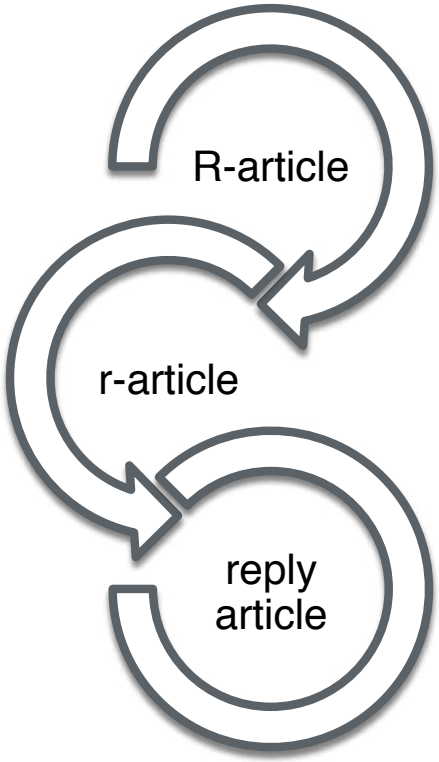


SCIENCE ROBOTICS

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



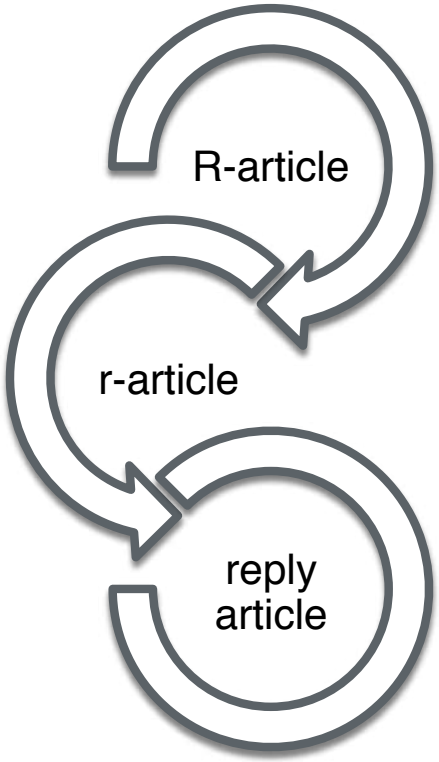
R-article Life Cycle



It is possible to publish a short article
About the results replication of an R-article. article.
Such articles will be peer reviewed like any other RAM article and will undergo a data and code consistency check.

Similarly, the authors of the original R-article will be able to submit, again, in the form of a short peer-reviewed article, a reply to the authors of the r-article, again, with a data and code consistency check.

R-article Life Cycle



Check:
http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8036322

and

RAM authors guidelines here (section 9.):
http://www.ieee-ras.org/publications/ram/information-for-authors
__R(eproducibile)-articles can already be submitted!!!__

Introduction R-Articles

FROM THE FIELD

A New Kind of Article for Reproducible Research in Intelligent Robotics

By Fabio Bonsignorio

The reproducibility of experimental results is a key characteristic of the scientific method. Despite that, in robotics and artificial intelligence (AI)—maybe for good reason—replicating experiments in many cases has, so far, been limited or outright lacking. This fact hampers both research progress and results exploitation [2], [10] and becomes even more relevant when new editorial initiatives, such as [14], increasingly regard (intelligent) robotics as a science.

Reporting practices and formats are a key issue if we want to have reproducible robotics and AI papers. After years of discussions in a long series of workshops [9] (Figure 1), the time is ripe for addressing this issue, and we are doing it! The first-ever special issue of a high-level, reputable robotics publication claiming the reproducibility of the published results was in this magazine in September 2015 [9] (Figure 2).

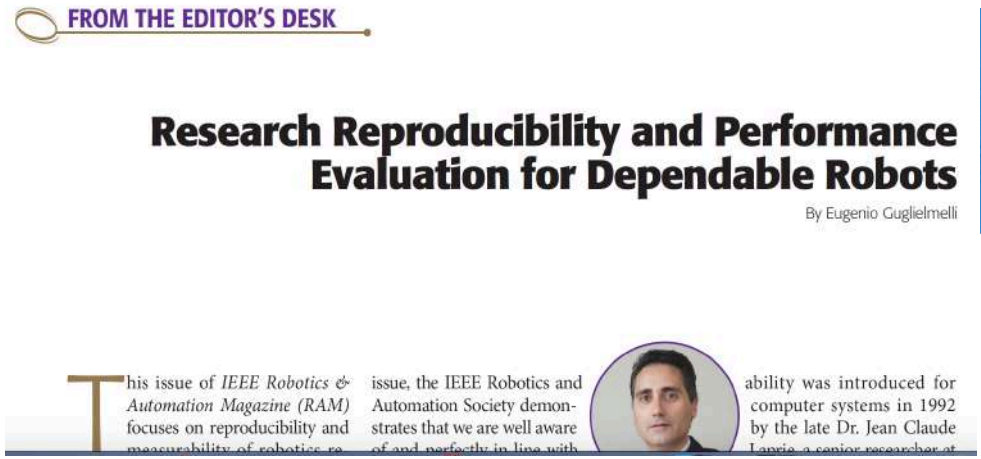
Reproducibility is now a priority for the IEEE, as shown by the fact that the organization recently decided to integrate the CodeOcean platform [15] in the websites of several magazines and journals. And we are going to do the same.

In the meantime, we are in the middle of what has been dubbed a *reproducibility crisis* hitting well-established scientific fields ranging from medicine to psychology [3]–[5], [13]. For example, a recent study [11] discovered that only about a third of psychology papers are reproducible. The situation is better in cancer research [12] but is still not optimal. However, the situation in robotics and AI is different. While, in other disciplines, a shared methodology for performing experiments has been in place for a long time and the problems might come from organizational, societal, and sometimes ethical causes, in robotics, the problems are of a methodological and even epistemological nature [9, pp. 32–35]. In the September 2015 *IEEE Robotics and Automation Magazine* (*RAM*) special issue [9], we gave authors a large degree of latitude in terms of how to define reproducibility and good reporting

Digital Object Identifier 10.1109/MRA.2017.2722918
Date of publication: 13 September 2017

http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8036322

Reproducible Research now an IEEE priority



FROM THE EDITOR'S DESK

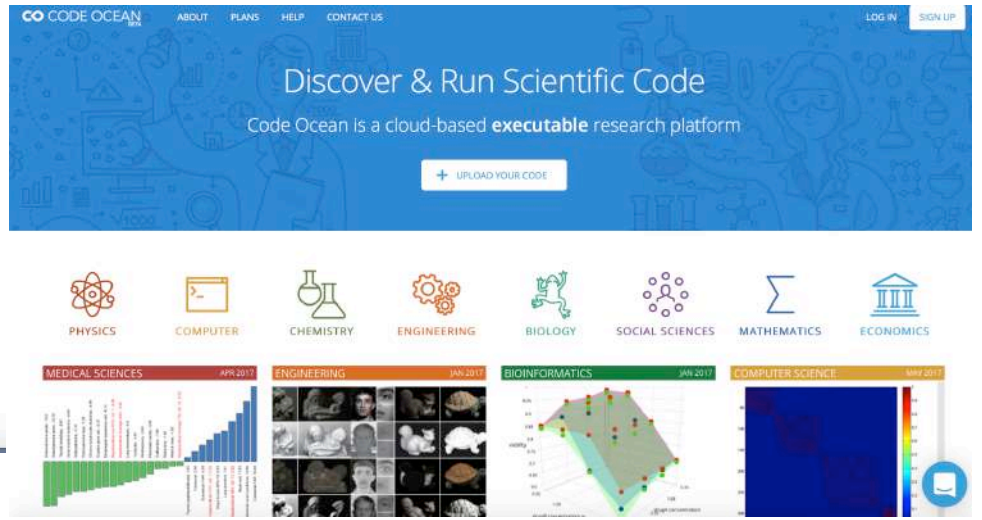
Research Reproducibility and Performance Evaluation for Dependable Robots

By Eugenio Guglielmelli

This issue of *IEEE Robotics & Automation Magazine (RAM)* focuses on reproducibility and

issue, the IEEE Robotics and Automation Society demonstrates that we are well aware

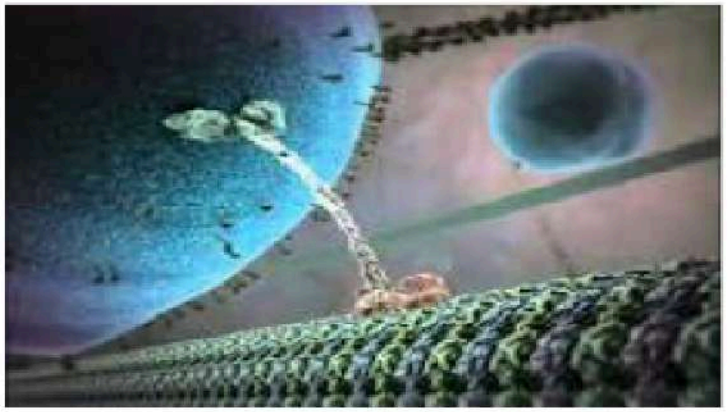
ability was introduced for computer systems in 1992 by the late Dr. Jean Claude



R(eproducible)-Articles on IEEE R&A Magazine

Is It Alive?

Big Questions lie in front of us!



Two views of intelligence

classical:
cognition as computation

embodiment
cognition emergent from sensory-motor and interaction processes

PARADIGM CLASHES

Soft Robotics: a working definition

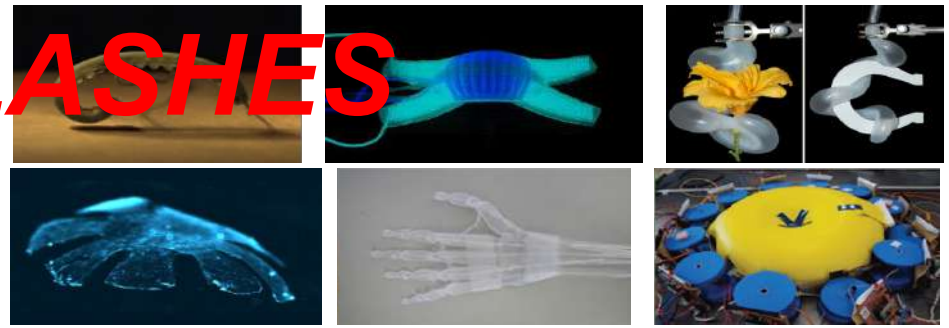
Variable impedance actuators and stiffness control

* Actuators with variable impedance
* Compliance/impedance control
* Highly flexible (hyper-redundant or continuum) robots

IEEE Robotics and Automation Magazine, Special Issue on Soft Robotics, 2008
A. Albu-Schaffer et al. (Ed.s)

Use of soft materials in robotics

* Robots made of soft materials that undergo high deformations in interaction
* Soft actuators and soft components
* Control partially embedded in the robot morphology and mechanical properties



Kim S., Laschi C., and Trimmer B. (2013) Soft robotics: a bioinspired evolution in robotics, *Trends in Biotechnology*, April 2013.
Laschi C. and Cianchetti M. (2014) "Soft Robotics: new perspectives for robot bodyware and control" *Frontiers in Bioengineering and Biotechnology*, 2(3)

PARADIGM CLASHES

Challenges

The observation of natural intelligent systems and the practice of robotics research and engineering lead us to think that 'intelligence' (and 'meaning' if not 'consciousness') are 'emerging' characteristics springing from the evolution of loosely coupled networks of intelligent 'embodied' and 'situated' agents.

Challenges

1. How the dynamics of an (embodied) agent is related to its information/computing capabilities (morphological computation)?

2. How information/computing capabilities behave in a multi body agent system?

3. How 'intelligence' and 'meaning' emerge from networks of embodied agent?

How to quantify?

Editorial | Published: 11 June 2019

Robotics and the art of science

Nature Machine Intelligence **1**, 259 (2019) | Download Citation

Bringing reproducibility to robotics.

It is an exciting time to work in robotics. There are plenty of interesting challenges in designing machines that intelligently interact with both humans and their environment, and a range of techniques and insights from engineering, computer science, physics, biomechanics, psychology and other fields are available to help solve them. The International Conference on Robotics and Automatio organized by the IEEE, is a lively affair: over 4,000 pa

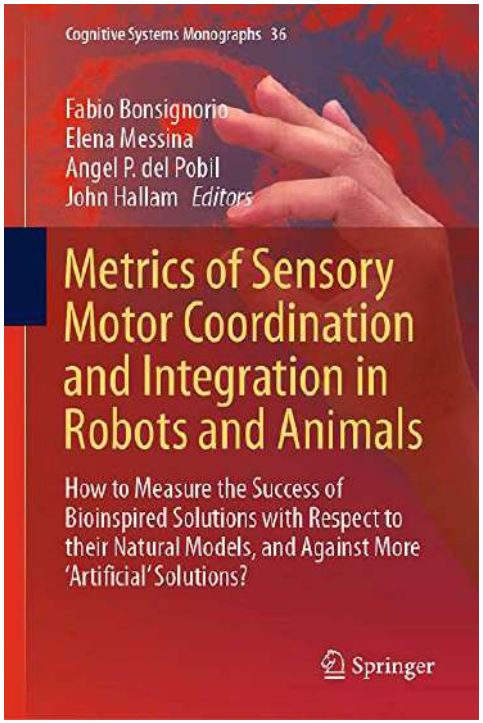
It is an exciting prospect that robotics can start growing as a scientific discipline, with clearly defined methods of evaluation and measurements in place.

References

1. Leitner, J. *Nat. Mach. Intell.* **1**, 162 (2019).
Article Google Scholar

2. Bonsignorio, F. & Del Pobil, A. P. *IEEE Robot. Autom. Mag.* **22**, 32–35 (September, 2015).

3. Bonsignorio, F. A. *IEEE Robot. Autom. Mag.* **24**, 178–182 (September, 2017).



Complete agents

Masano Toda's
Fungus Eaters

Properties of embodied agents

- subject to the laws of physics
- generation of sensory stimulation through interaction with real world
- affect environment through behavior
- complex dynamical systems
- perform morphological computation

Parallel, loosely coupled processes

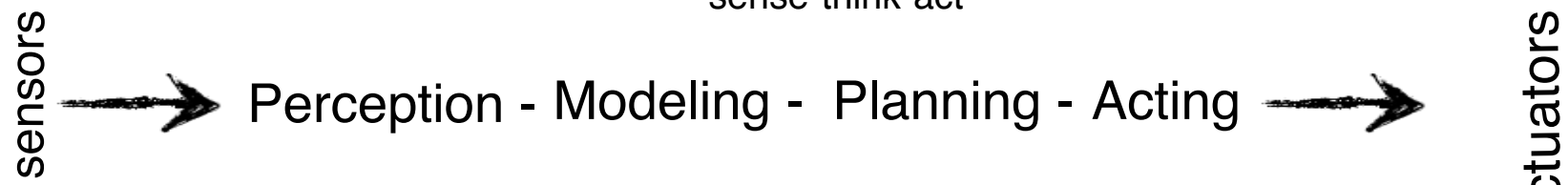
‘Intelligent' behavior:

- **emergent from system-environment interaction**
- **based on large number of parallel, loosely coupled processes**
- **asynchronous**
- **coupled through agent’s sensory-motor system and environment**

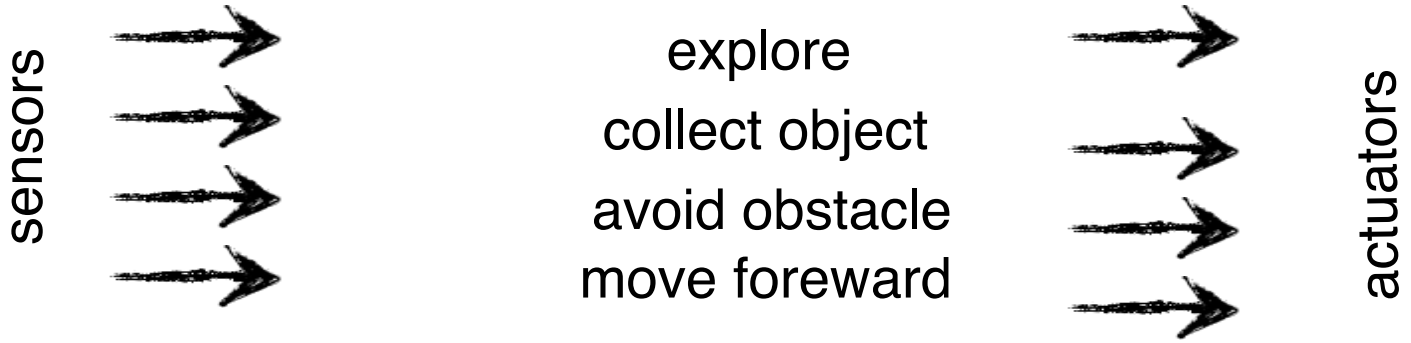
The subsumption architecture: the “behavior-based” approach

classical, cognitivistic

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



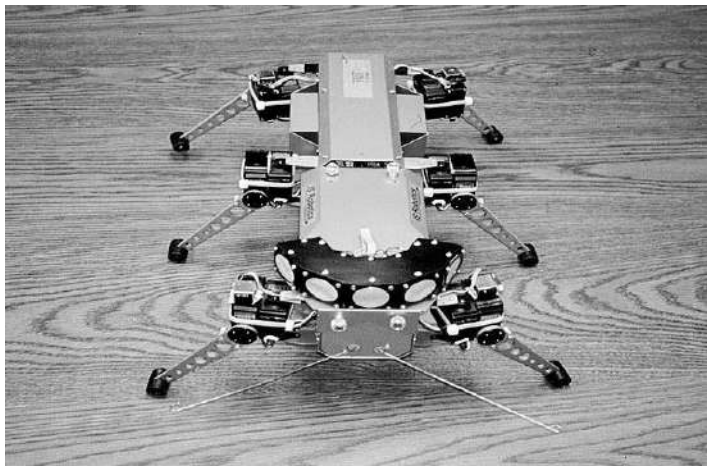
“behavior-based”, subsumption



Mimicking insect walking

- **subsumption architecture**

six-legged robot “Ghenghis”



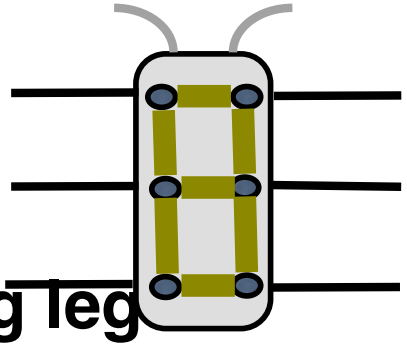
Insect walking

Holk Cruse, German biologist

- **no central control for leg coordination**

neural connections →

- **only communication**
- **between neighboring leg**



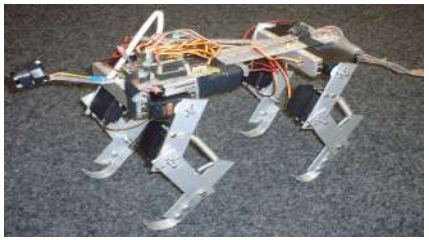
Scaling issues:
the “Brooks-Kirsh” debate

- insect level —> human level?

- David Kirsh (1991): “Today the earwig, tomorrow man?”
- Rodney Brooks (1997): “From earwigs to humans.”

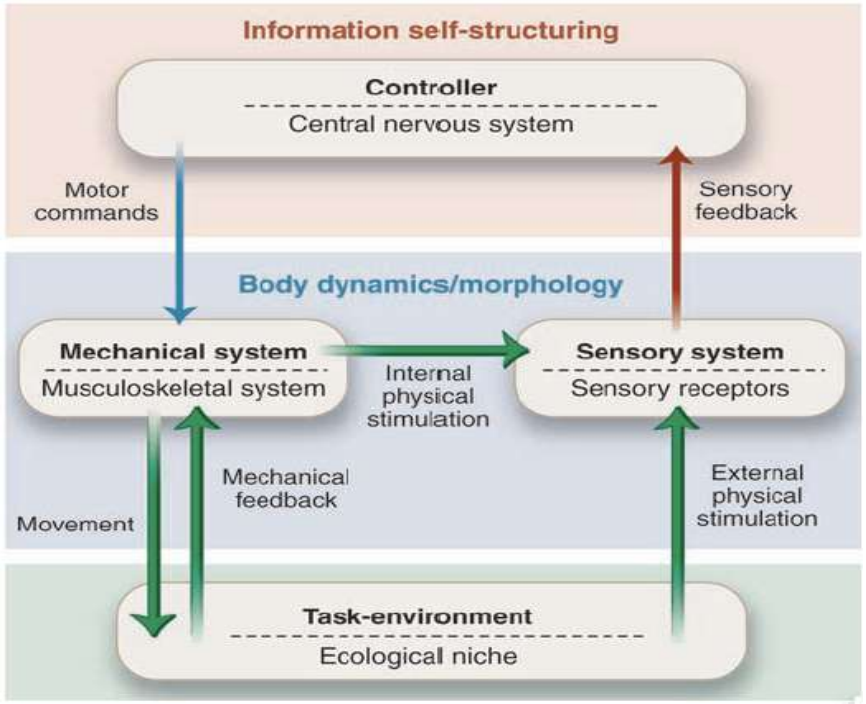
Iida's "Puppy's" simple control

- **rapid locomotion in biological systems**
- **emergence of behavior**



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

Implications of embodiment
Self-stabilization



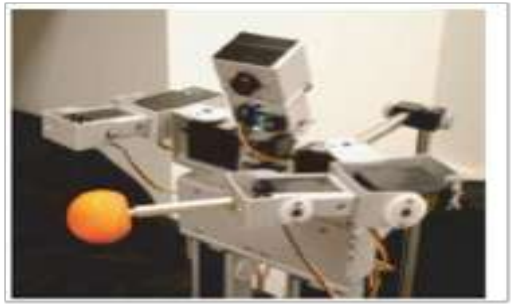
Cruse's Ant, Iida's 'Puppy',
…

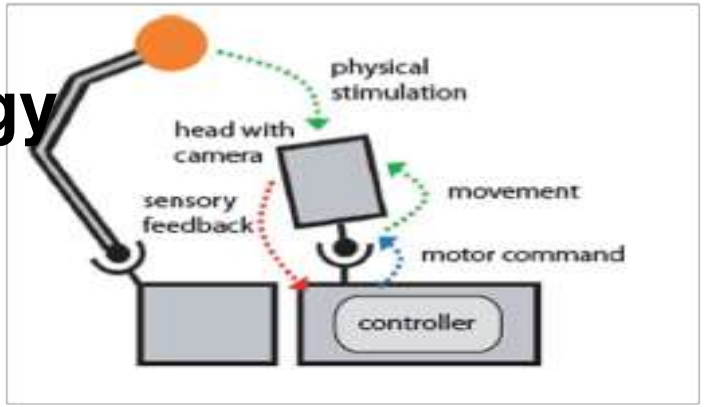
Pfeifer et al.,Science,
16 Nov. 2007

Information self-structuring

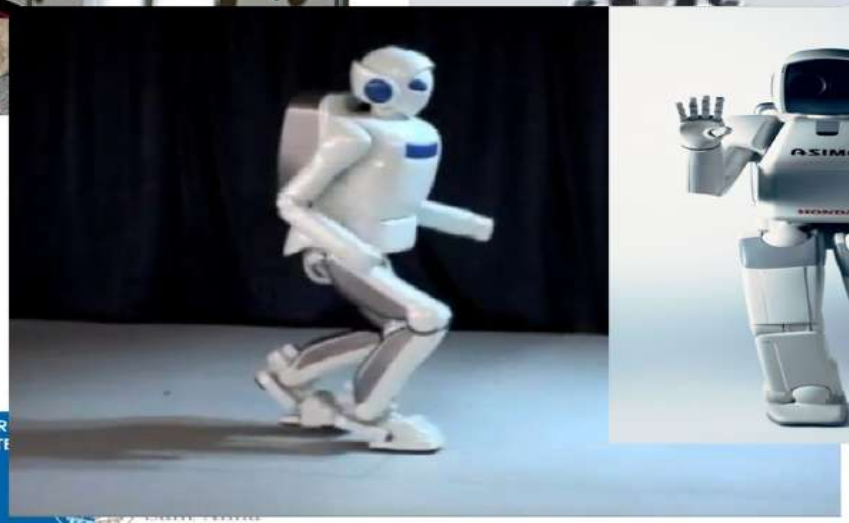
•Experiments:

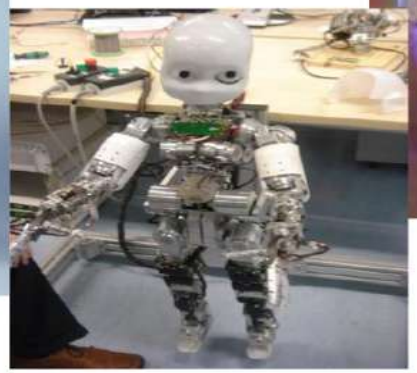
•Lungarella and Sporns**, 2006**
Mapping information flow in sensorimotor networks
PLoS Computational Biology



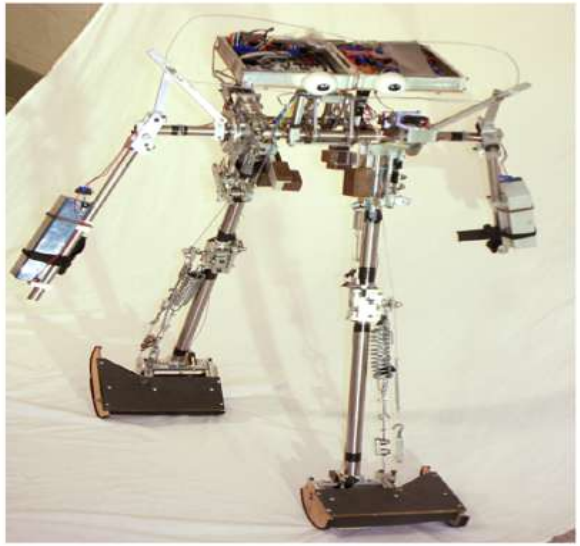


Today's humanoids





Conceptually different humanoid designs (mainly research)



THE BIOROBOTICS INSTITUTE

Scuola Superiore Sant'Anna

How to build a ‘new paradigm’ robot like the Cornell Ranger able to wave the hands like NAO?
(and manipulate objects…)

a) Cornell ranger

b) Nao walking down a ramp

c) Andy Ruina’s ‘passive walker’ walking down a ramp

Carry-home messages (and remarks) (1)

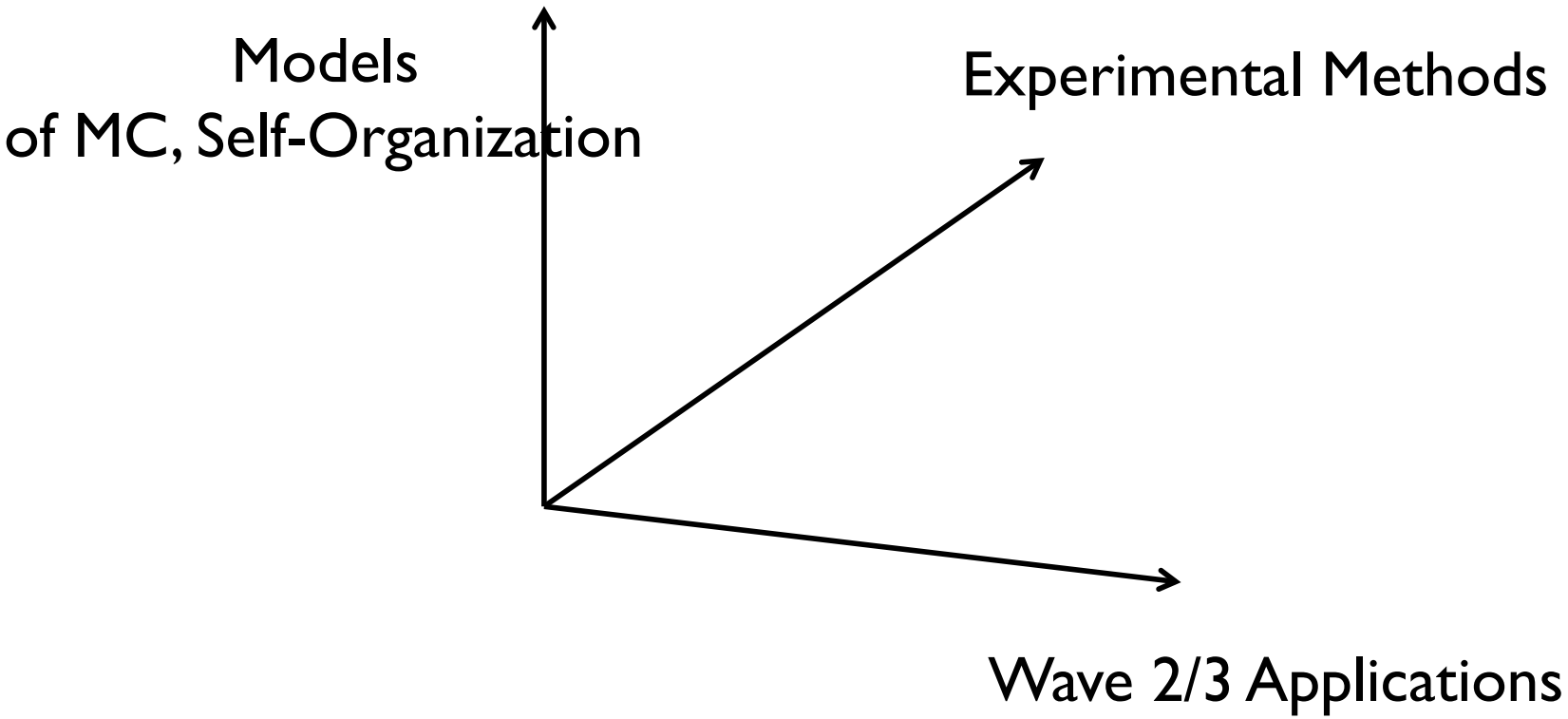
We will need to dramatically increase work productivity not only to cope with a shrinking work-force and growing number of people in old and very old age, but also to mobilize resources to help the ecologically sustainable development of the global economy and provide food and infrastructures to billions of more people.

- A steep progress in Robotics and AI seems a dramatic necessity in this context.
- The Advanced Mechatronic Technologies of the 'Second Wave' will have tremendous impact
- it seems unlikely that they can provide satisfactory 'companions' or life-like robustenss and adaptation
- An evidence-based answer to this question requires a boost in the ways research is performed and reported
- To enable the 'Third Wave' of Robotics a massive effort will be needed (also in terms of dramatically improved research methodologies as existing results are 'anedoctical')

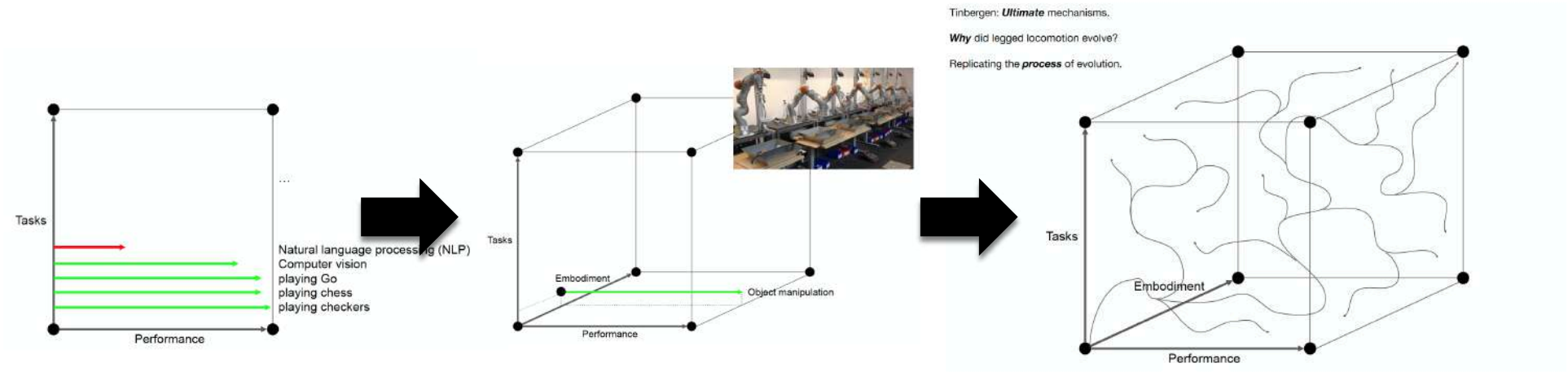
Carry-home messages (and remarks) (2)

- We will have to structure/digitalize living spaces to be able to exploit the existing and close future available technologies
- Given the cognitive/perception limits of current robots teleoperation, scalable autonomy and in general human-in-the-loop solutions will work better
- Non obvious human-in-the-loop solutions: prosthetics, body-augmentation, artificial organs, high-bandwidth BCI/BRI
- We should take care of the disciplinary interfaces with traslational genomics, connectomics, brain sciences, digital medicine, emerging rejuvenating technologies, to pursue successful holistic solutions for late age healthy and independent living
- We will still (sometimes remotely operating) need human caregivers: we should not leave elders andd impaired persons alone with deceptive robot 'companions'(it would/will make sense iff/when we will have conscious robots, that would open a huge number of different issues, though). Hopefully Industry 4.0, Robotics and AI (and what will follow) will free human resources!

The 'research space' we should – imo - explore (and that I have actually been exploring and I'm continuing to explore….)

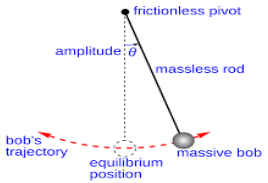


The 'research space' we should – imo - explore (and that I have actually been exploring and I'm continuing to explore….)

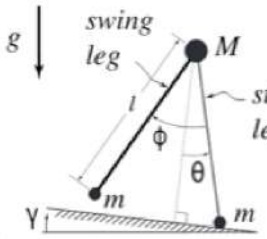


from Joshua Bongard, University of Vermont

The link between Morphological Computation and Soft Robotics



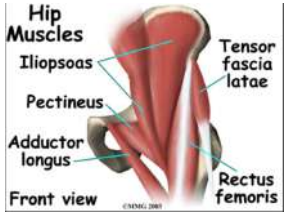
$$T \approx 2\pi\sqrt{\frac{L}{g}}$$



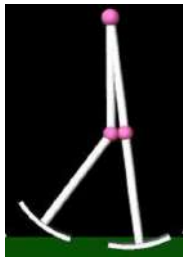
(Andy Ruina)

T=f(l/g)

Fixed speed!



(Wikipedia)



(Fumihiko Asano)

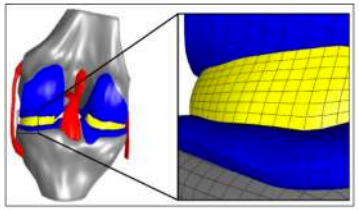
T=f(l/g)

l=f(controlled input)

Speed can change!

Quantitative Modelling of the trade-offs between physical morphology (and associated dynamics)
and information processing is crucial

That's what Morphological Computation is about.
It explains why 'soft' components help many task performances and can provide design guidance.



(Yale Image Finder)

the promise of robotics….

Feel free to contact me or the guest lecturers after the lectures

Let’s strengthen our community

Let’s start to scale up, take the ShanghAI Koans Challenge and prepare for Koans ++ ☺

Thank you!!!