Università di Pisa
Corso di Laurea Magistrale in Informatica
Corso di Robotica (ROB)
A.A. 2015/16

Introduzione alla Robotica e alla Biorobotica e introduzione al Corso

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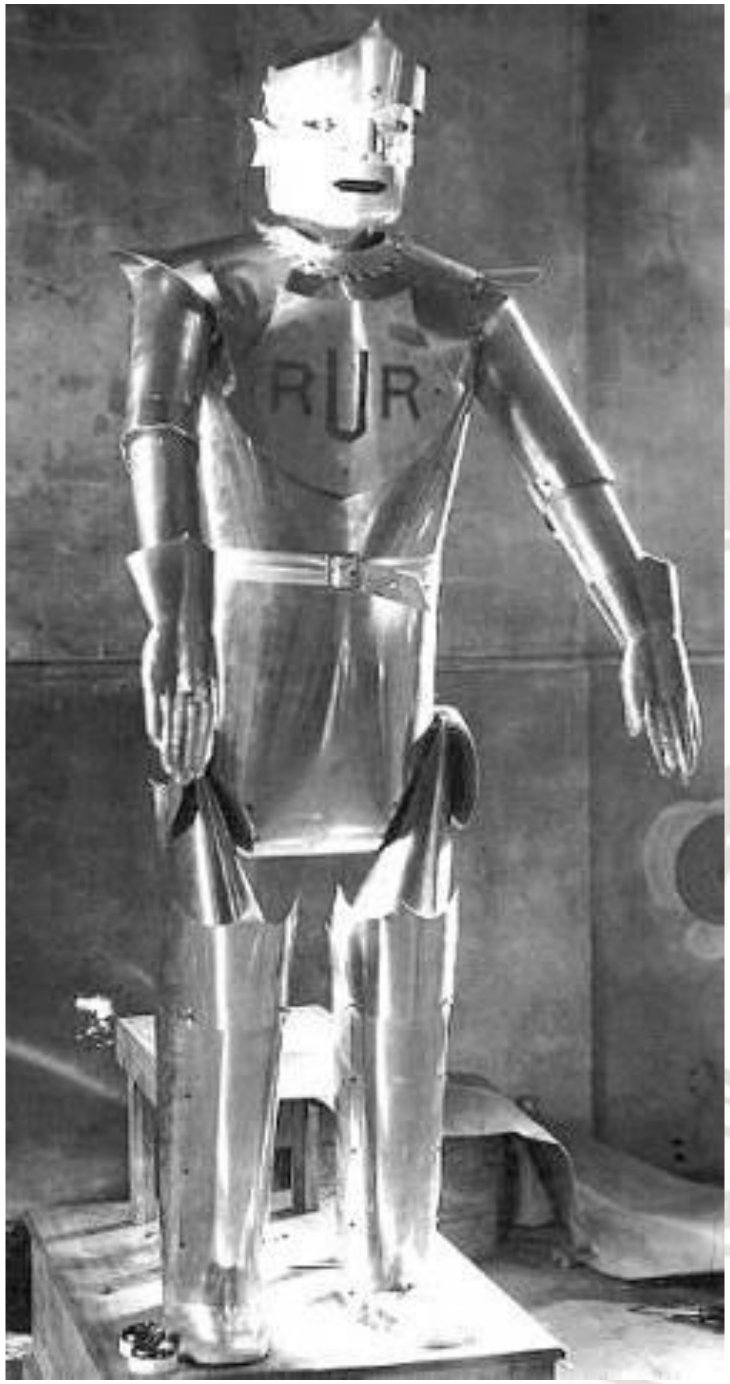
http://didawiki.cli.di.unipi.it/doku.php/magistraleinformatica/rob/start

Etimologia del termine “robot”

Il termine ***robot*** fu usato per la prima volta dallo scrittore ceco <u>**Karel Čapek**</u>, nel <u>**1920**</u> nel suo romanzo <u>*R.U.R. (Rossum's Universal Robots)*</u>. Deriva dal termine <u>**ceco**</u> ***robota***, che significa "**lavoro pesante**" o "**lavoro forzato**".



In realtà il vero inventore della parola *robot* fu il fratello di Karl Čapek, **Josef**, anche lui scrittore e pittore cubista, il quale utilizzò la parola “*automat*”, (automa), in un suo racconto del **1917**, ***Opilec*** (“L'ubriacone”).
Il termine greco ***autòmaton*** significa “che si muove da sé”.

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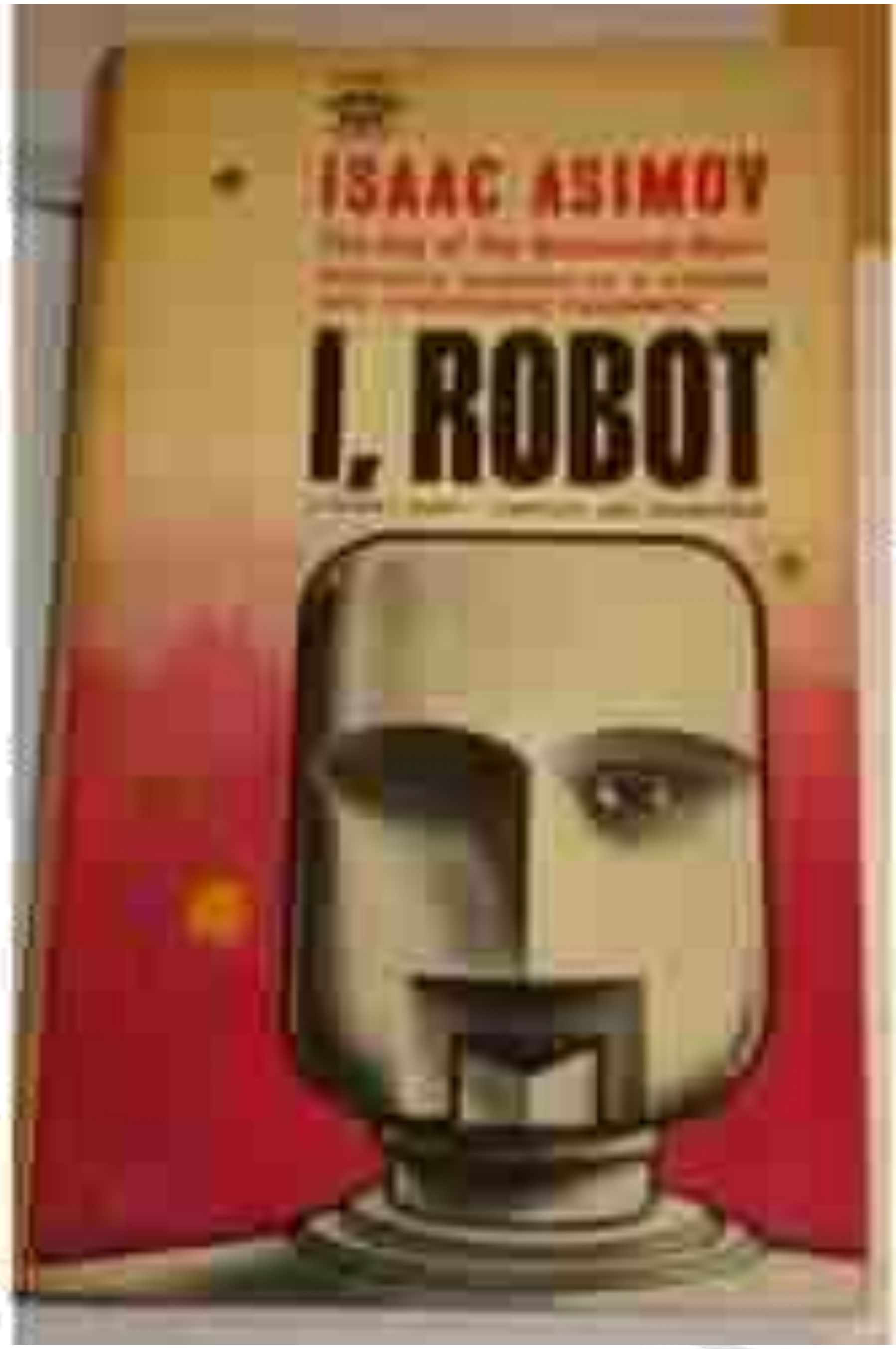
Etimologia del termine "robotica"

- Il termine "**robotica**" venne usato per la prima volta (su carta stampata) nel racconto di Isaac Asimov intitolato *Circolo vizioso* (*Runaround*, 1942), presente nella sua famosa raccolta *Io, Robot*.

- In esso, egli citava le *tre regole della robotica*, che in seguito divennero le **Tre leggi della robotica**.



Le tre leggi della robotica di Asimov

- Un robot non può recare danno a un essere umano, né può permettere che, a causa del suo mancato intervento, un essere umano riceva danno.
- Un robot deve obbedire agli ordini impartiti dagli esseri umani, purché tali ordini non contravvengano alla Prima Legge.
- Un robot deve proteggere la propria esistenza, purché questa autodifesa non contrasti con la Prima e la Seconda Legge.

Le origini della robotica moderna

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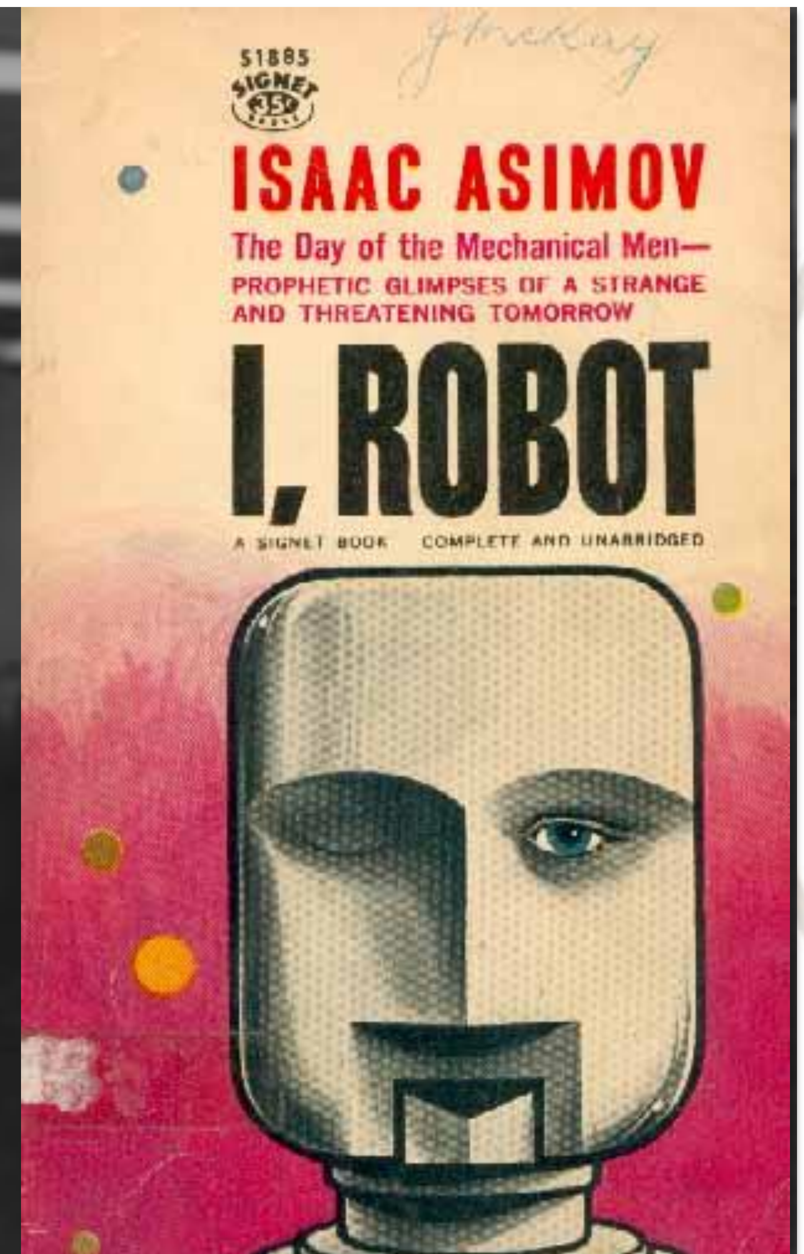
Isaac Asimov
Scrittore



Le origini della robotica moderna

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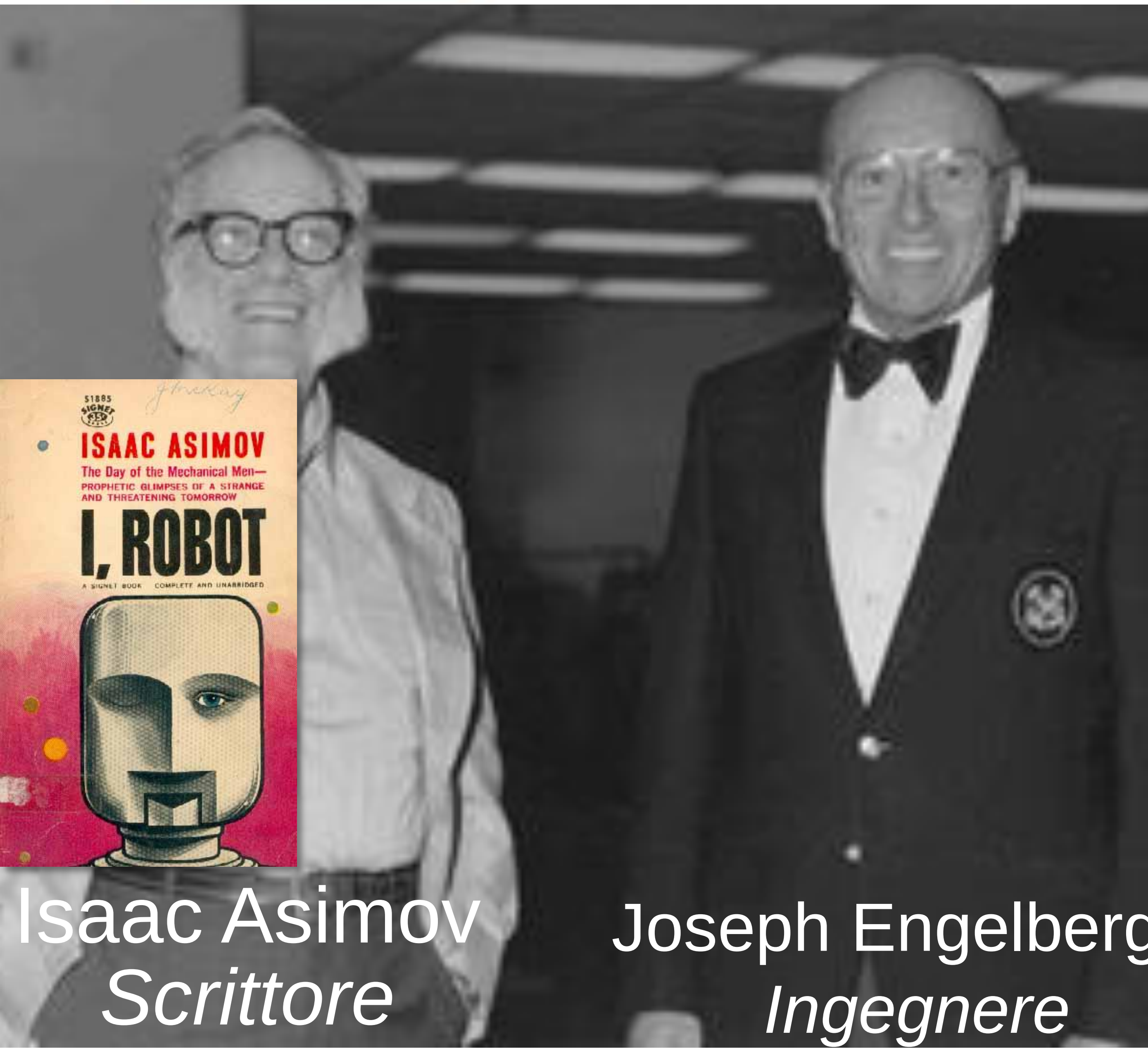

Isaac Asimov
Scrittore

Joseph Engelberger
Ingegnere

Nel 1960 il primo robot industriale fu installato presso un impianto produttivo General Motors in New Jersey (USA)

Automazione Industriale: la nascita e lo sviluppo della Robotica

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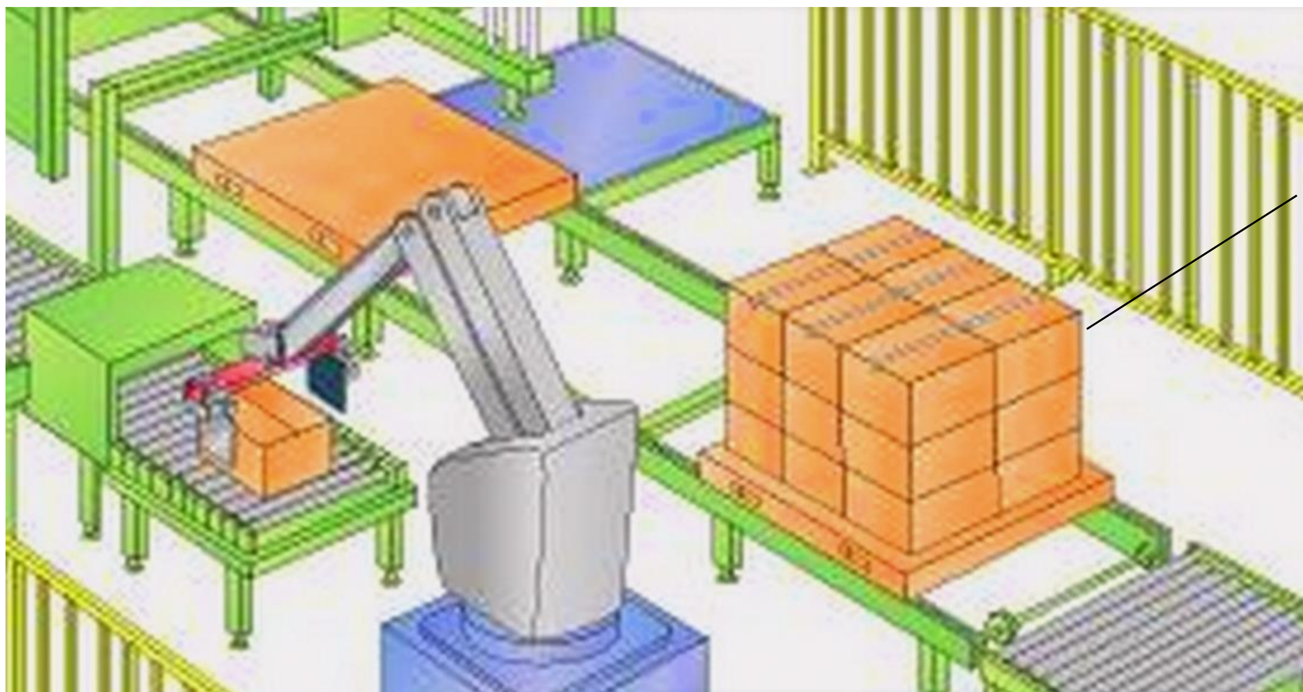
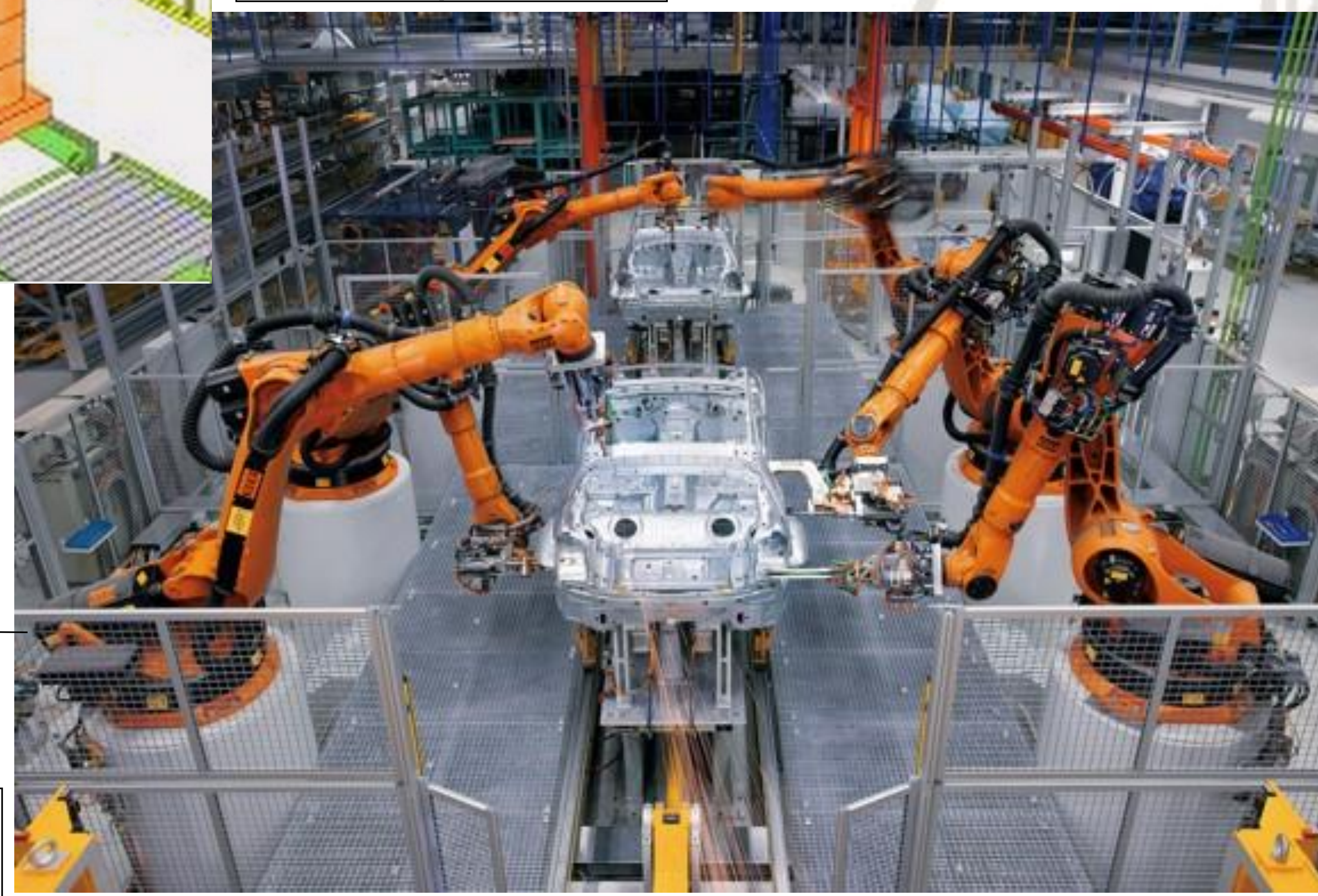
Tipico scenario per la robotica industriale



Ambiente strutturato

Posizioni note degli oggetti da manipolare

Nascita e sviluppo delle teorie e delle tecniche per il controllo di robot



Manipolatori ad elevate prestazioni in termini di accuratezza, ripetibilità, velocità, robustezza

Presenza umana ben delimitata

Operatori esperti (formati all'uso)

Definizioni di Robotica

- A robot is a re-programmable, multi-functional, manipulator designed to move material, parts, or specialized devices through variable programmed motions for the performance of a task
- *Un robot è un manipolatore multifunzionale riprogrammabile progettato per muovere materiali, componenti, o dispositivi specializzati, attraverso movimenti variabili programmati per lo svolgimento del compito*

Robotics Industry Association (~ 1980)

Jablonsky J., Posey J. 1985. “Robotics Terminology”, in *Handbook of Industrial Robotics*, ed. S. Nof, J. Wiley, New York, pp.1271-1303

Italy in industrial robotics from the very beginning

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1973: The origin of Comau dates back to the **CO**nsorzio **MA**cchine **U**tensili established to gather all commercial activities of the Turin area manufacturers involved in the technological equipment supply of the Togliattigrad VAZ plant in Russia.

1977: A number of companies merge into a company named **Comau Industriale S.p.A.**: MST S.p.A., Morando S.p.A., I.M.P. S.p.A., Colubra Lamsat S.p.A.

Robotica Industriale: il motore per lo sviluppo delle tecnologie robotiche

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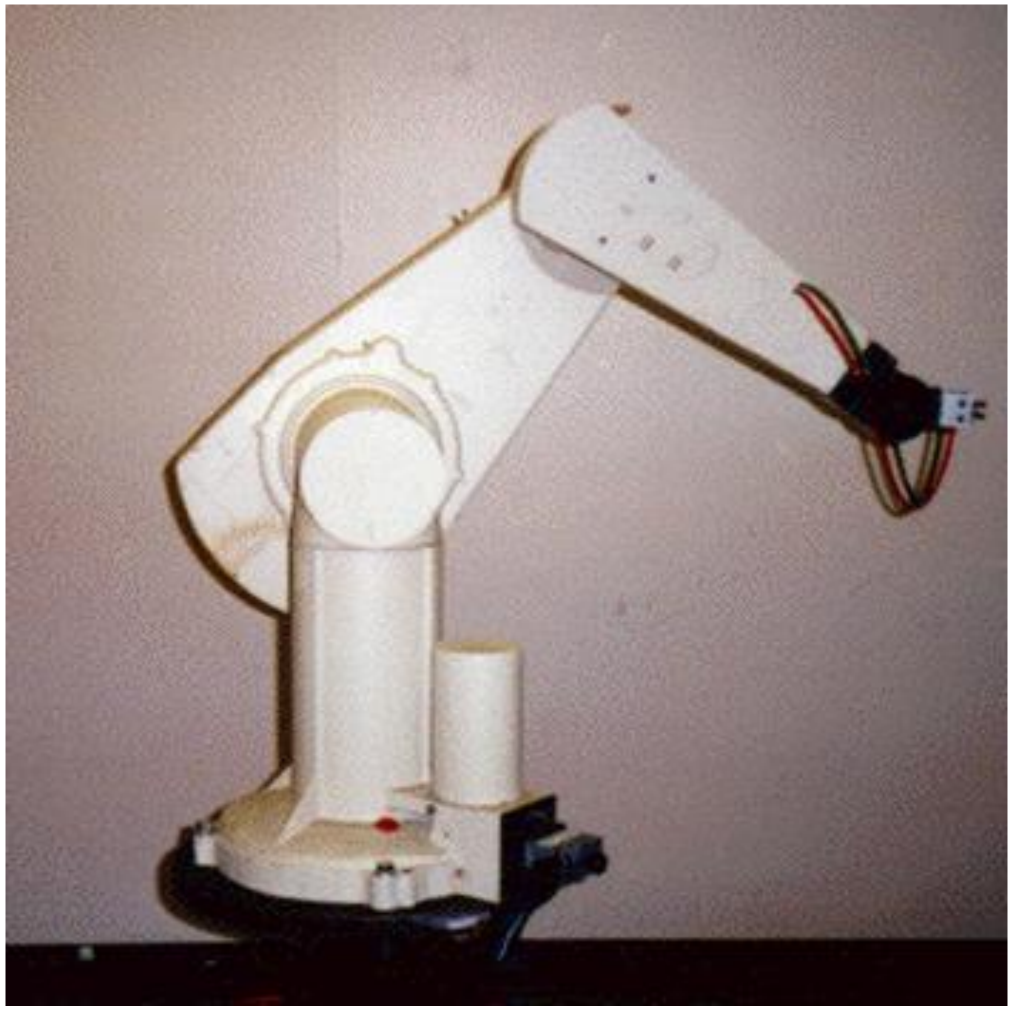
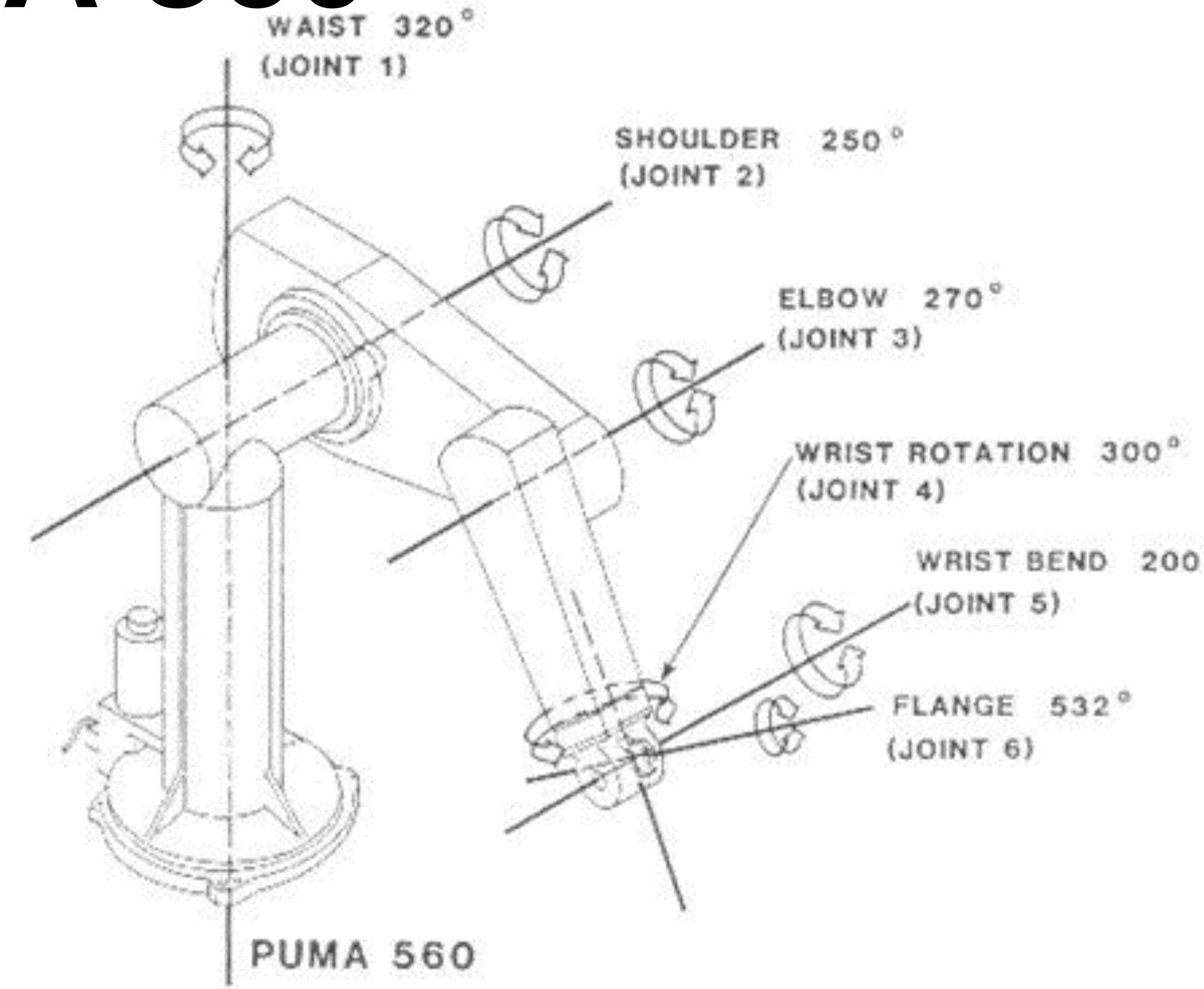
More than ***1 million operational industrial robots in the world***, with a growth rate of **6% per year** (*Source: IFR*)

Reliability of industrial robots:
Mean Time Before Failure = 40,000 hrs
Efficiency η > 99.99875%
(*Source: COMAU*)

PUMA 560





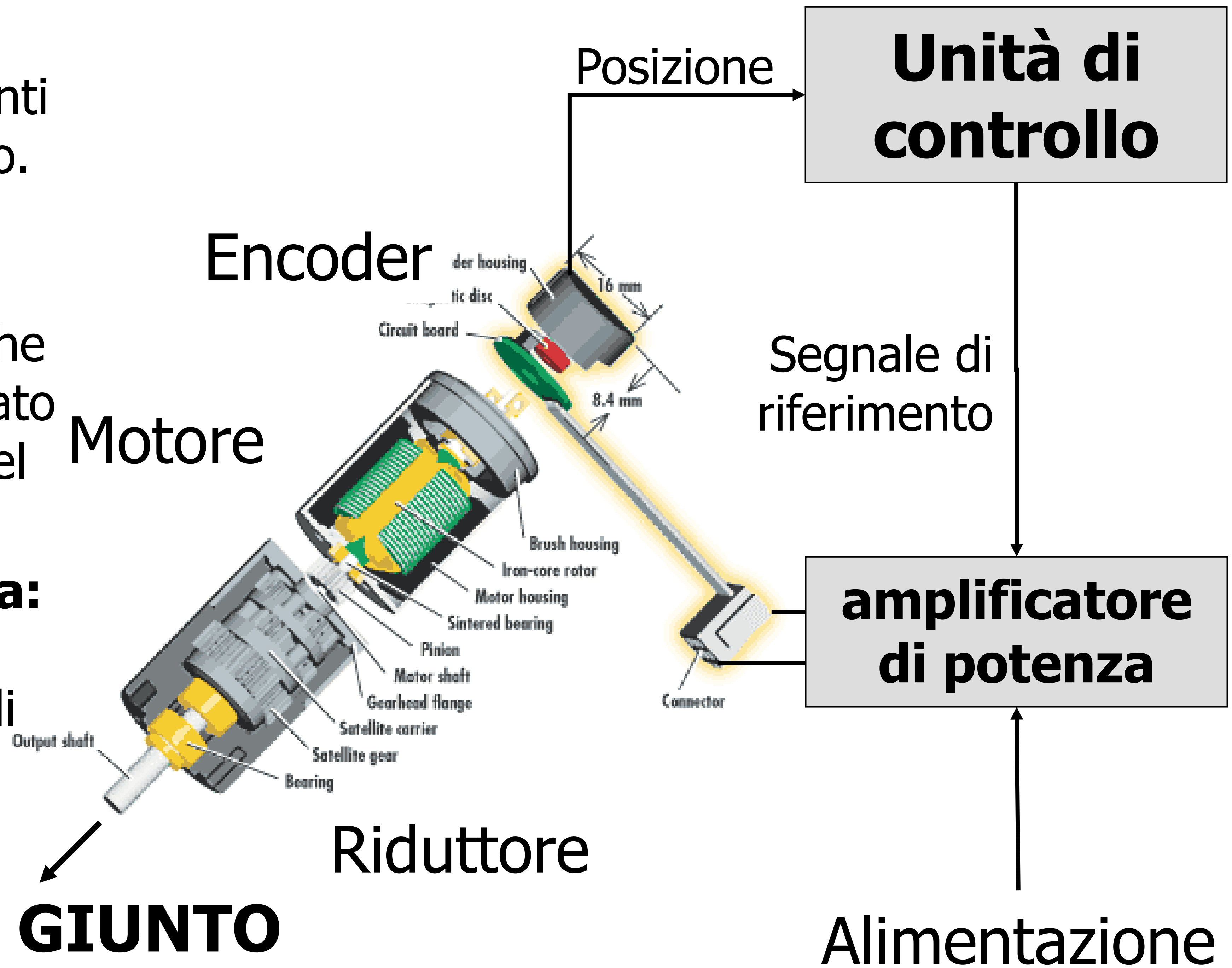
- Industrial Robot manipulator with 6 d.o.f
- The six degrees of freedom are controlled by six brushed DC servo motors
- Each motor is provided with a 500-1000 count 3 channel encoder and a potentiometer

	Repeatabili ty	Operating velocity	Weight
PUMA 560	± 0.1 mm	1.0 m/s	120 lb

P.I. Corke and B. Armstrong-Helouvry. *A search for consensus among model parameters reported for the Puma 560 Robot.* Proc. IEEE Conf. Robotics and Automation, 1994 pp. 1608-1613

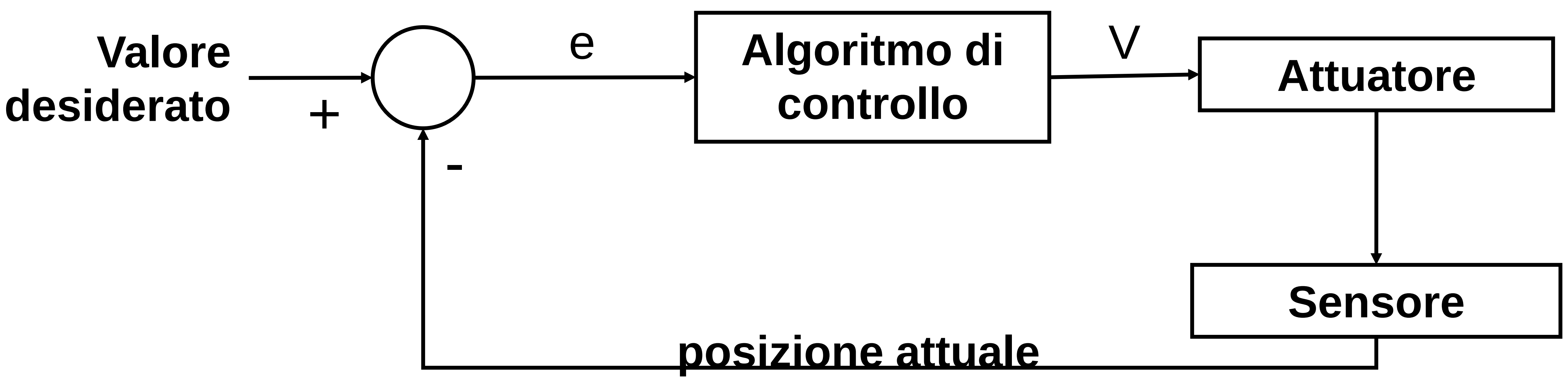
Schema di una unità di controllo

- **Encoder**: sensore che misura la rotazione dei giunti in valore relativo o assoluto. La misurazione avviene in "*tacche di encoder*"
- **Riduttore:** meccanismo che riduce i giri dell'asse montato sul giunto rispetto ai giri del motore (es. riduzione 1:k)
- **Amplificatore di potenza:** amplifica un segnale di riferimento in un segnale di potenza per muovere il motore
- **Unità di controllo**: unità che produce un segnale di riferimento per il motore

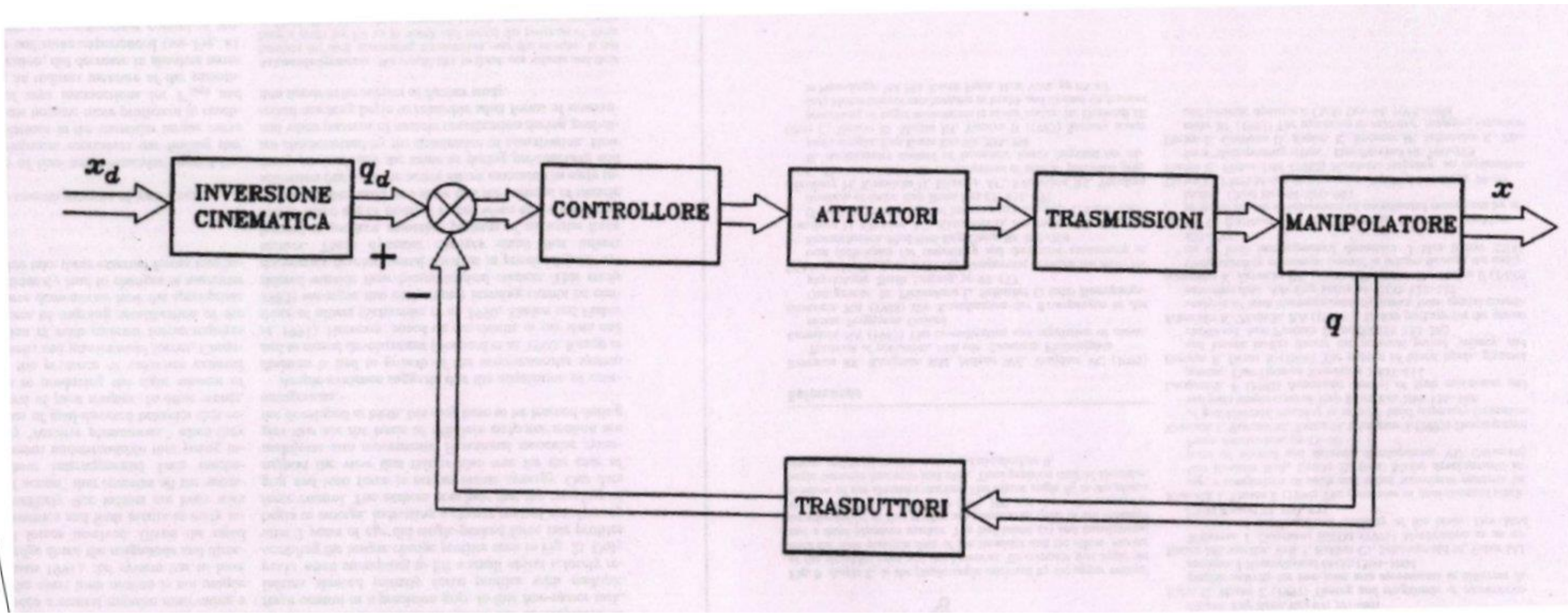


Controllo ad anello chiuso (feedback)

- La variabile da controllare è misurata e confrontata con il valore desiderato
- la differenza, o errore, è elaborata secondo un algoritmo prefissato
- il risultato di quest'elaborazione costituisce il valore d'ingresso dell'attuatore

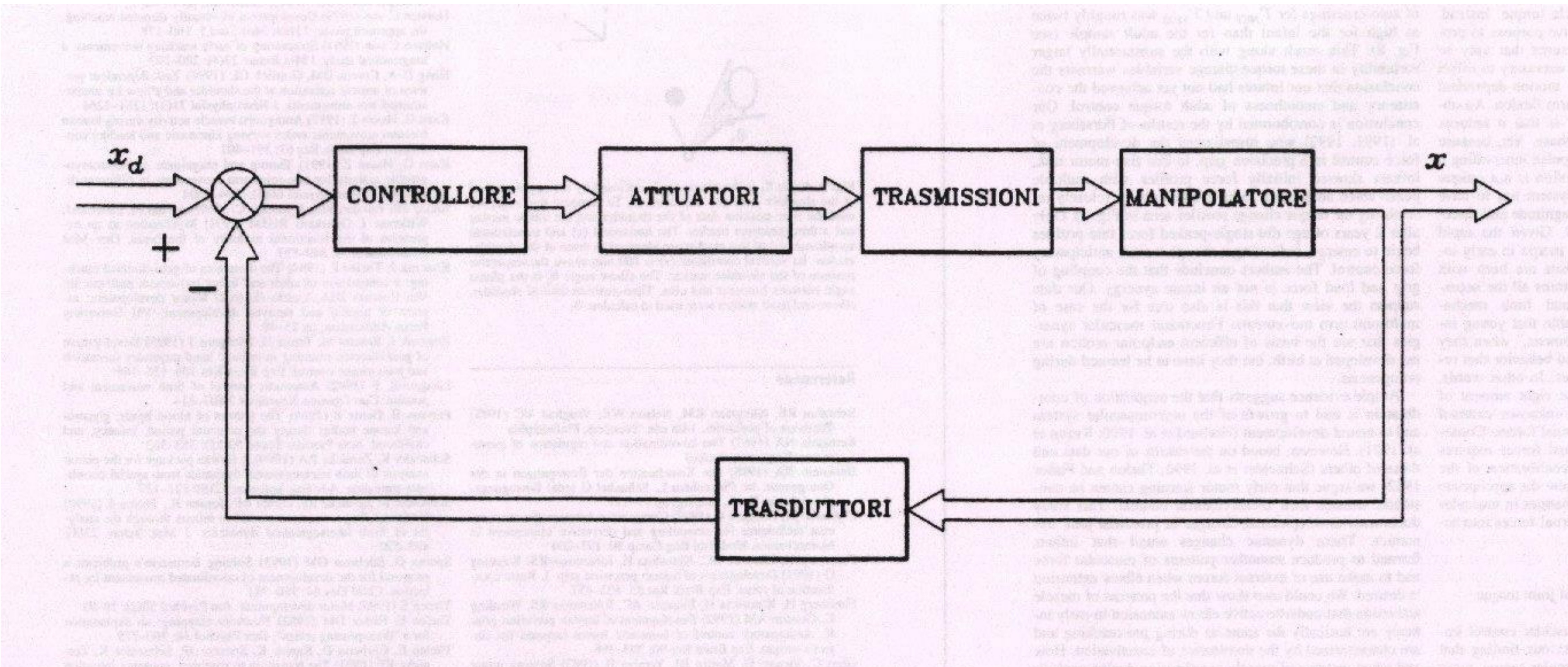


Controllo del moto nello spazio dei giunti



L'inversione cinematica viene effettuata al di fuori del ciclo di controllo

Controllo del moto nello spazio operativo



L'inversione cinematica viene effettuata all'interno del ciclo di controllo

I robot fuori dalle fabbriche: Robotica di Servizio

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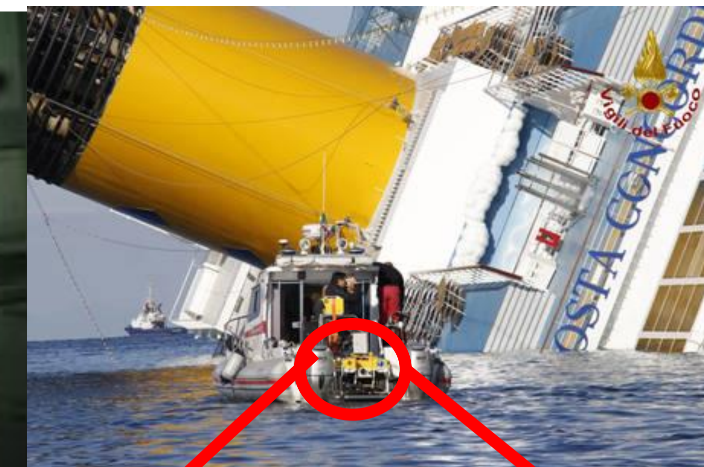
Pulizia, ambiente

Photo: Center for Robot-Assisted Search and Rescue



- Ambiente non strutturato
- Condivisione dello spazio di lavoro tra persone e robot
- Capacità percettive
- Comportamento reattivo

Ambienti pericolosi per l'Uomo o inaccessibili

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DustCart: il primo robot sperimentato nel suo utilizzo reale con i cittadini

Peccioli (Pisa), giugno-agosto 2010

35 cittadini – 402 servizi forniti – 120Km percorsi – 585Kg di rifiuti raccolti (carta, plastica e indifferenziata)

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Dedalus SOFTWARE FOR HEALTHCARE
Belvedere S.p.A. innovazione - progetti - sviluppo
Comune di Peccioli
Scuola Superiore Sant'Anna di Studi Universitari e di Perfezionamento
DustBot Networked and Cooperating Robots for Urban Hygiene
EU-IST Project no. FP6-045299
www.dustbot.org

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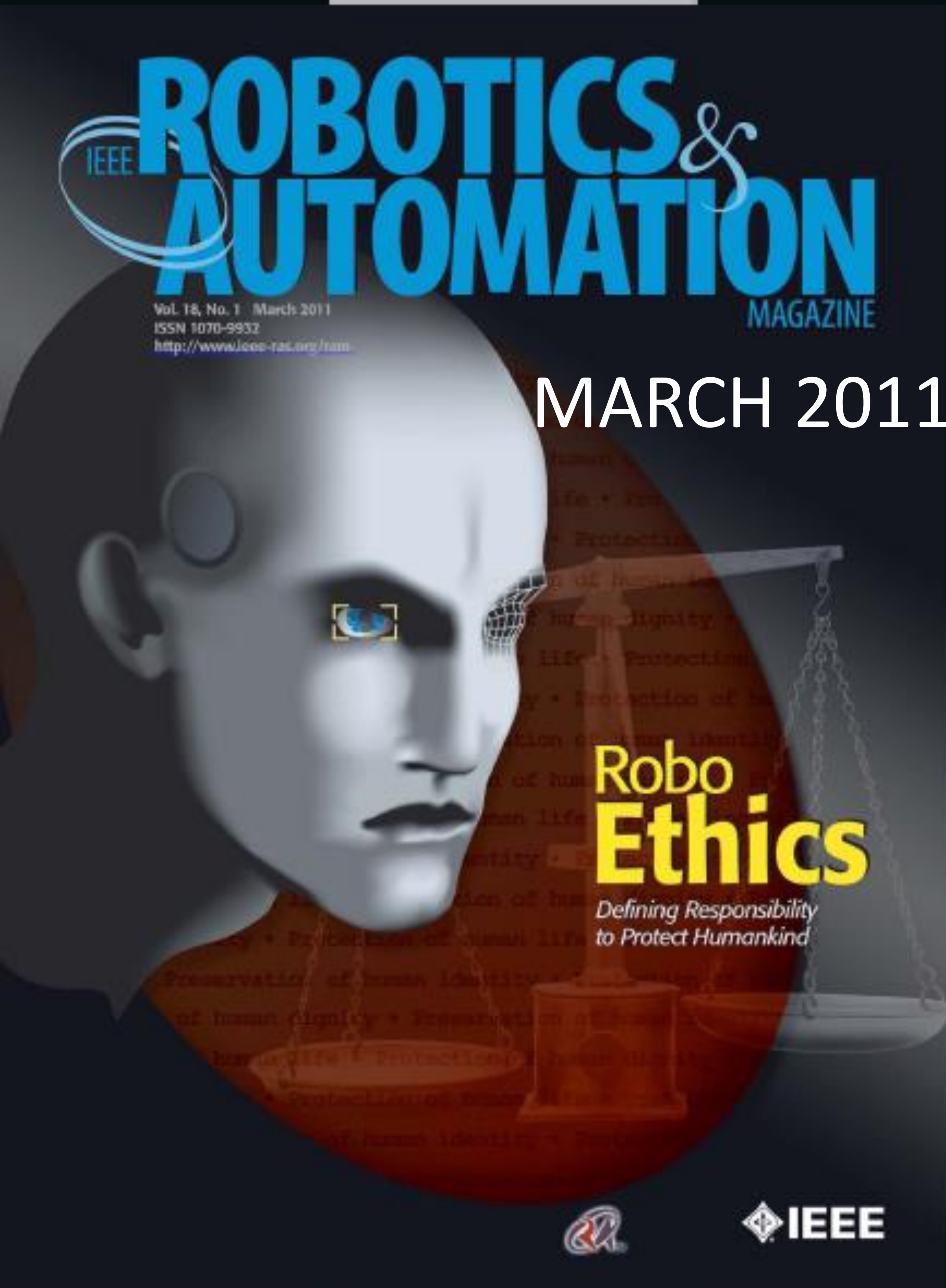

The Robot DustCart

By Fiorella Salvini, Gianardo Teti, Enza Spadoni, Cecilia Laschi, Barbara Mazzolai, and Paolo Dario

Focus on Social and Legal Challenges

Peccioli, a small medieval town in Italy, became one of the first places in the world where a robot was used (not demonstrated) to carry out a public service in the urban environment (from 15 June 2010 to 7 August 2010). Thirty-five real users *accepted* to trash their domestic waste using the robot DustCart, a mobile robot designed to collect, transport, and discharge rubbish bags in complete autonomy. During the testing period, the robot safely traveled along the public streets of Peccioli, carrying out its daily service and sharing the urban environment with the passers-by, bicycles, and cars, without causing any problems. Drawing on this unique event, in which the authors also participated, the article addresses some of the implications originating from the actual deployment of autonomous mobile robots in urban areas. Our reflections will gravitate around two major issues: legal regulations and social acceptance. More specifically, we will report on the legal solutions adopted for deploying DustCart in the streets of Peccioli and the activities carried out to increase the social acceptance of the robot.

Till today, the deployment of autonomous mobile robots in urban environments has been the talk of science fiction. A memorable example is a short story and the movie based on it, *I Robot* [1], where the robots carry out various kinds of services in human-inhabited settings. In a particular scene, humanoid robots are walking down the street, shoulder to shoulder with human beings. This is an exemplary case of coexistence between human beings and robots. In this article, we recount a similar story, but this time it is based on real facts: that of a service robot called DustCart, which was used for more than a month in a small Italian town to collect rubbish bags and then transport them to a discharge site. The robot, which was designed and developed within the framework of the European Union (EU) project DustBot [1], traveled on public roads in complete autonomy, interacting with people and cars and coexisting in the urban life of Peccioli. As far as we know, there are no references in literature to service robots being deployed in an urban environment or for such a lengthy period of time.

The objective of this article is to report on the testing of the robot DustCart in Peccioli and to point out some of the ethical, legal, and social implications that emerged before and during the test period.

Digital Object Identifier 10.1109/MRA.2010.940151
Date of publication: 14 April 2011

The RoboLaw Project

Programme "Capacities" - Call ID "FP7-SCIENCE-IN-SOCIETY-2011-1" Topic: SiS.2011.1.1.1-3 Regulating emerging scientific and technological developments. **EU Financial Contribution**: 1.497.966 EUR. **Duration:** 24 Months.

1) Scuola Superiore Sant'Anna, Pisa, Italy
2) Tilburg University, the Netherlands
3) University of Reading, England (UK)
4) University of Humboldt, Germany

"White Book on Regulating Robotics",

containing guidelines for the European Commission in the field of regulating emerging robotic technologies replying to the ethical concerns regarding its applications.

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Definizioni di Robotica

- A robot is a re-programmable, multi-functional, manipulator designed to move material, parts, or specialized devices through variable programmed motions for the performance of a task
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Jablonsky J., Posey J. 1985. "Robotics Terminology", in *Handbook of Industrial Robotics*, ed. S. Nof, J. Wiley, NY, pp.1271-1303

- Robotics is the intelligent connection of perception to action
- *Robotica è la connessione intelligente della percezione all'azione*

Michael Brady (~1985)

M. Brady, 1985. "Artificial Intelligence and Robotics", *Artificial Intelligence and Robotics*, Vol.26, pp.79-121

- A robot is a machine able to extract information from its environment and use knowledge about its world to move safely in a meaningful and purposeful manner
- *Un robot è una macchina in grado di estrarre informazioni dall'ambiente e di usare la conoscenza sul mondo per muoversi in maniera sicura, significativa e intenzionale*

Ronald Arkin, Maja Mataric (~ 1990)

(Ronald Arkin, *Behaviour-based Robotics*, MIT Press, 1999)

- Robotics is the science and technology of the design of mechatronic systems capable of generating and controlling motion and force
- *Robotica è la scienza e tecnologia della progettazione di sistemi meccatronici capaci di generare e controllare movimento e forza*

Paolo Dario (~ 2000)

Una definizione generale di robot

Un robot è una **macchina** che raccoglie informazioni dall'ambiente circostante (**sente**) e le utilizza per pianificare determinati comportamenti (**"pensa"**) che le permettono di compiere delle azioni nell'ambiente in cui si trova (**agisce**)

George Bekey, 2005

Definizione di robot autonomo

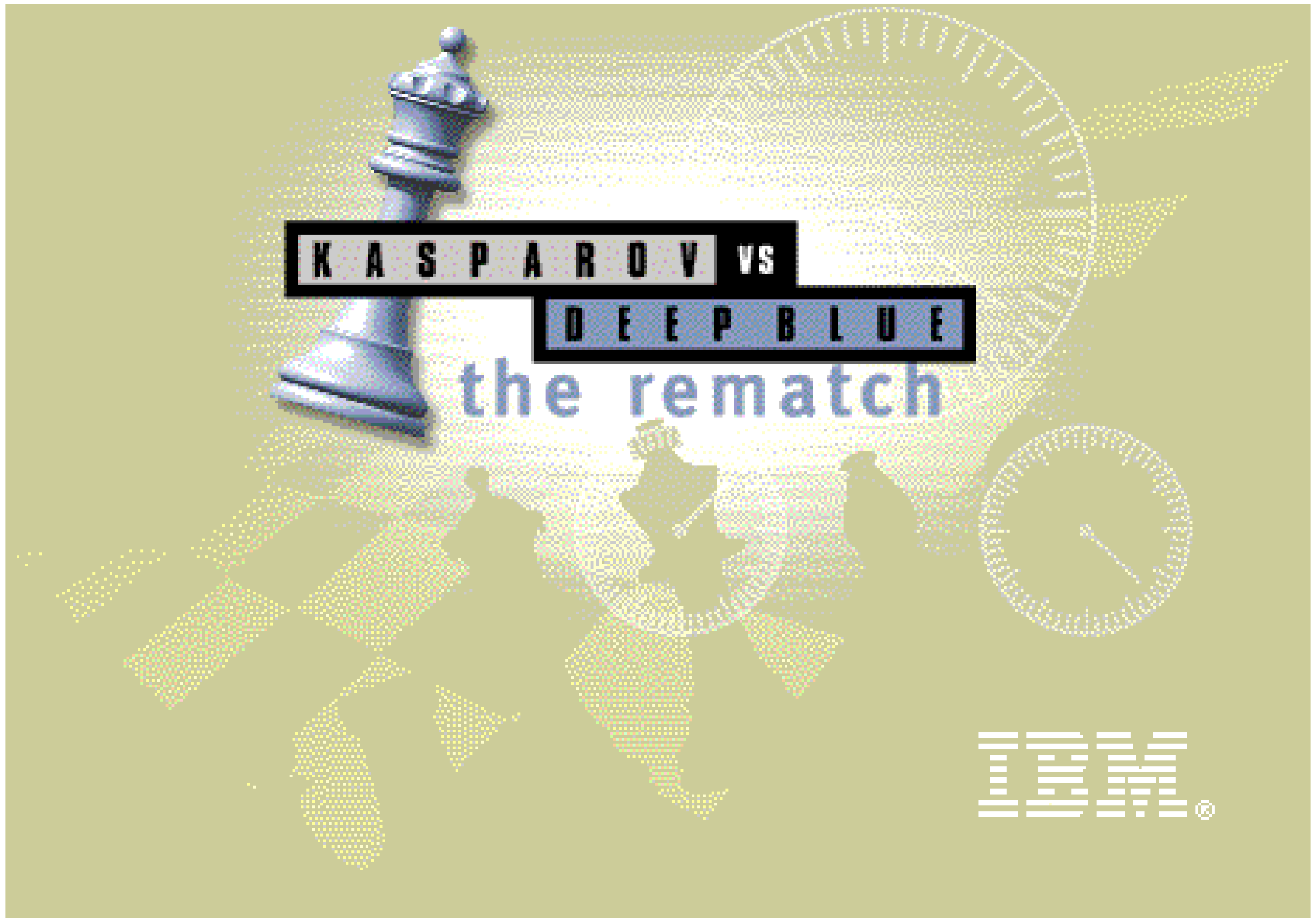
- Macchina capace di accettare ed eseguire **autonomamamente** comandi o missioni in ambienti **non completamente strutturati senza l'intervento dell'uomo**
- Problematiche:
  "pianificare dinamicamente i comportamenti del robot in un ambiente di lavoro non noto a priori e variabile nel tempo in funzione della richiesta di esecuzione di un determinato compito"

Intelligenza Artificiale

- L'abilità di un computer di svolgere funzioni e ragionamenti tipici della mente umana.
- L'espressione "Intelligenza Artificiale" (Artificial Intelligence) fu coniata nel 1956 dal matematico americano John McCarthy, durante uno storico seminario interdisciplinare svoltosi nel New Hampshire. Secondo le parole di Marvin Minsky, uno dei "pionieri" della I.A., lo scopo di questa nuova disciplina sarebbe stato quello di "far fare alle macchine delle cose che richiederebbero l'intelligenza se fossero fatte dagli uomini".
- L'intelligenza artificiale è una disciplina dibattuta tra scienziati e filosofi, la quale manifesta aspetti sia teorici che pratici.
- Nel suo aspetto puramente informatico, essa comprende la teoria e le tecniche per lo sviluppo di algoritmi che consentano alle macchine (tipicamente ai calcolatori) di mostrare un'abilità e/o attività intelligente, almeno in domini specifici.
- Uno dei problemi principali dell'intelligenza artificiale è quello di dare una definizione formale delle funzioni sintetiche/astratte di ragionamento, meta-ragionamento e apprendimento dell'uomo, per poter poi costruire dei modelli computazionali che li concretizzano e realizzano (in modo "goal-oriented")

La sfida dell’intelligenza artficiale negli anni ‘80: Deep Blue, IBM

- Il computer che ha battuto il campione di scacchi Kasparov



Embodiment

- “Non può esistere una macchina con un’intelligenza e un comportamento simili all’uomo che non sia dotata di un sistema sensoriale con prestazioni simili a quelle umane”

Rodney A. Brooks, 1998

Direttore Artificial Intelligence Laboratory

MIT - Massachussettes Institute of Technology

Boston, USA

La nuova sfida: una squadra di calcio di robot umanoidi

RoboCup

Nel 2050 una squadra di calcio di robot umanoidi sfiderà la nazionale vincitrice del Campionato del Mondo

Dalle architetture gerarchiche a quelle reattive

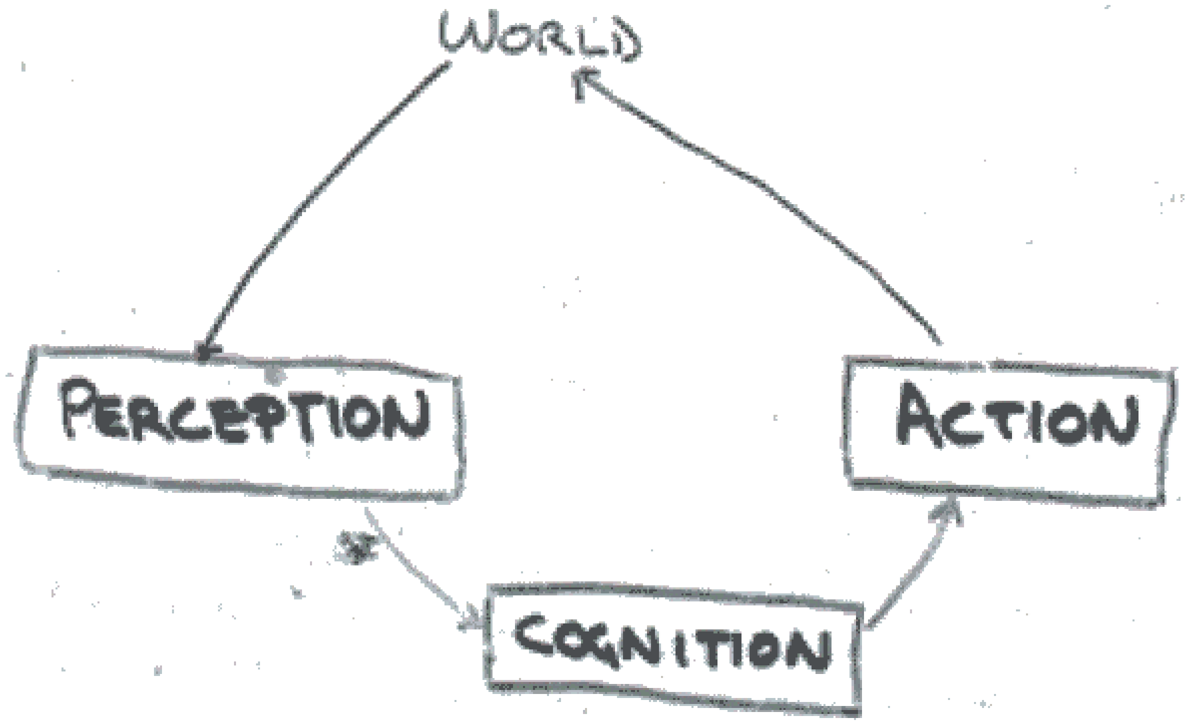


Figure 1: The traditional model where cognition mediates between perceptions and plans of actions.

deliberative, model-based

reactive, behavior-based

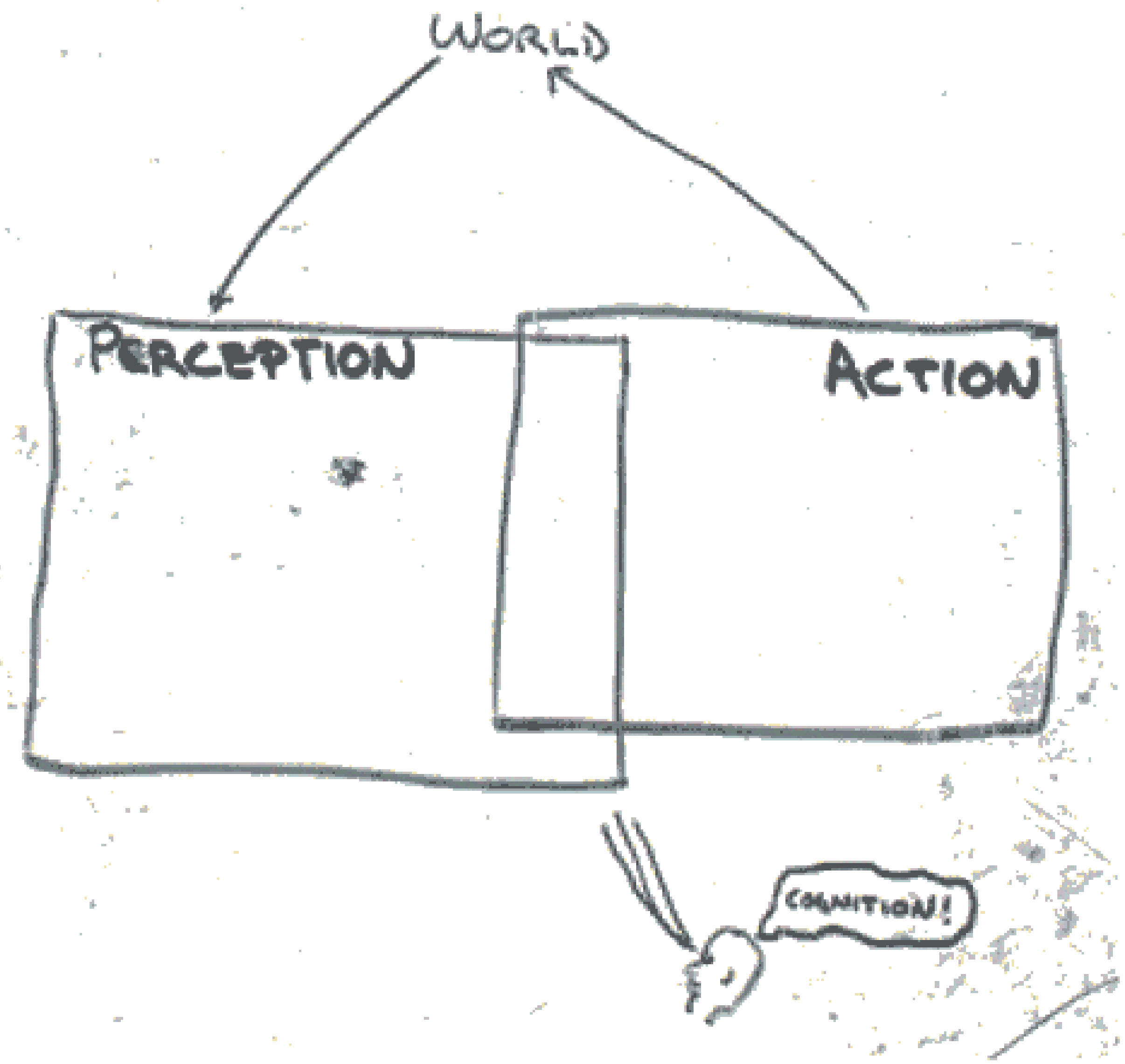


Figure 2: The new model, where the perceptual and action subsystems are all there really is. Cognition is only in the eye of an observer.

R. Brooks, *Cambrian Intelligence"*
MIT Press, 2000

I robot fuori dalle fabbriche…

…dovendo operare nel mondo reale, devono saper gestire le incertezze e reagire prontamente ai cambiamenti nell'ambiente

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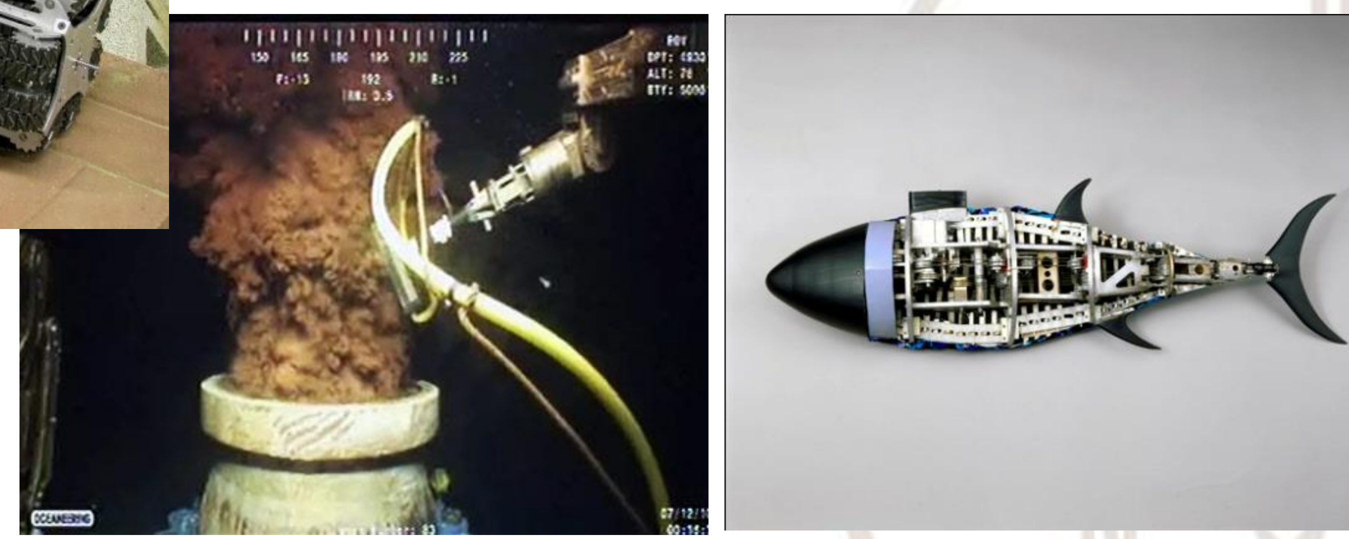
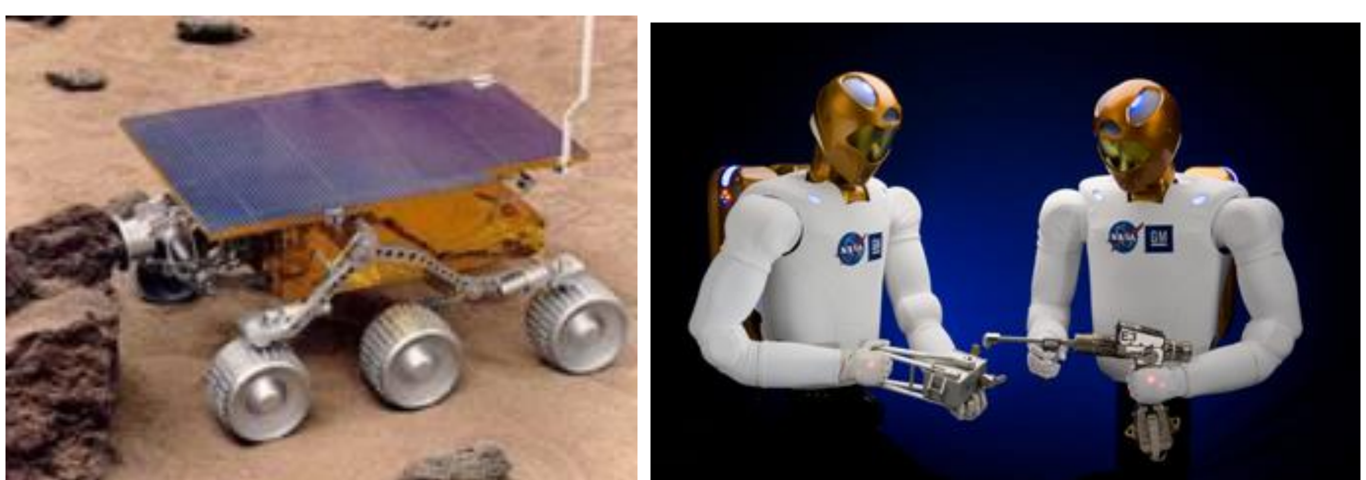
I sistemi biologici rappresentano un'eccellente fonte di ispirazione

Salvataggi



Applicazioni sottomarine

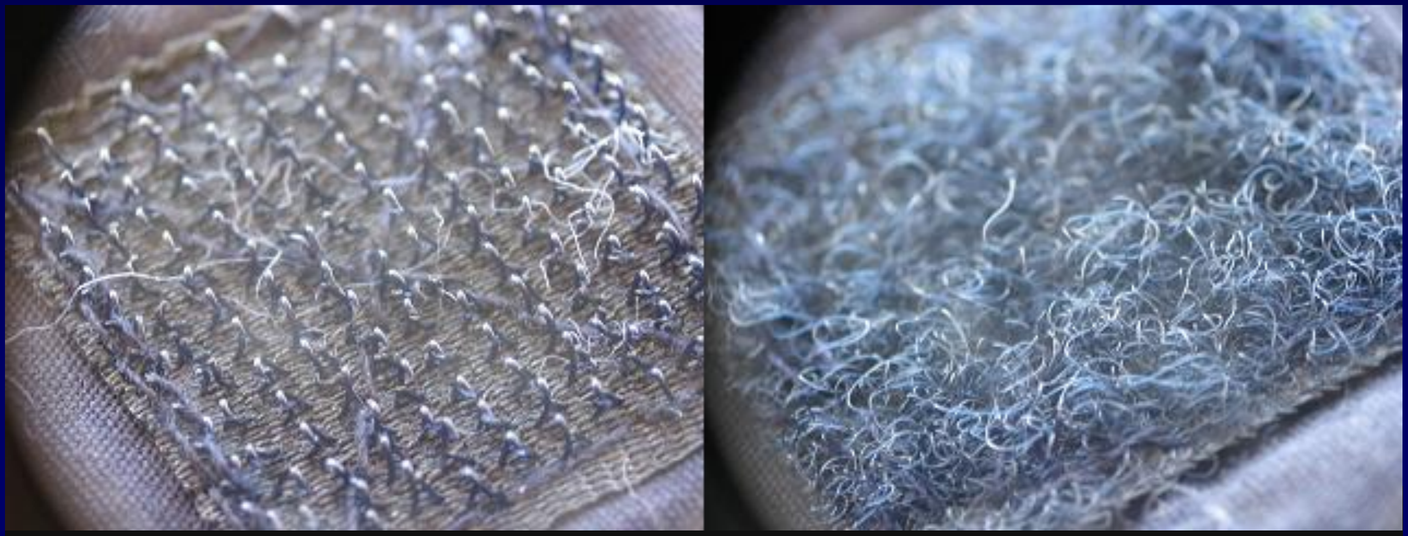


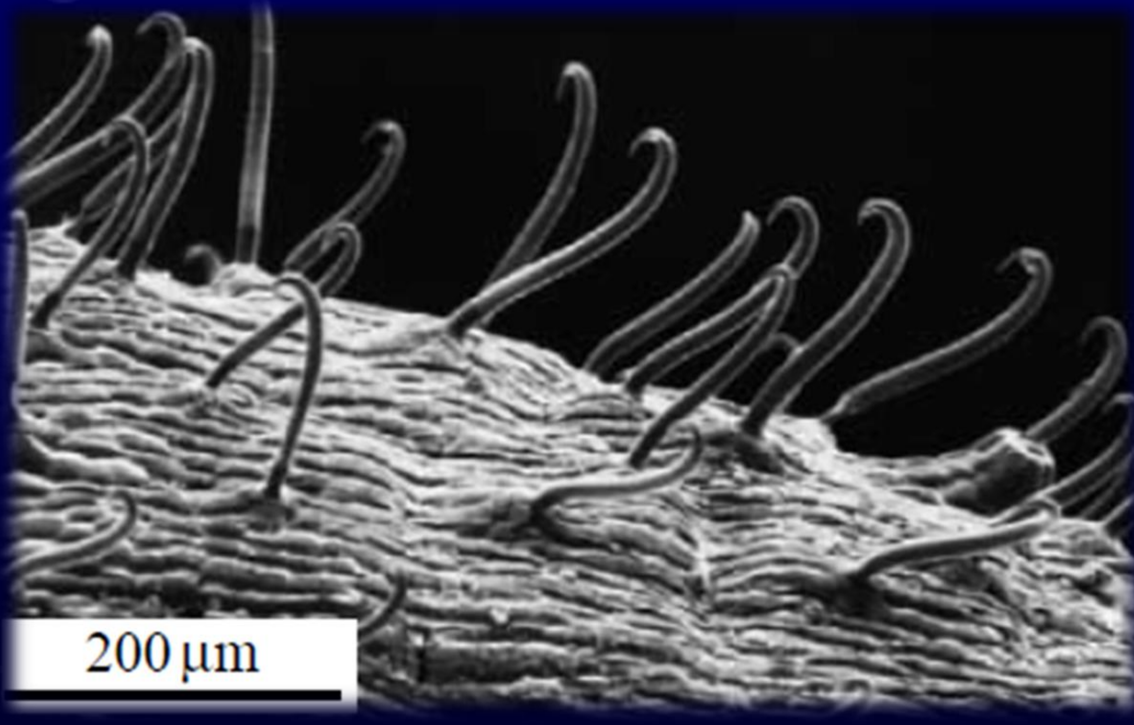
Applicazioni spaziali

- Ambiente non strutturato
- Condivisione dello spazio di lavoro tra persone e robot
- Maggiori capacità percettive
- Comportamento reattivo

Some examples of biomimetics in action

- Velcro resulted in 1948 from a Swiss engineer, George de Mestral, noticing how the hooks of the plant burrs (*Arctium lappa*) stuck in the fur of his dog.

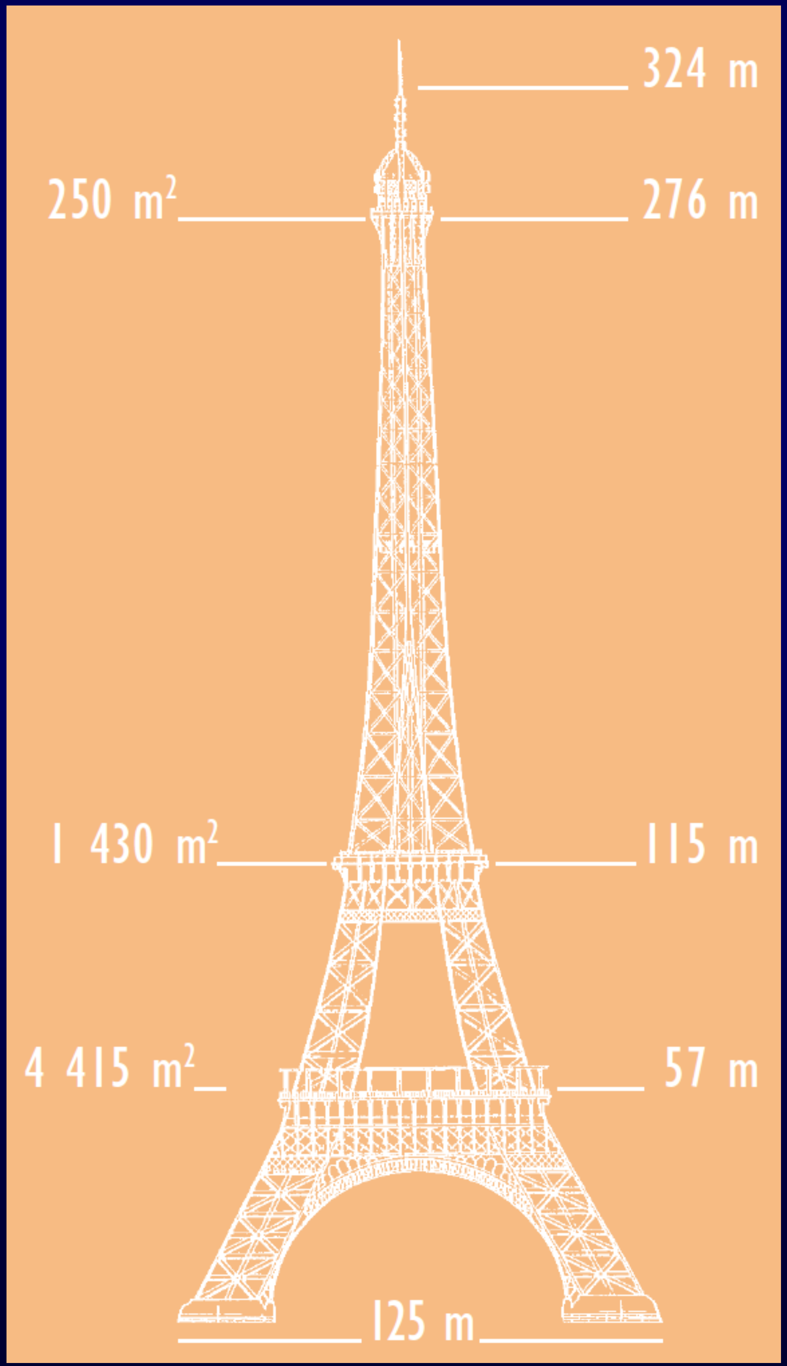




Some examples of biomimetics in action

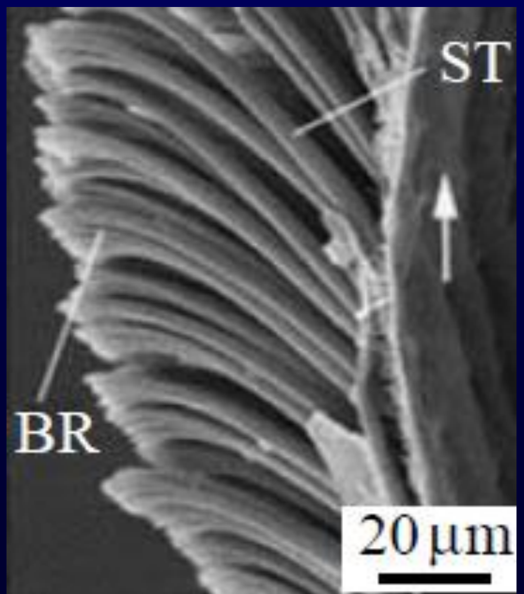
The **Eiffel Tower**: the perfect structure of trabecular struts in the head of the human femur inspired a French engineer at the end of the 19th Century. He was intended to design the higher structure all the world. The name of this engineer is Gustave Eiffel.

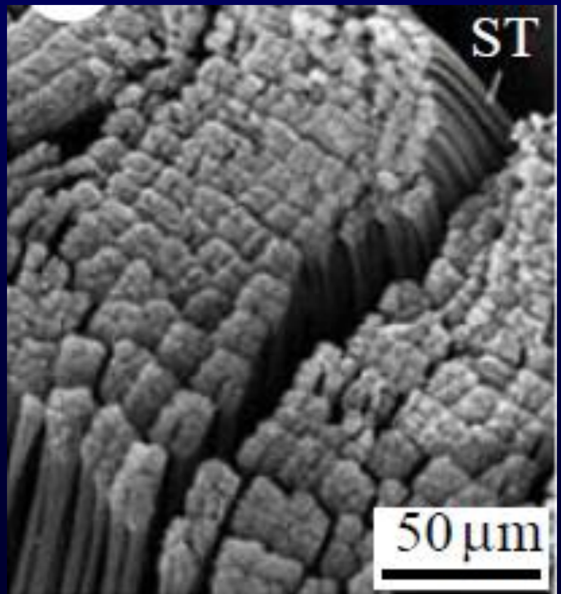
In 1889 the Tower is completed.

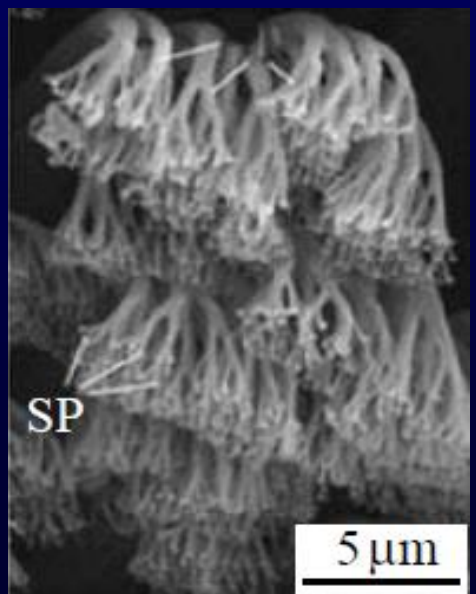


Some examples of biomimetics in action

- the **gecko tape and robot**: a gecko is the largest animal that can produce (dry) adhesion to support its weight. The gecko foot comprises a complex hierarchical structure of lamellae, setae, branches, and spatula.







Bioinspiration: lessons from Nature

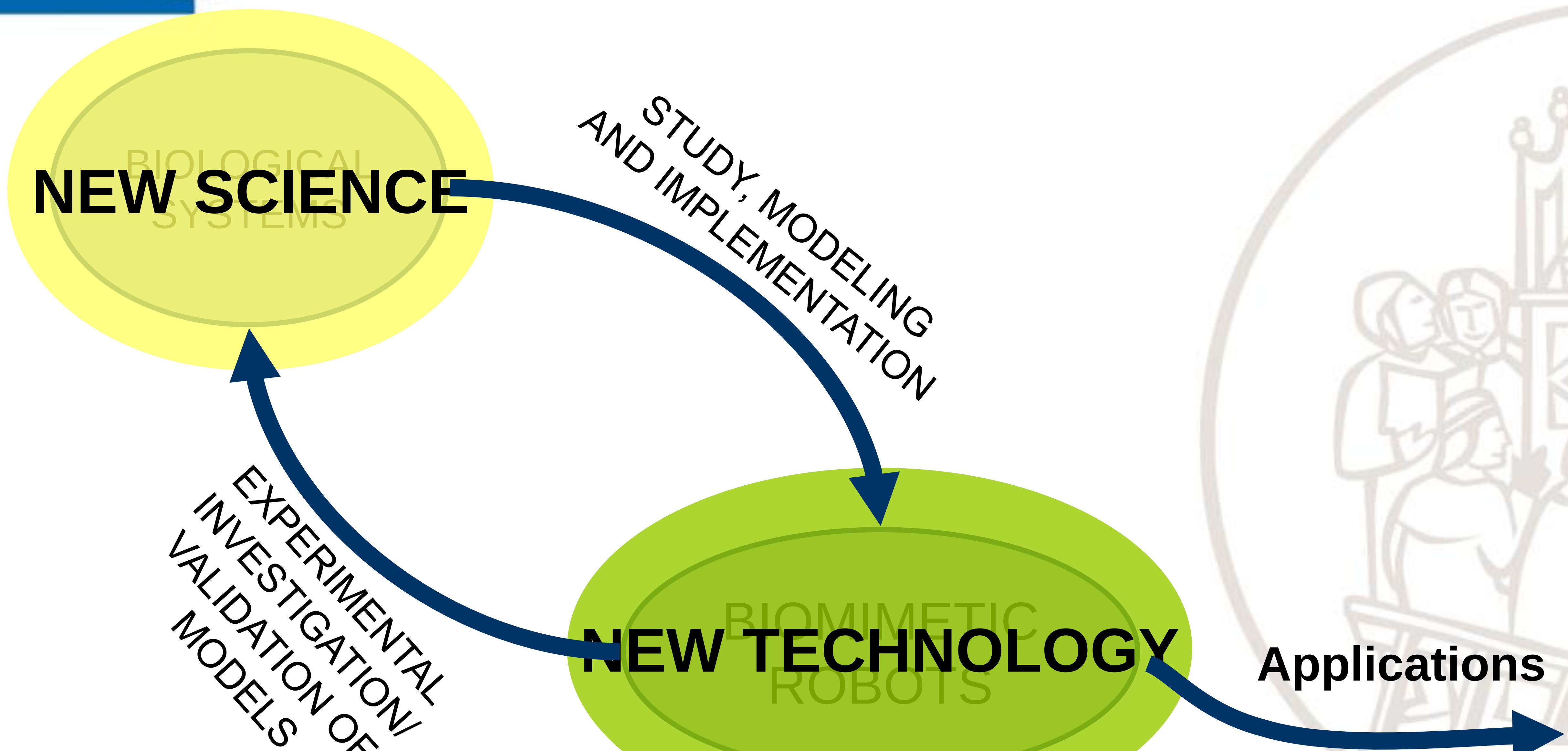
Nevertheless... Natural selection is not Engineering

Organisms that are capable of surviving are not necessarily **optimal** for their technical performance. They need to survive long enough to reproduce. **Models are never complete or correct: need to interpret with caution.**

"We think blind copying is exactly what you don't want to do," says Robert Full, a biologist at the University of Berkeley, California. *"You will fail miserably, because nature is way too complex."*

One cannot **simply copy** Nature, but rather carefully **choose** Nature's behaviour of interest, and **extract** the underlying key **principle** at a level of description that is actually possible to implement.

The two-fold relation between robotics and biology



Biomimetic robotics:

- developing robots for real-world applications
- studying biological systems by robotic platforms

Unified approach to the study of living organisms and robots

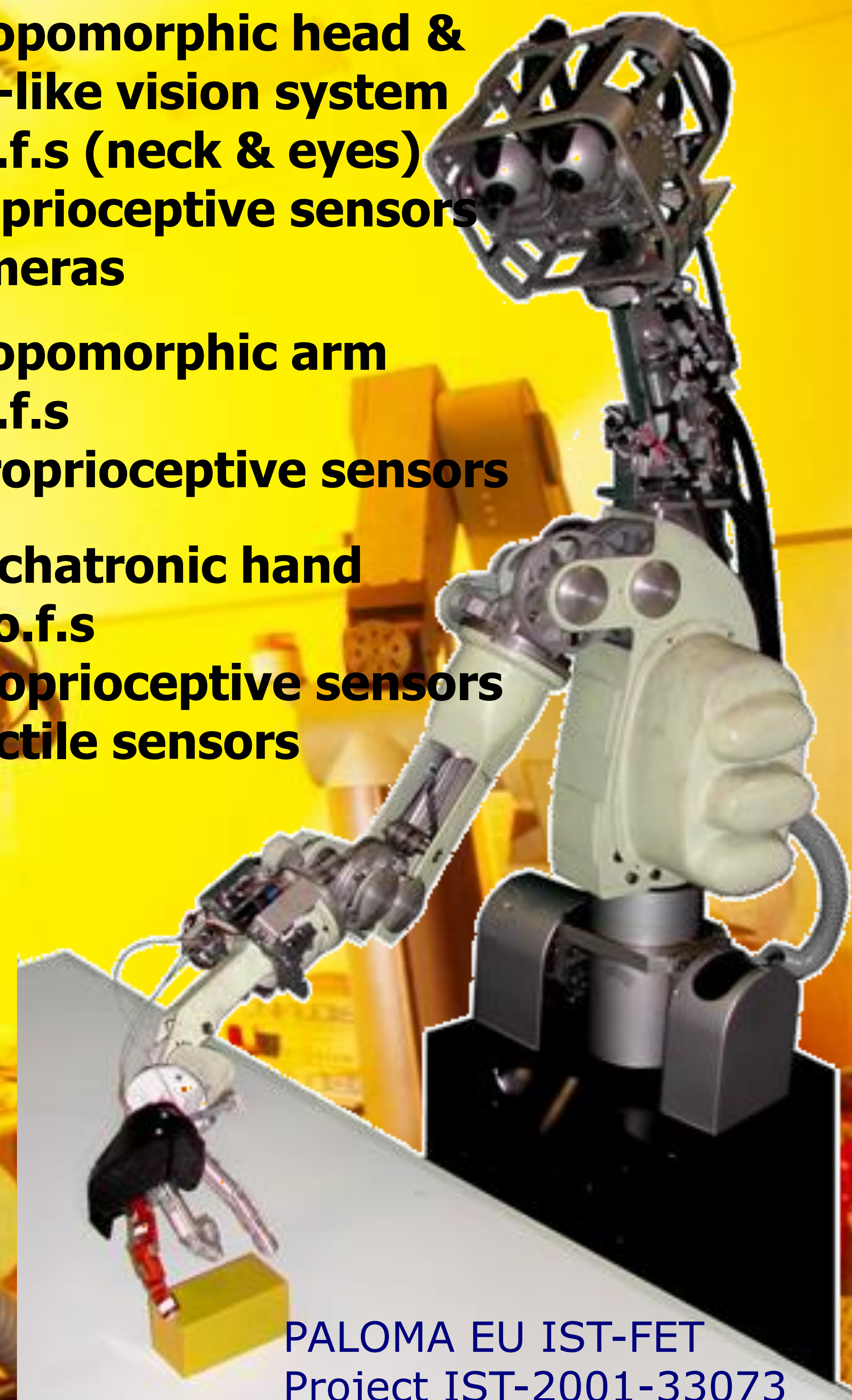
The ARTS humanoid robot

Total
- **d.o.f.s: 25**
- **Visual sensors: 2**
- **Proprioceptive sensors: 39**
- **Tactile sensors: 135**

Anthropomorphic head & retina-like vision system
- **7 d.o.f.s (neck & eyes)**
- **7 proprioceptive sensors**
- **2 cameras**

Anthropomorphic arm
- **8 d.o.f.s**
- **16 proprioceptive sensors**

Biomechatronic hand
- **10 d.o.f.s**
- **16 proprioceptive sensors**
- **21 tactile sensors**



P. Dario, M.C. Carrozza, E. Guglielmelli, C. Laschi, A. Menciassi, S. Micera, F. Vecchi, "Robotics as a "Future and Emerging Technology: biomimetics, cybernetics and neuro-robotics in European projects", *IEEE Robotics and Automation Magazine*, Vol.12, No.2, June 2005, pp.29-43.

PALOMA EU IST-FET
Project IST-2001-33073

Learning motor control: **neurocontroller** for controlling arm position and orientation

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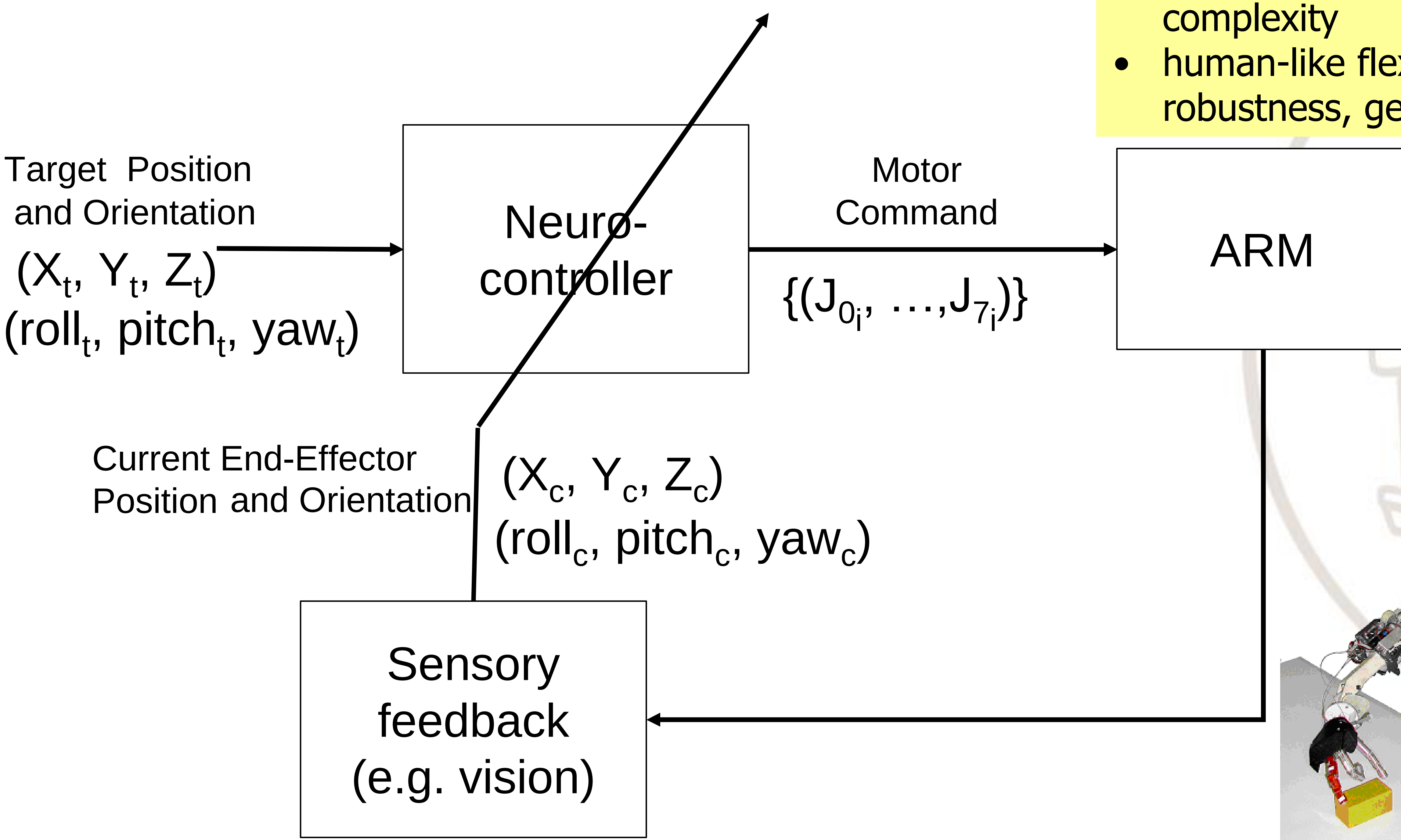
- No a priori knowledge on the geometry, kinematics and dynamics of the robot is required
- ***learning*** capability, to develop an internal model that builds such knowledge
- low computational complexity
- human-like flexibility, robustness, generalization



Experimental results on a 3-link arm in simulation

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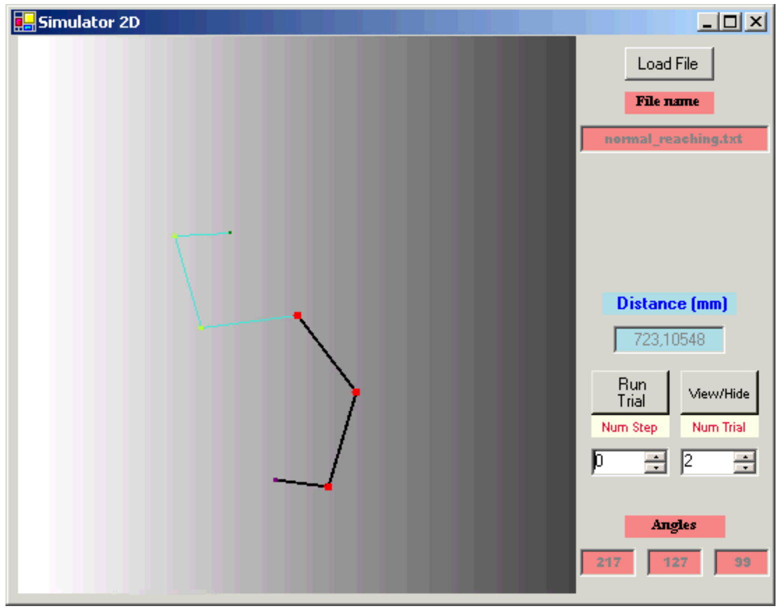
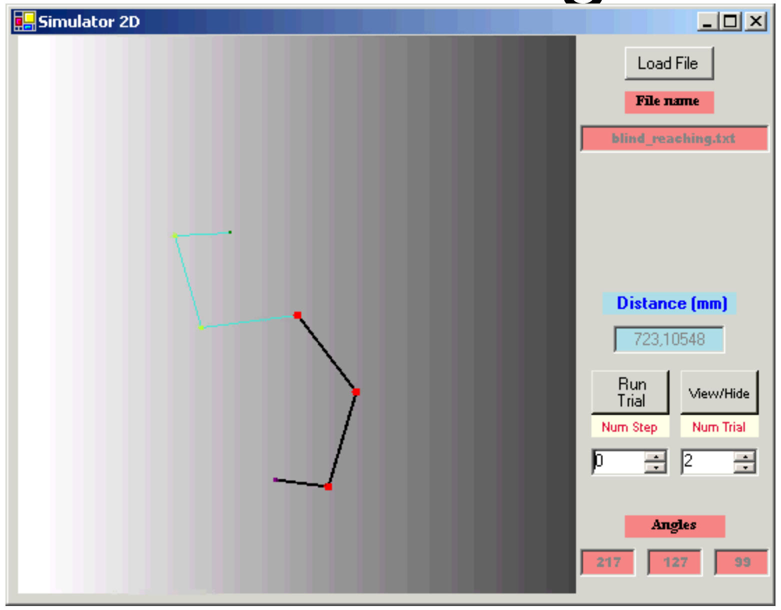
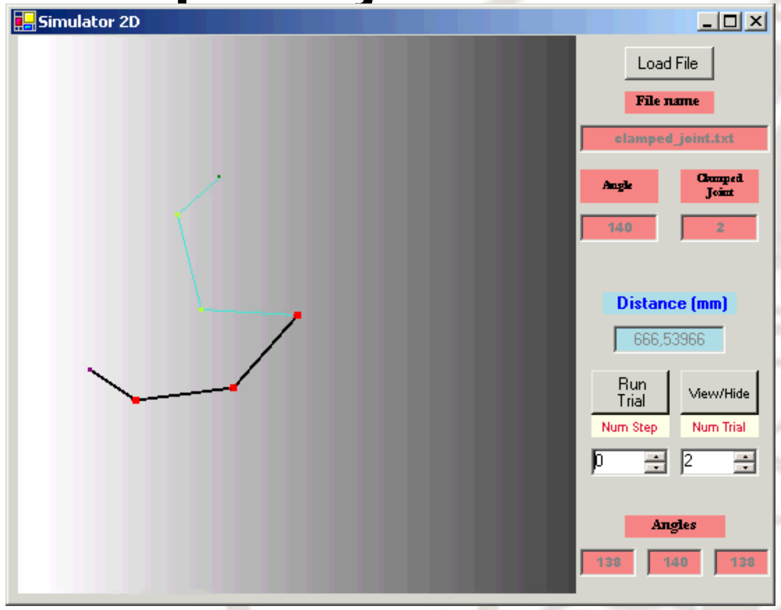
Normal reaching



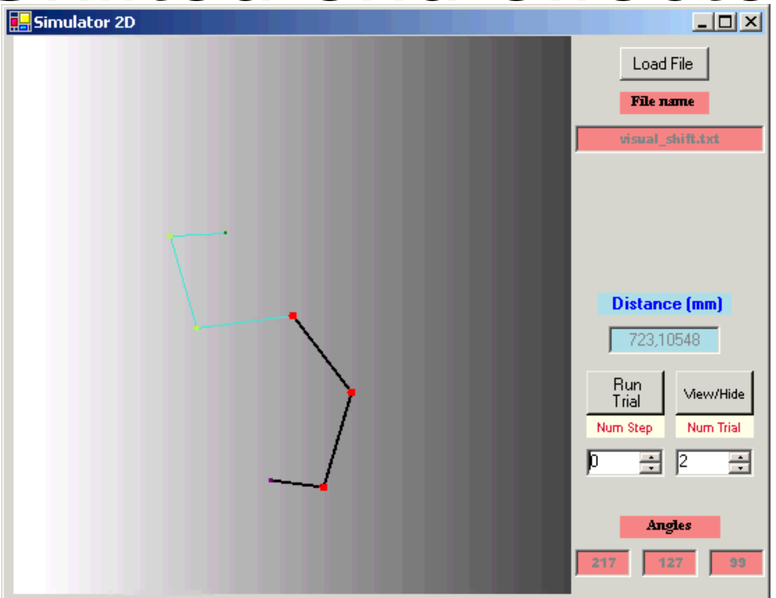
Blind reaching



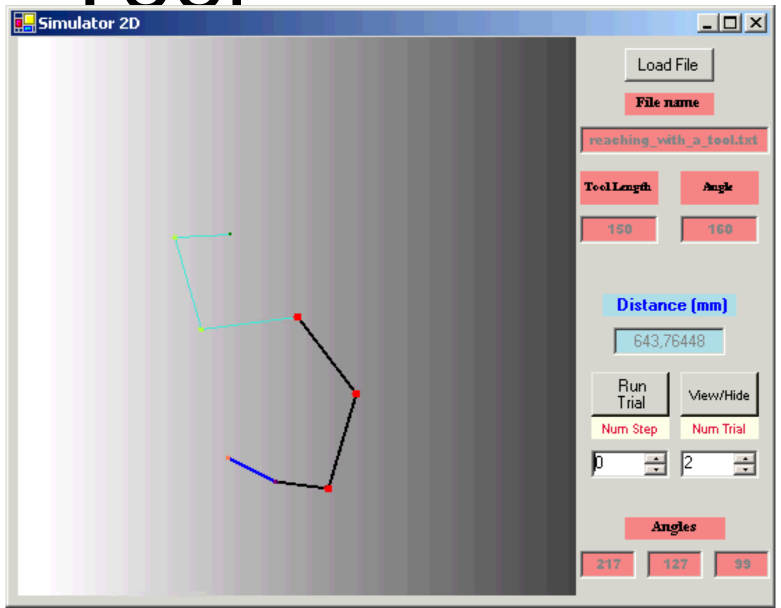
Clamped joint



Shifted end effector



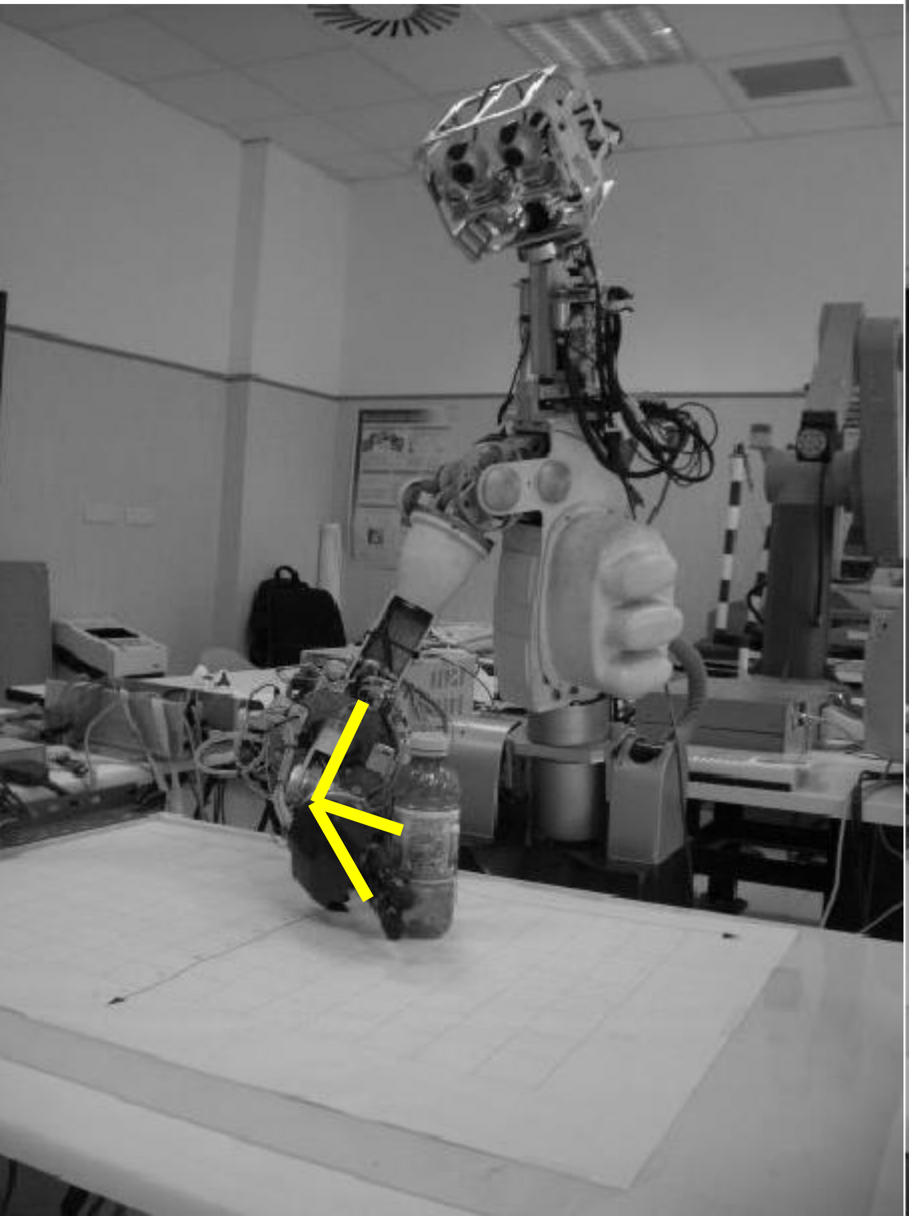
Tool



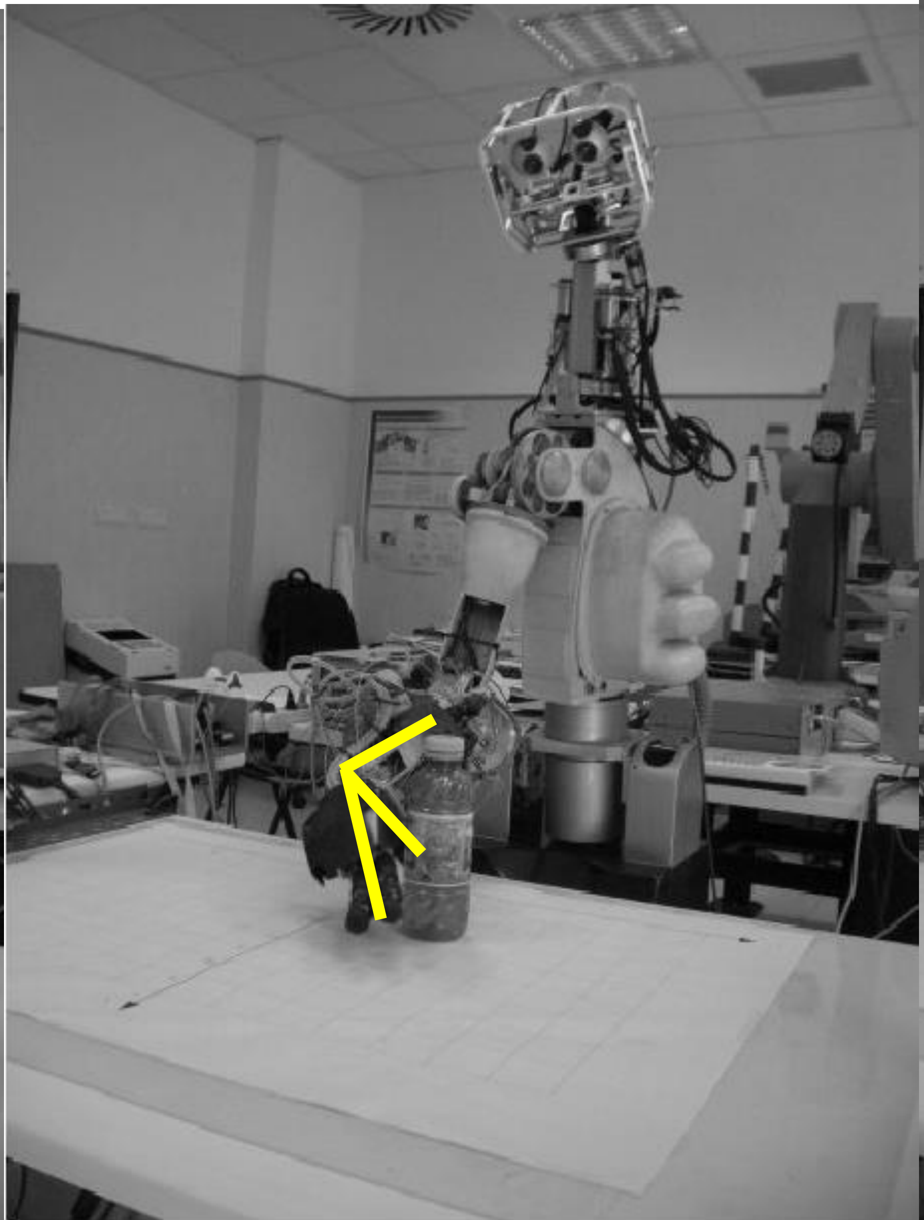
Experimental results on the DEXTER robotic arm

Target and final postures

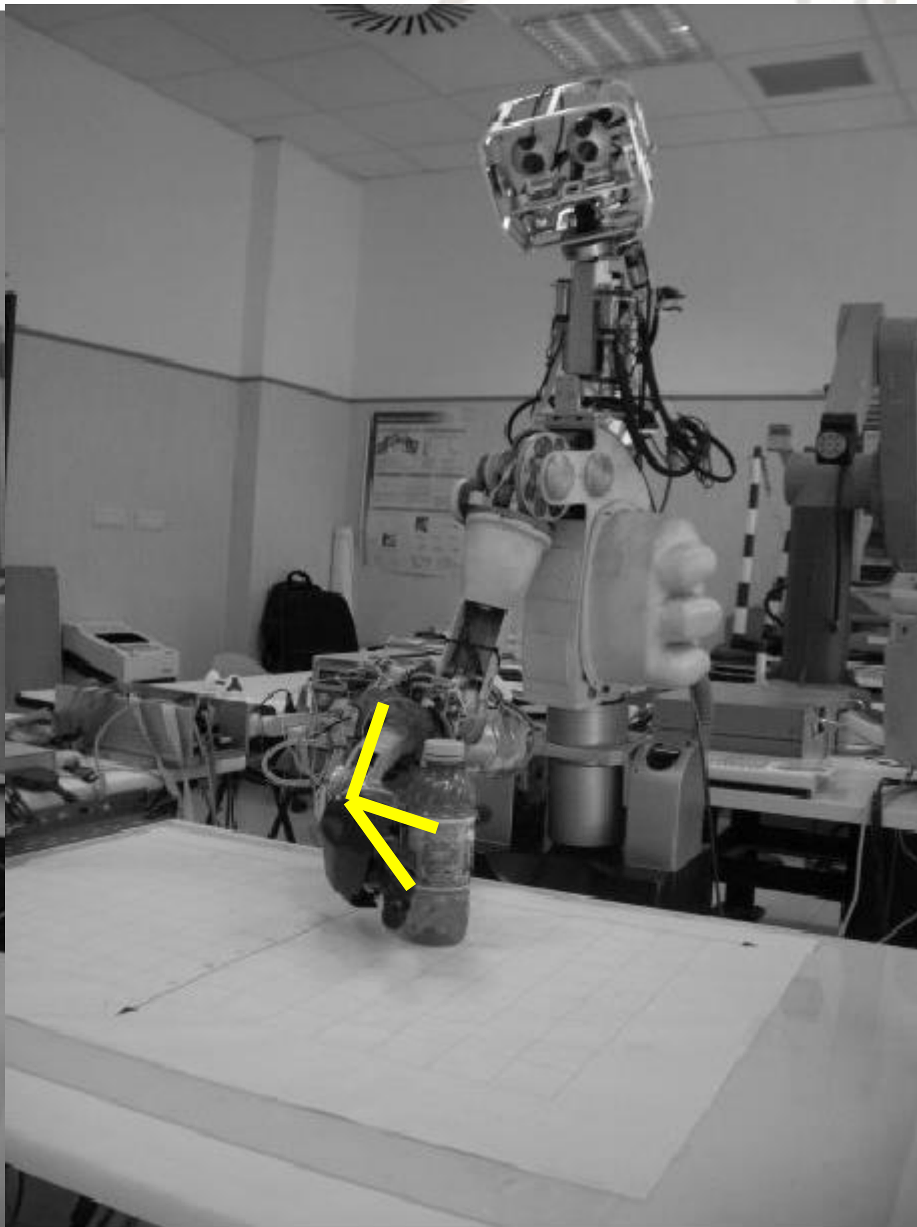
Target posture



Final posture
(no orientation)



Final posture
(with orientation)



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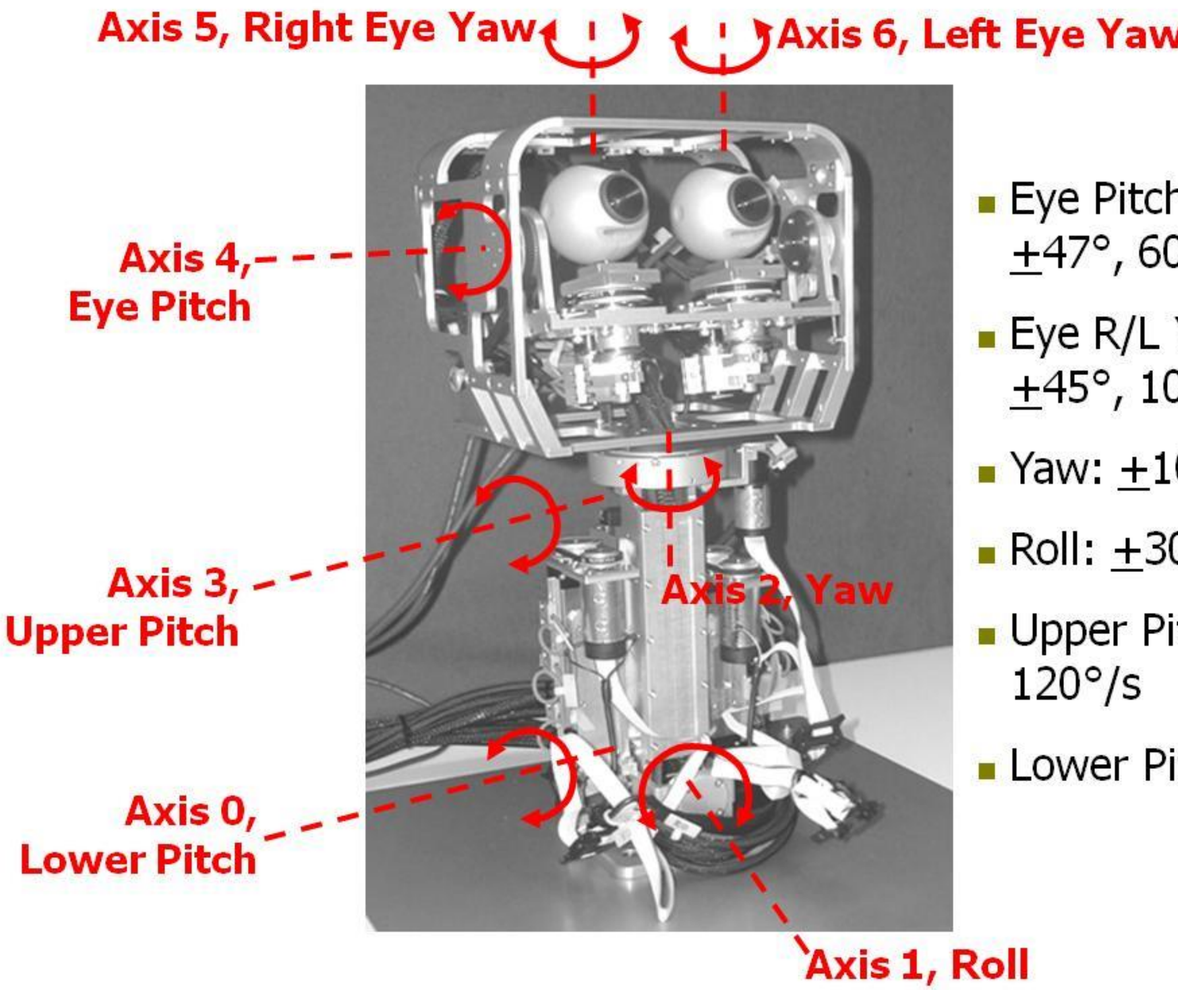
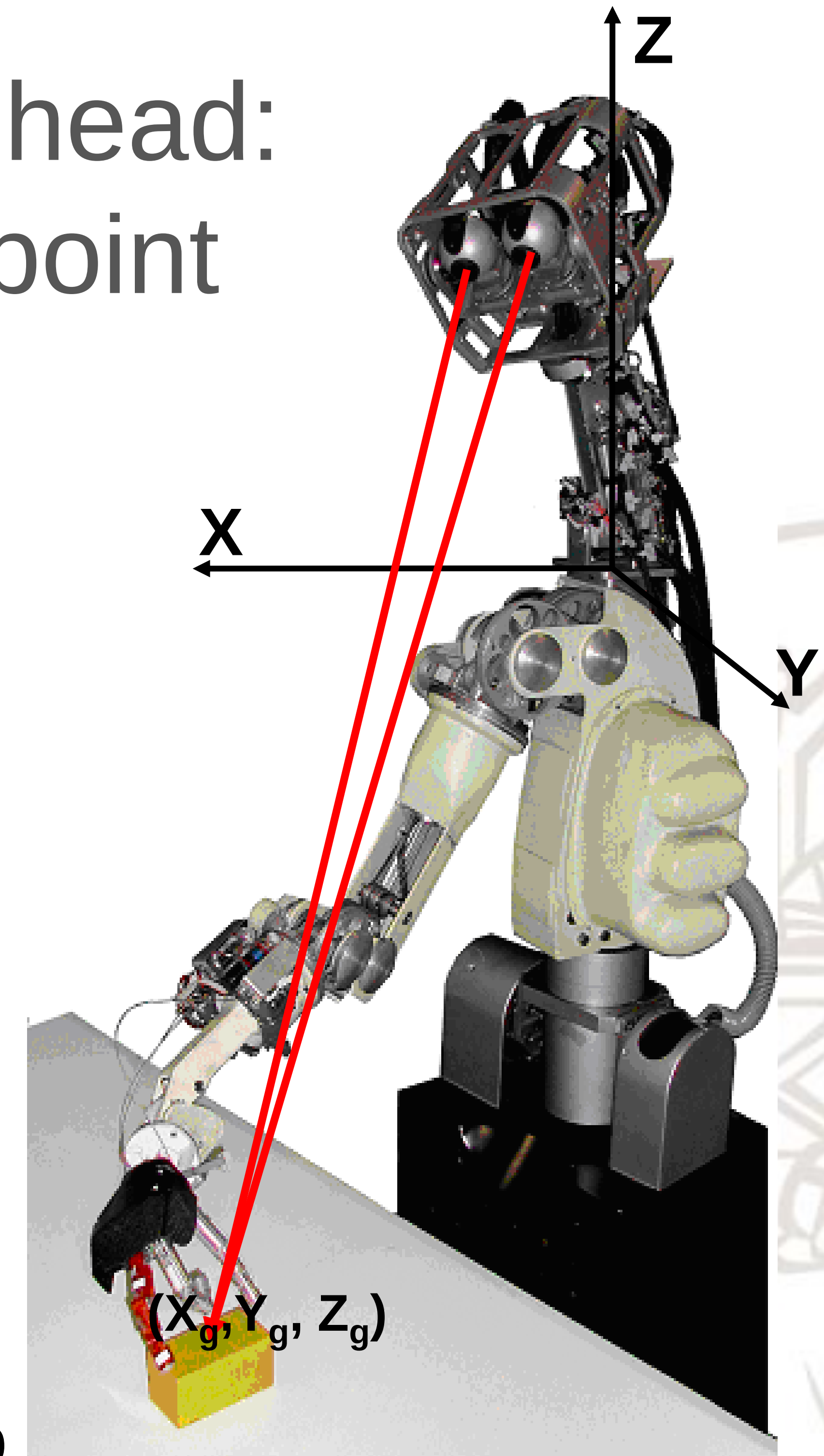
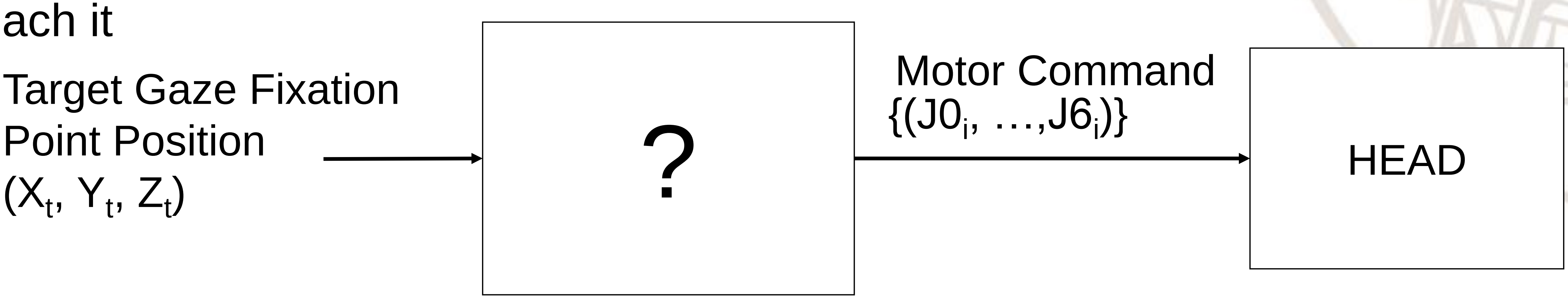
Application to the robot head: control of gaze fixation point



- Eye Pitch Axis: ±47°, 600°/s
- Eye R/L Yaw Axis: ±45°, 1000°/s
- Yaw: ±100°, 170°/s
- Roll: ±30°, 25°/s
- Upper Pitch: ±30°, 120°/s
- Lower Pitch: ±25°, 20°/s



Control module that receives in input a target gaze position and provides in output a command sequence to reach it



Application of the same approach to different robotic systems

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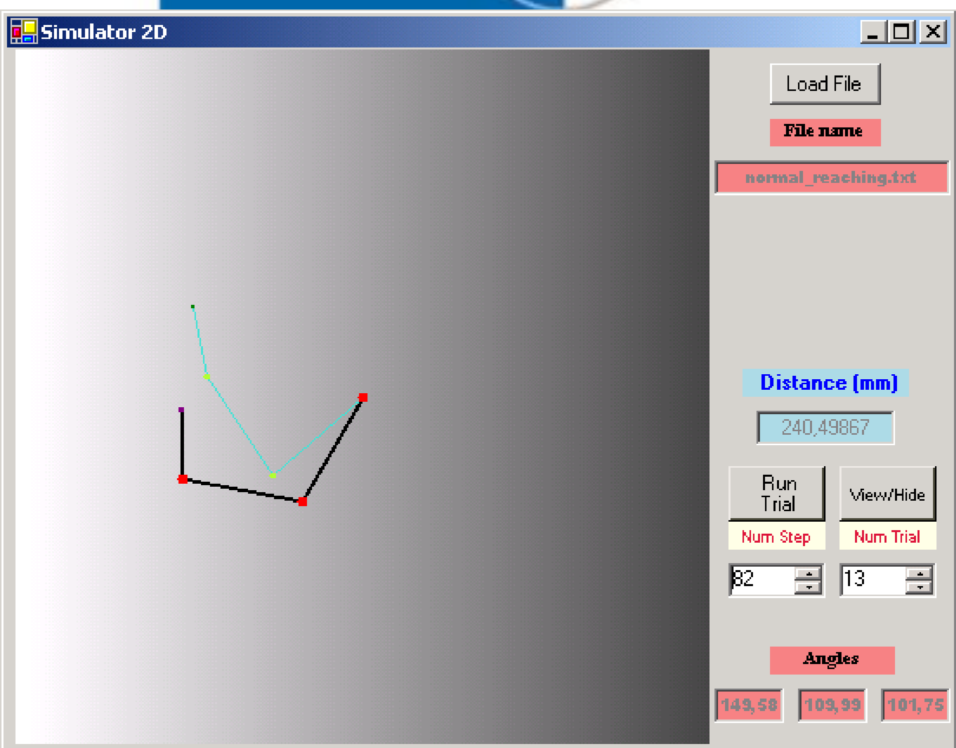
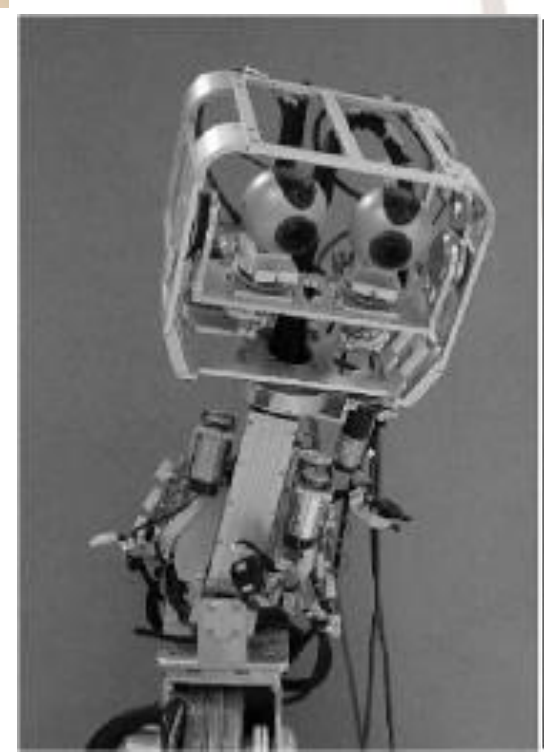
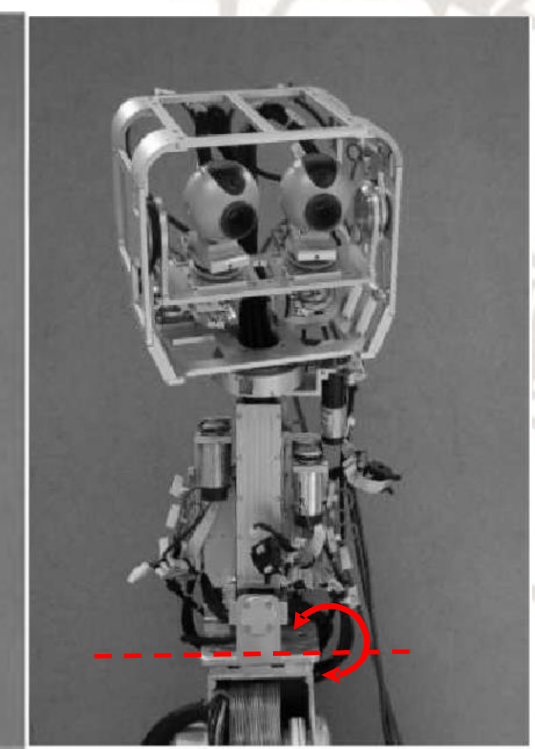






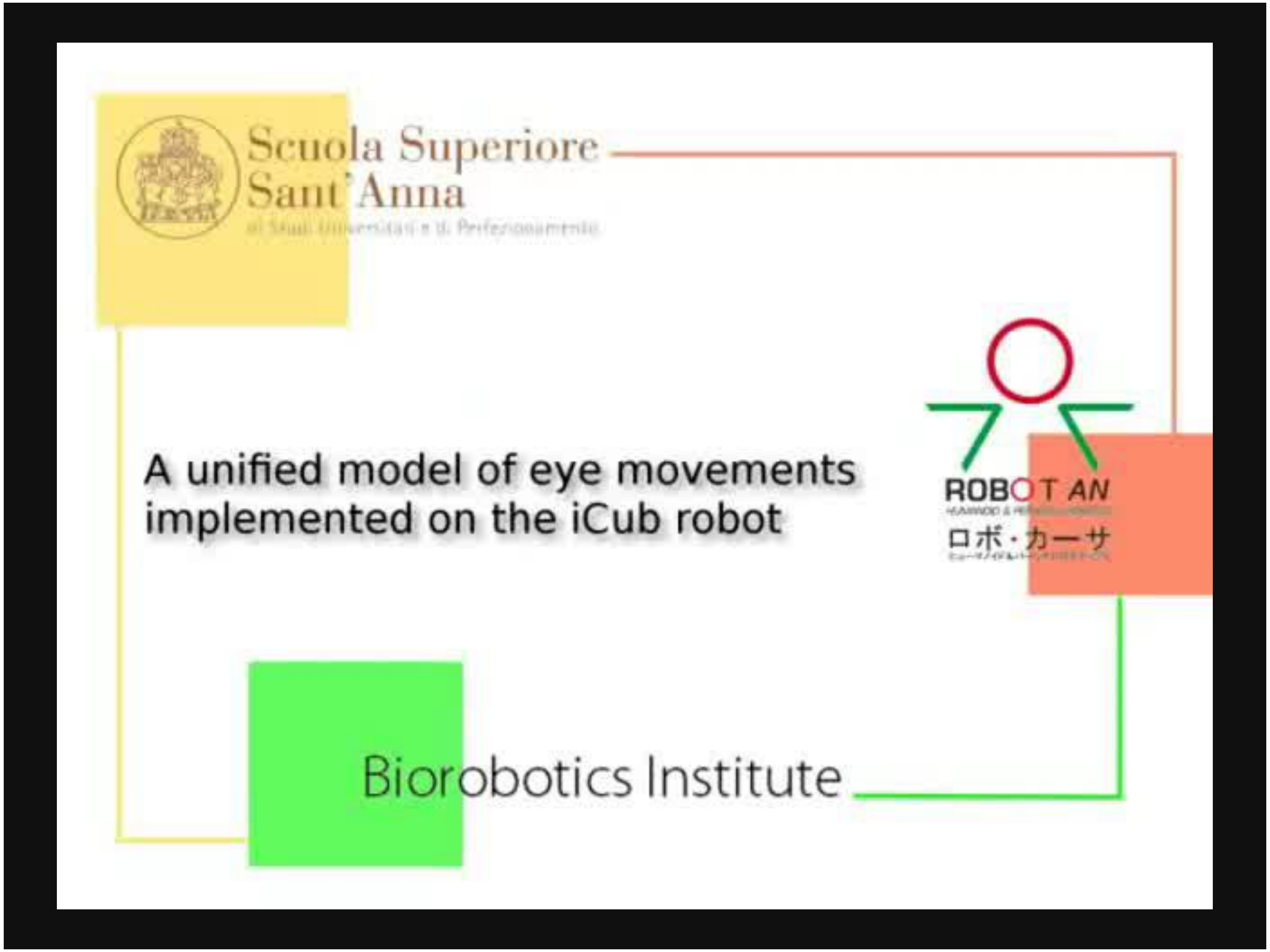
G. Asuni, Leoni F., Starita A., Guglielmelli E., Dario P., "A Neuro-controller for Robot Arms Based on Biologically-Inspired Visuo-Motor Coordination Neural Models", *The 1st International IEEE EMBS Conference on Neural Engineering*, 20 - 22 March, 2003, Capri Island, Italy.

E.Guglielmelli G. Asuni, F. Leoni, A. Starita, P. Dario, "A Neuro-controller for Robot Arms Based on Biologically-Inspired Visuo-Motor Co-ordination Neural Models", *IEEE Handbook of Neural Engineering*, M. Akay (Ed.), IEEE Press, 2007.

G. Asuni, G. Teti, C. Laschi, E. Guglielmelli, P. Dario, "A Robotic Head Neuro-controller on Biologically-Inspired Neural Models", *IEEE International Conference on Robotics and Automation* April 18-22, 2005, Barcelona, Spain

Humanoid robots as platforms for neuroscience

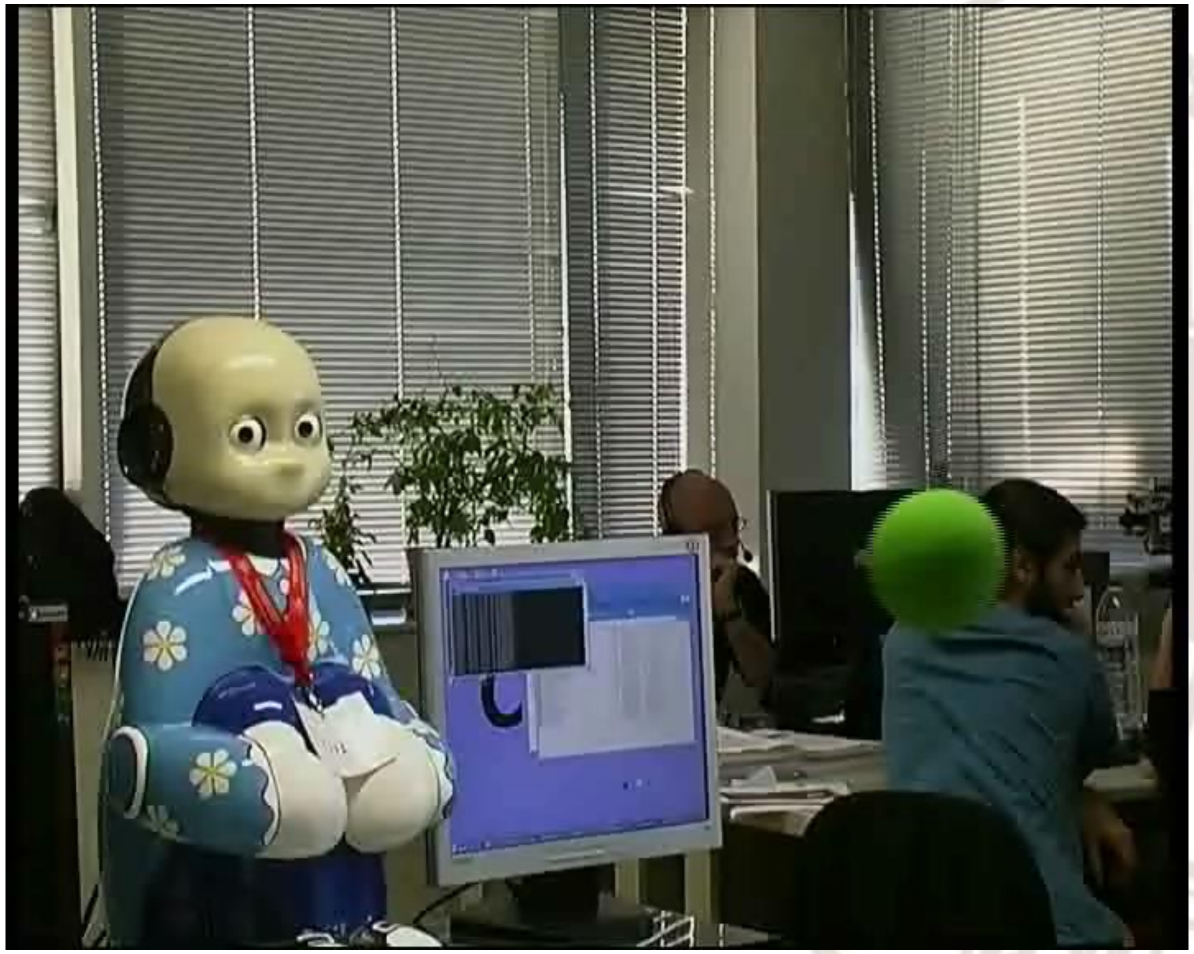
Robotic implementation of gaze control, integrating different eye movements



E. Falotico. D. Zambrano, C. Laschi, P. Dario, "Bioinspired integrated eye movements in a humanoid robot", (in preparation) Autonomous Robots

D. Zambrano, E. Falotico. C. Laschi, P. Dario, "A model of basal ganglia for robotic eye movement control", (in preparation) Autonomous Robots

Predictive smooth pursuit eye movement



The retinal slip (target velocity onto the retina) reaches zero after the algorithm convergence.
When the target is unexpectedly stopped, the system continues to follow the target for a short period.

Punching a moving target - robot experiments

The prediction is iterated ahead 0.5 seconds
As the predicted target is inside the arm workspace, the robot executes a movement to punch the ball in the ***predicted position***

Why bioinspiration in robotics?

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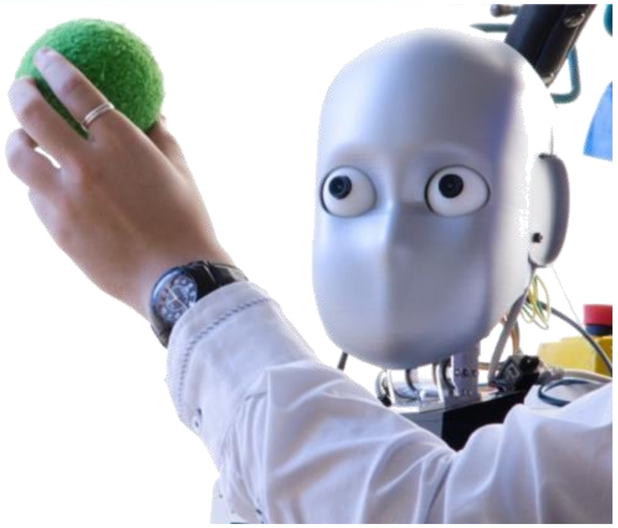

Today, more functionality means

more complexity, energy, computation,

less controllability, efficiency, robustness, safety

Lessons from Nature: simplification mechanisms

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In robotics, we need **simplification mechanisms** for control and new materials, fabrication technologies and energy forms

- Studying natural organisms and understanding what makes them so smart and efficient
- Studying tasks that only living organisms can do, and how they do it

Embodied Intelligence or Morphological Computation: the modern view of Artificial Intelligence

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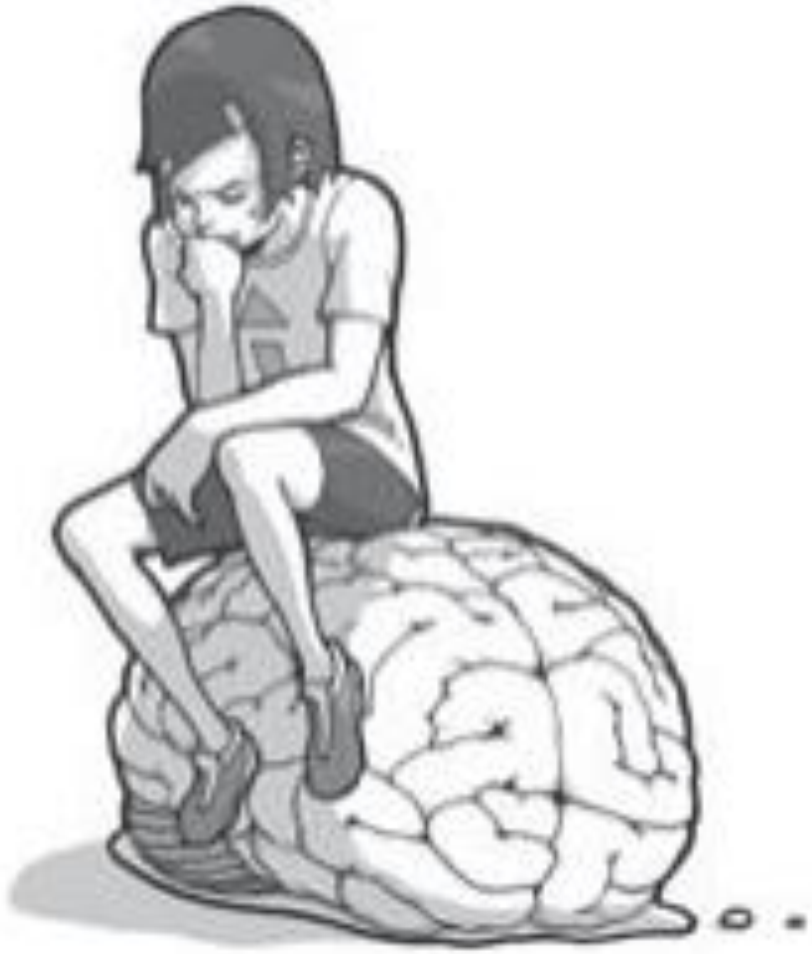
Classical approach
The focus is on the brain and central processing



Modern approach
The focus is on interaction with the environment. Cognition is emergent from system-environment interaction

Rolf Pfeifer and Josh C. Bongard, *How the body shapes the way we think: a new view of intelligence*, The MIT Press, Cambridge, MA, 2007

Embodied Intelligence

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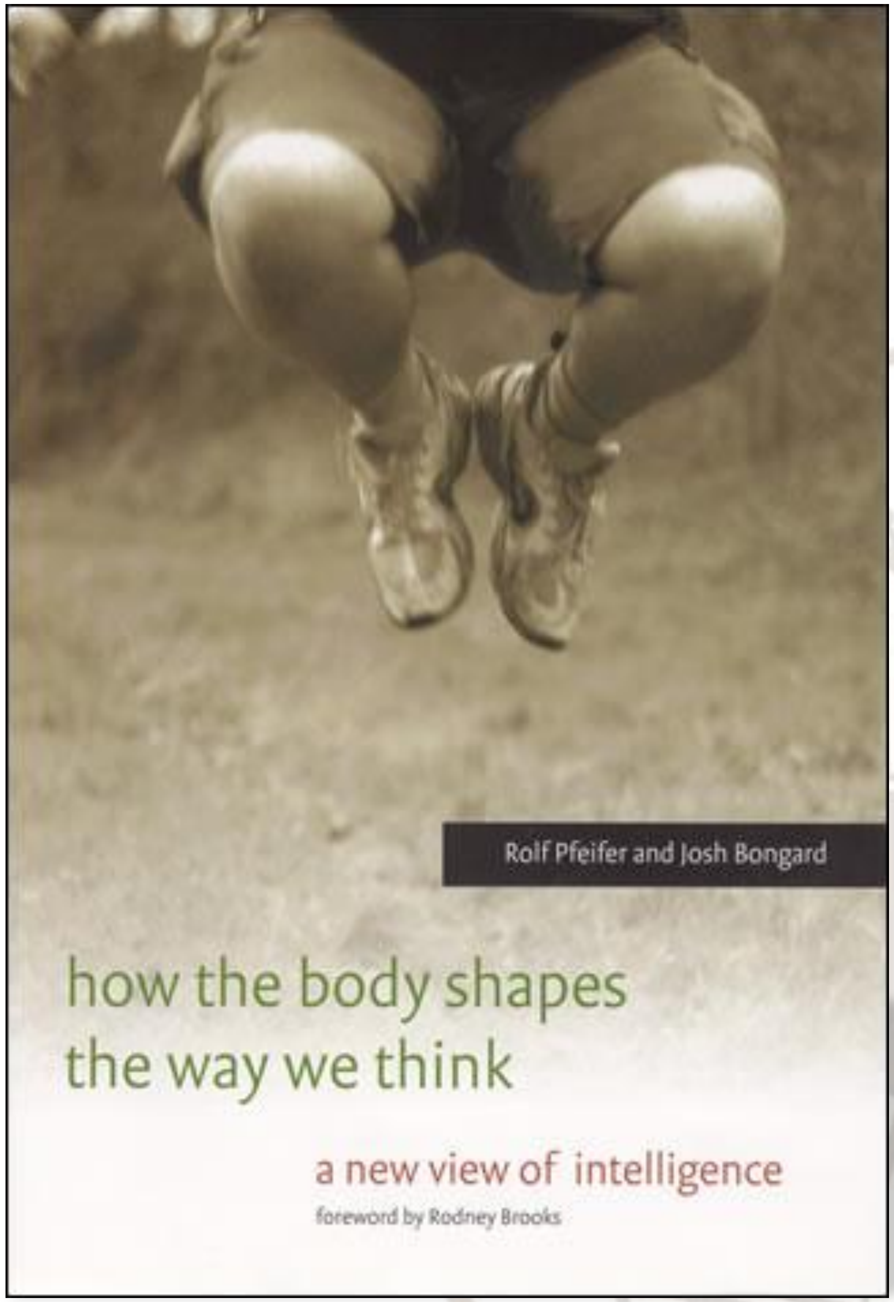
Il comportamento adattivo non è dato solo da controllo e calcolo, ma emerge dall'interazione complessa e dinamica tra la morfologia del corpo, il controllo senso-motorio e l'ambiente.
Molti compiti risultano più semplici tenendo in considerazione l'Embodied Intelligence.
"Mechanical Intelligence"
"Morphological Computation"



La natura della mente umana è largamente determinata dalla forma del corpo

Rolf Pfeifer and J. C. Bongard, *How the body shapes the way we think: a new view of intelligence*, The MIT Press, Cambridge, MA, 2007

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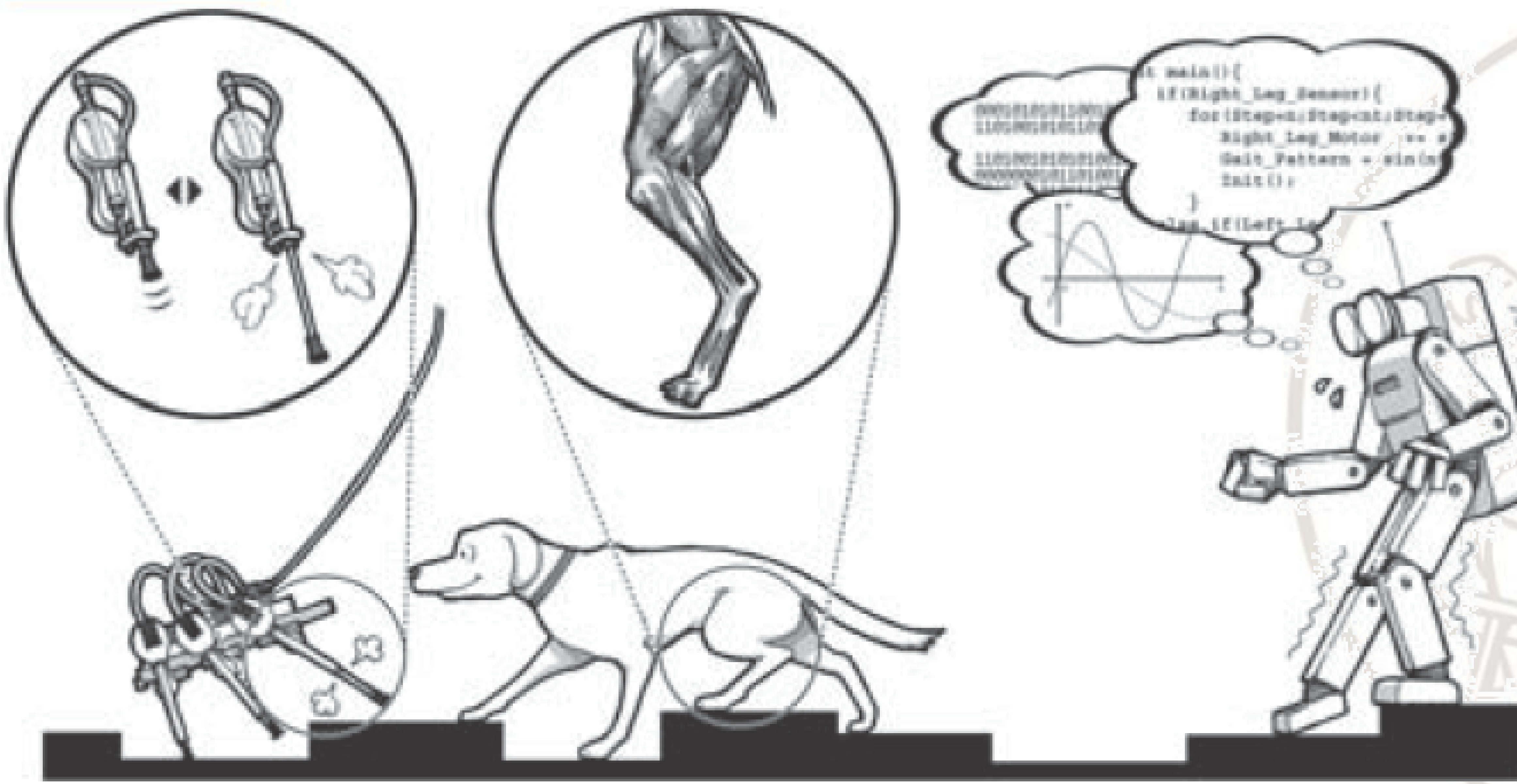
Embodied Intelligence or Morphological computation



Rolf Pfeifer and Josh C. Bongard, *How the body shapes the way we think: a new view of intelligence*, The MIT Press, Cambridge, MA, 2007

Embodied Intelligence or Morphological Computation: the modern view of Artificial Intelligence

Any cognitive activity arises from the ***interaction*** between the body, the brain and the environment.

Adaptive behaviour is not just control and computation, but it emerges from the complex and dynamic interaction between the morphology of the body, sensory-motor control, and environment.

Many tasks become much easier if morphological computation is taken into account.

=> A new soft bodyware is needed

Modern approach

The focus is on interaction with the environment. Cognition is emergent from system-environment interaction

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Rolf Pfeifer and Josh C. Bongard, *How the body shapes the way we think: a new view of intelligence*, The MIT Press, Cambridge, MA, 2007

Il progetto OCTOPUS

OCTOPUS IP (2009-2013)

Novel Design Principles and Technologies for a New Generation of High Dexterity Soft-bodied Robots Inspired by the Morphology and Behaviour of the Octopus

EU-funded Project # 231608
ICT-FET Proactive:
ICT-2007.8.5 "Embodied Intelligence"
Total grant: 7.6 M€

C. Laschi, B. Mazzolai, M. Cianchetti, L. Margheri, M. Follador, P. Dario, "A Soft Robot Arm Inspired by the Octopus", *Advanced Robotics (Special Issue on Soft Robotics)*, Vol.26, No.7, 2012.
M. Calisti, M. Giorelli, G. Levy, B. Mazzolai, B. Hochner, C. Laschi, P. Dario, "An octopus-bioinspired solution to movement and manipulation for soft robots", *Bioinspiration & Biomimetics*, Vol.6, No.3, 2011, 10 pp.
C. Laschi, B. Mazzolai, V. Mattoli, M. Cianchetti, P. Dario, "Design of a biomimetic robotic octopus arm", *Bioinspiration&Biomimetics*, Vol.4, No.1, 2009.

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The octopus as a model for both soft robotics and embodied intelligence

What are the principles that give the octopus:

- **strength**, without rigid parts?
- **control** of infinite dof, with relatively small computing resources?

D. Accoto, C. Laschi, E. Guglielmelli, "Embodied Intelligence in the biomechatronic design of robots", in *The Future of Scientific Practice 'Bio-Techno-Logos': History and Philosophy of Technoscience,* M. Bertolaso (Ed.), 2015, Pickering & Chatto Publishers, London

The octopus as a model for embodied intelligence / morphological computation

The *Octopus vulgaris* is a paradigm of the tight relation between the morphology of the body and the behaviour and the development of intelligence

Crawling and swimming

Opening a box

Camoufflage

Probing the environment

Videos courtesy of Graziano Fiorito and Binyamin Hochner

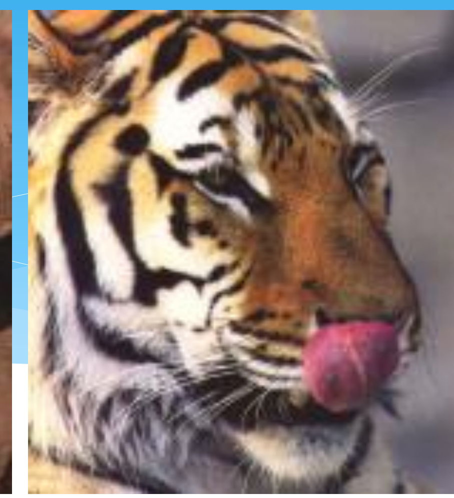
Video taken at the BioRobotics Institute

Self-cleaning

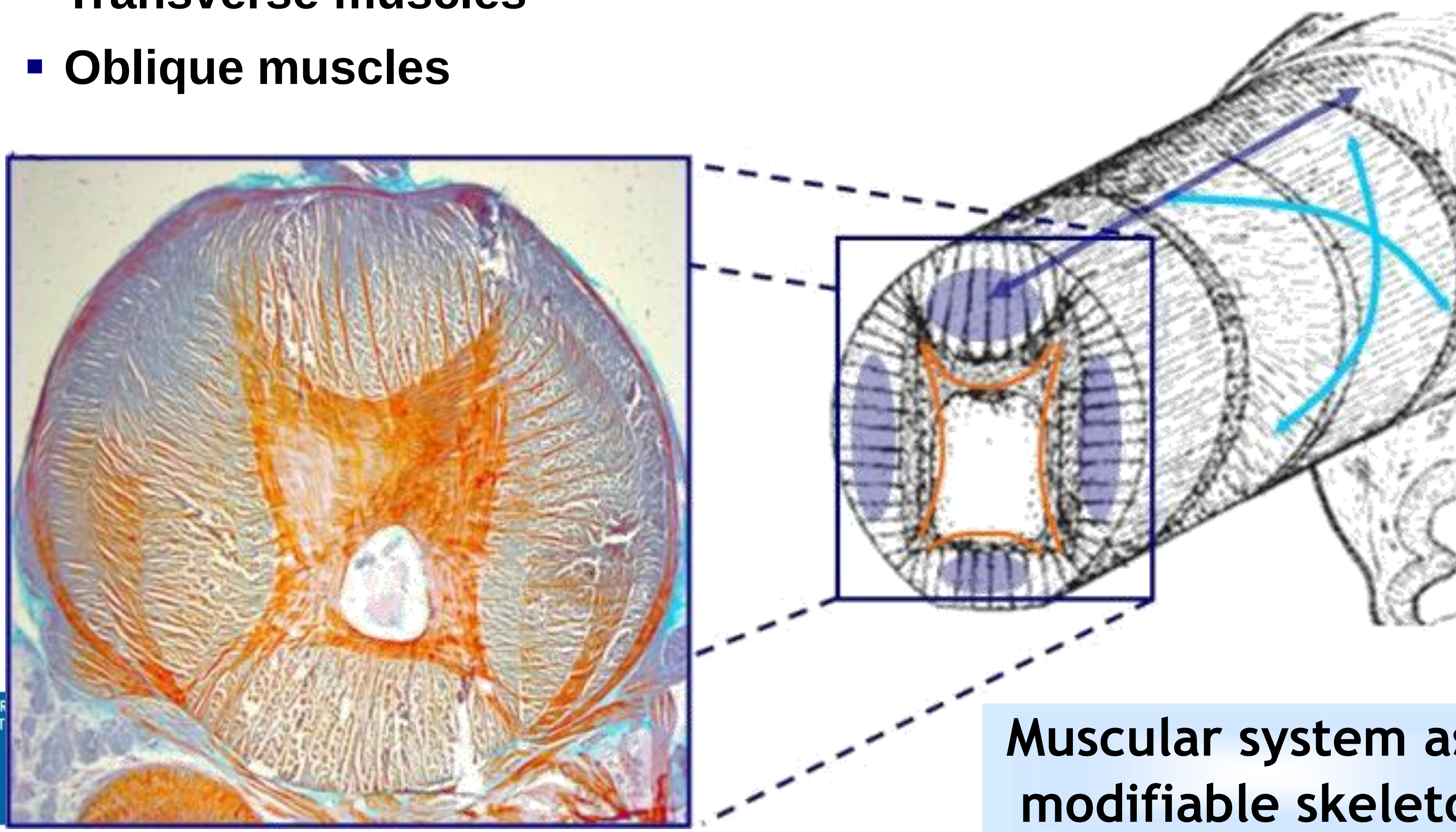
The octopus muscular hydrostat

Constant volume during contractions



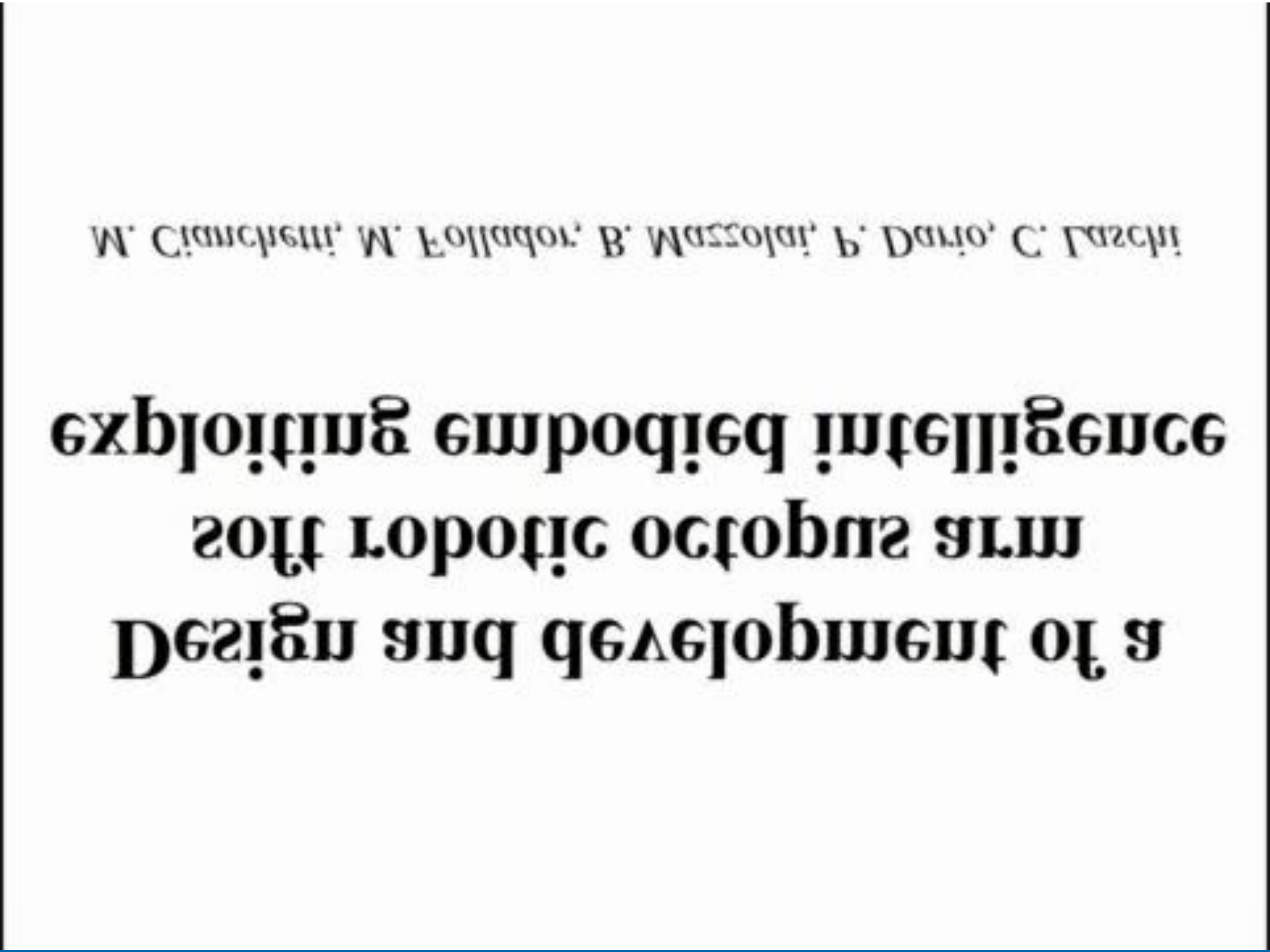


- **Longitudinal muscles**
- **Transverse muscles**
- **Oblique muscles**

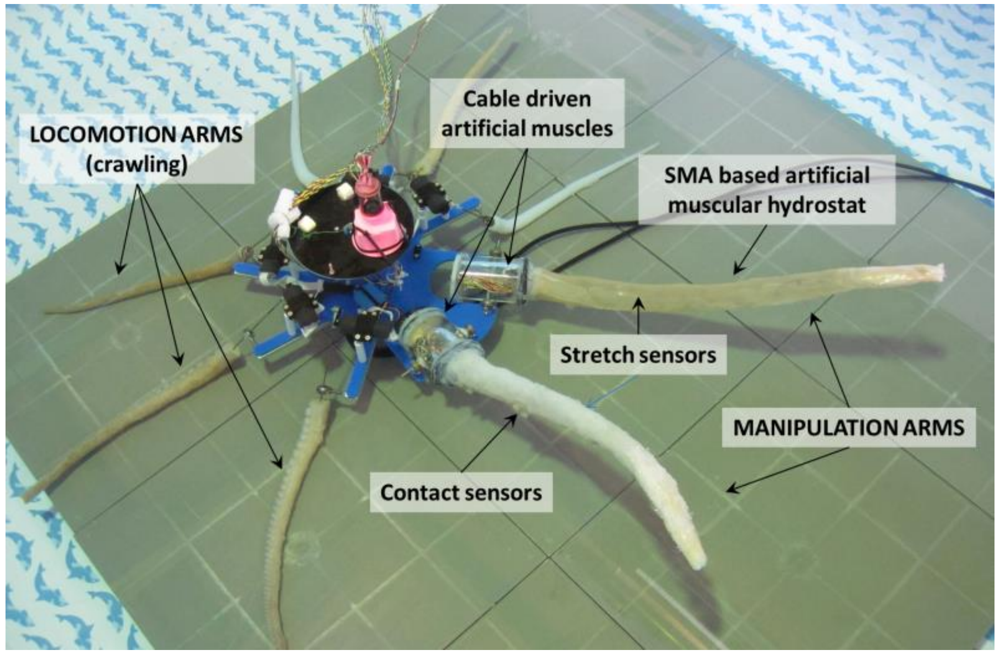


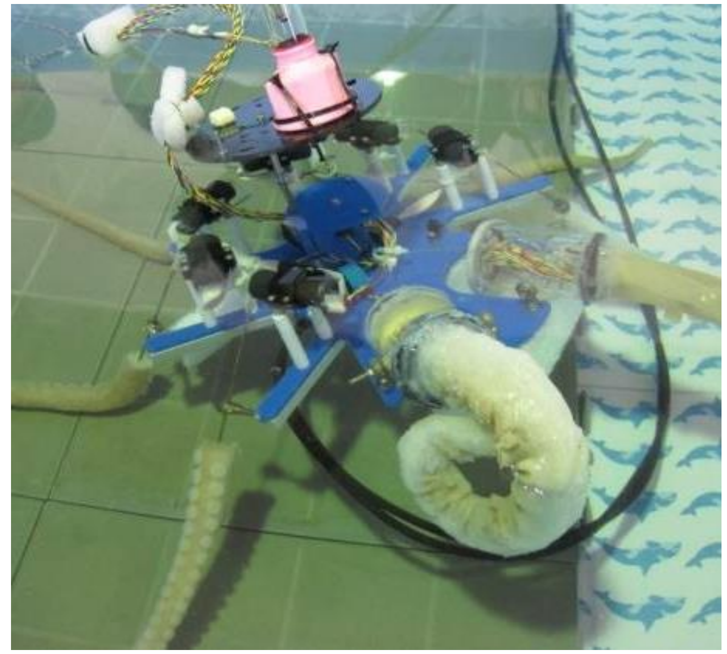
Muscular system as a modifiable skeleton

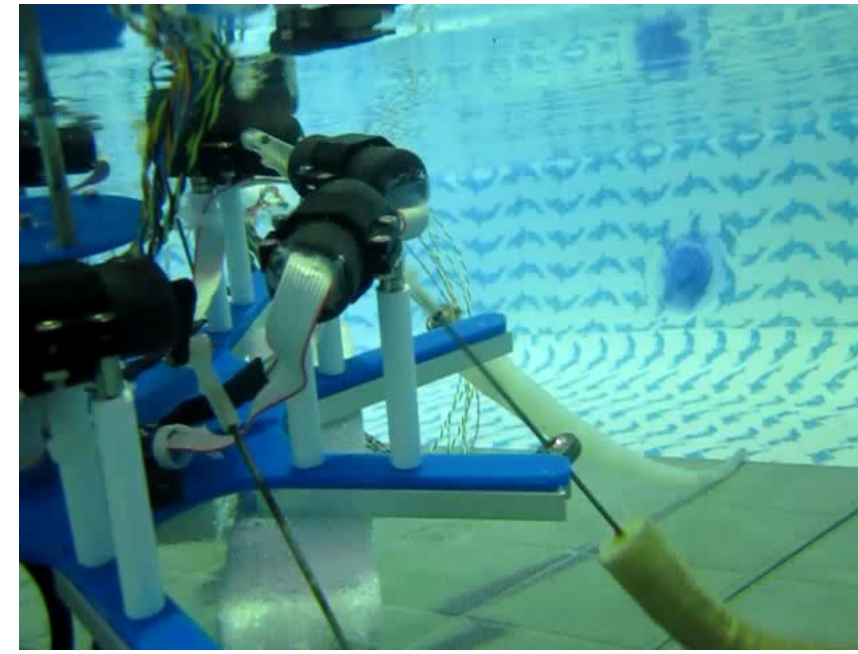
Octopus-like robot arm

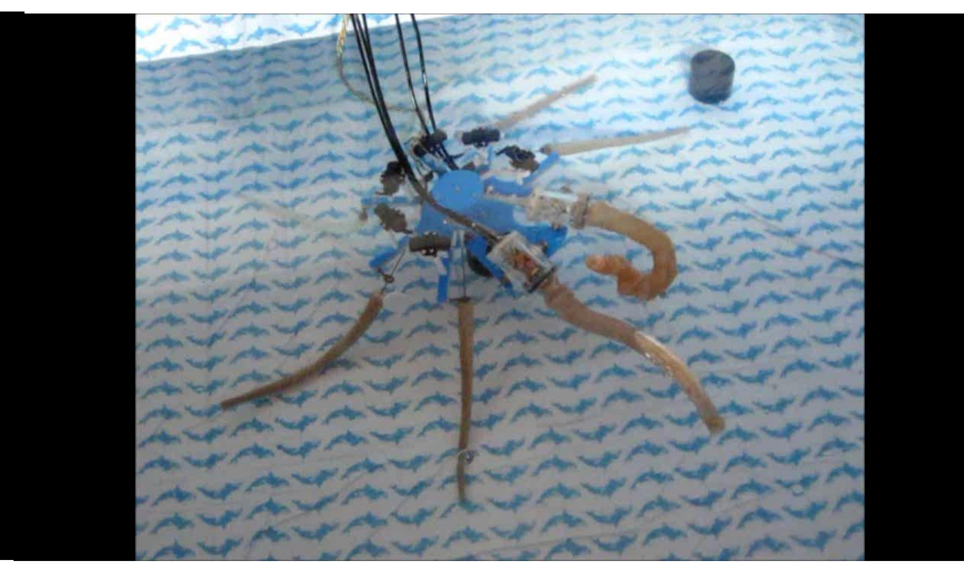


OCTOPUS robot





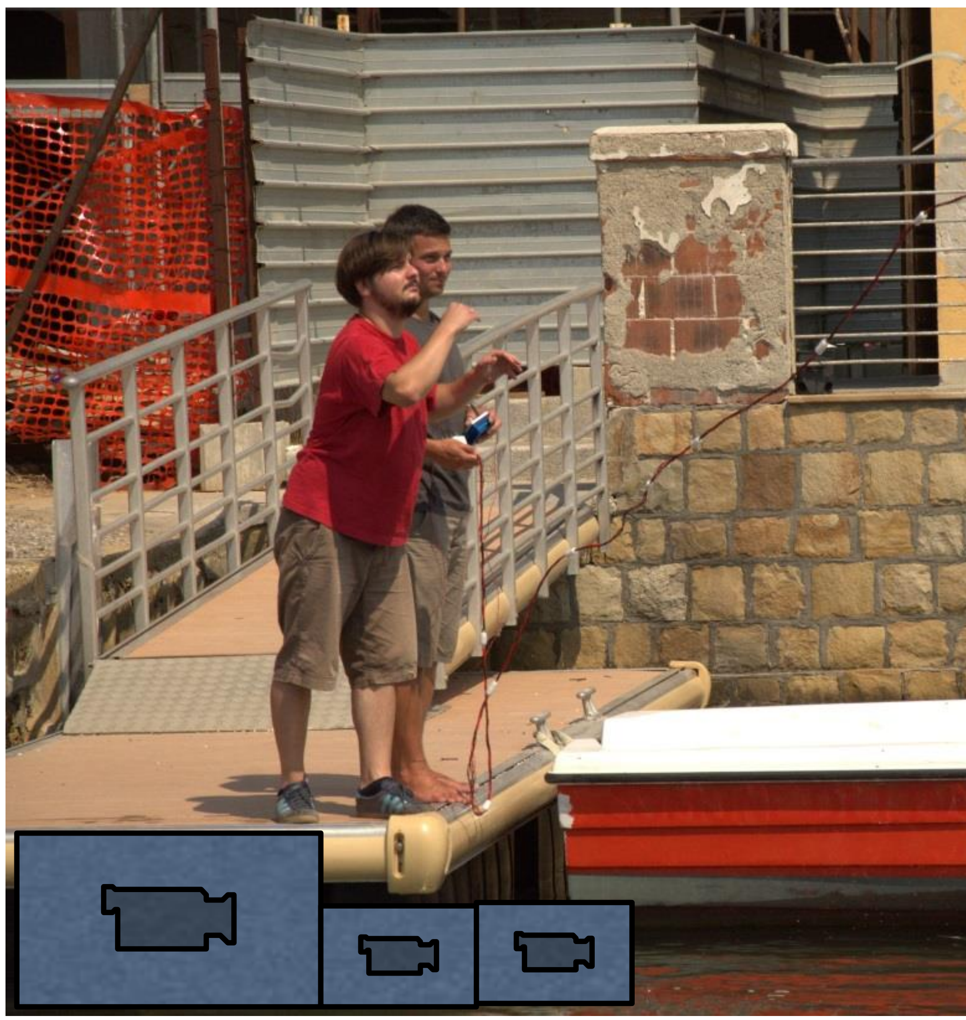


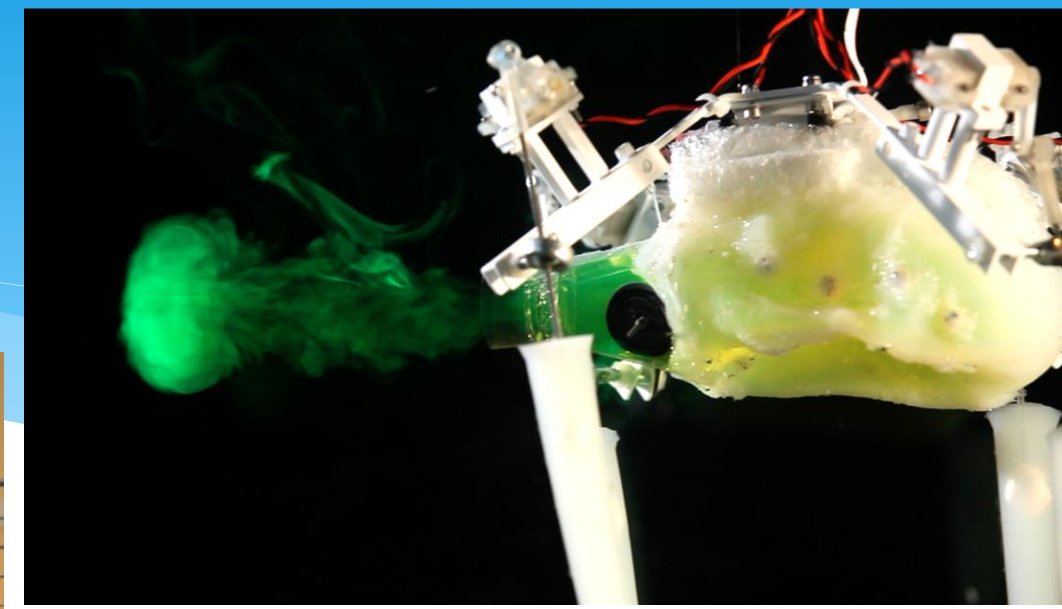


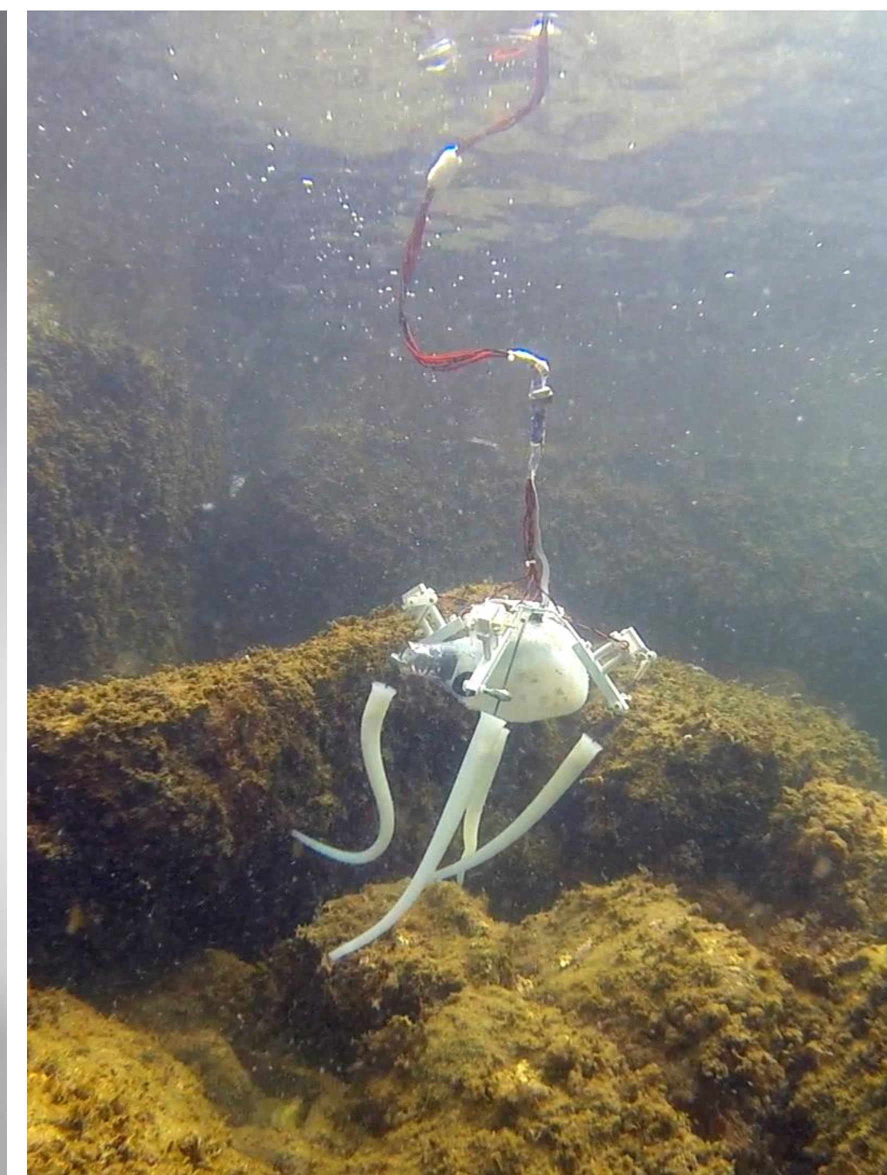
- Wide range of grasping capabilities
- Max force: 10.8 N
- Speed: typical 1.9 cm/s - max: 5 cm/s
- CoT: 2.9

Cianchetti M., Calisti M., Margheri L., Kuba M., Laschi C., “Bioinspired locomotion and grasping in water: the soft eight-arm OCTOPUS robot" , *Bioinspiration & Biomimetics*, in press

First PoseiDRONE prototype







F. Giorgio Serchi, et al, 2013 OCEANS

M. Giorelli et al, 2013 OCEANS

A. Arienti et al, 2013 OCEANS

M. Calisti et al, 2013 SoftRob

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Self-stabilized locomotion: complex design for simple control

- Octopus pushing-based locomotion strategy
- Just one motor per leg, soft silicone limbs
- Complex, dynamic, self-stabilized behaviors emerge from a simple open-loop actuation

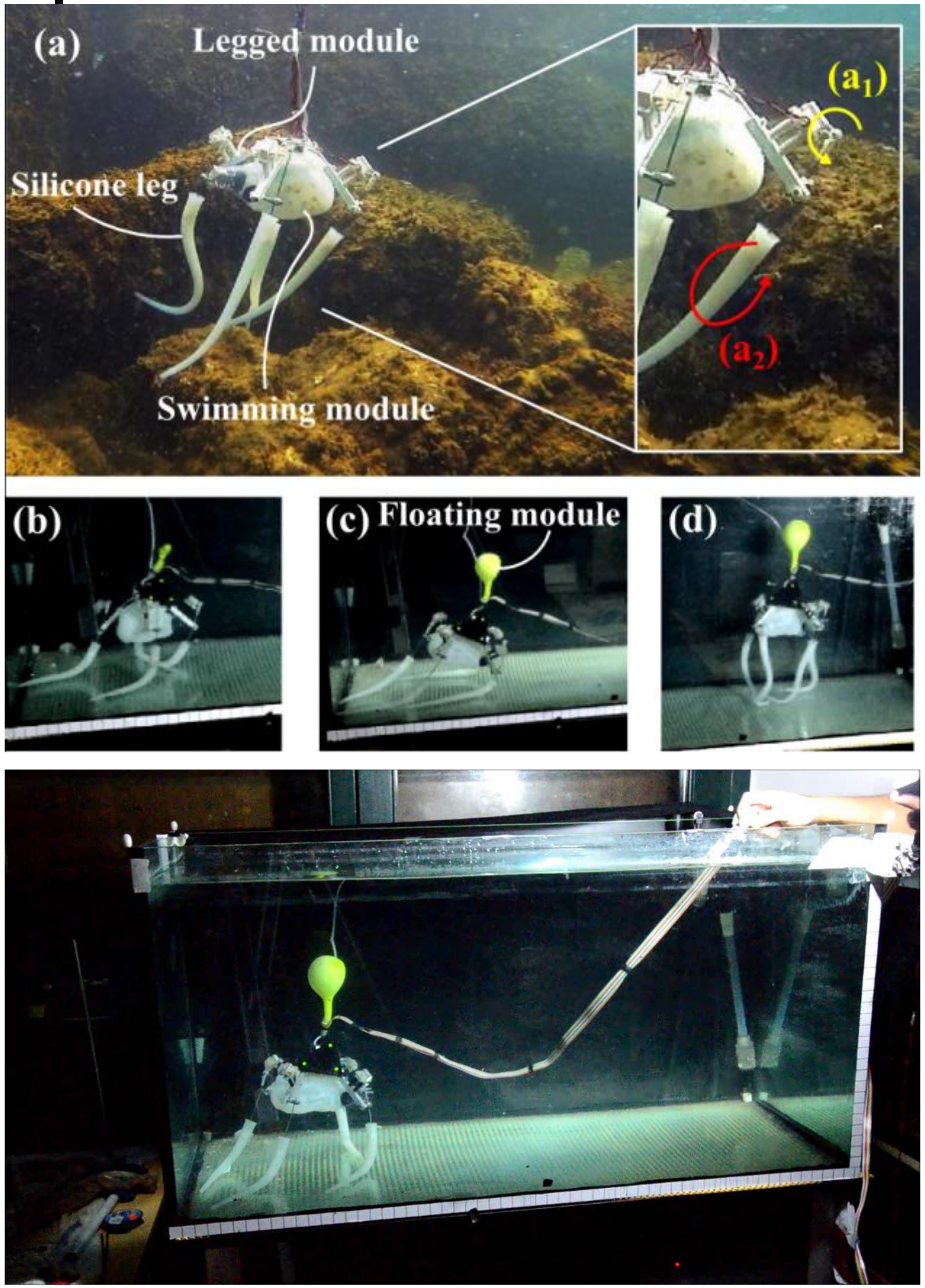
  → Embodied intelligence

Evolutionary design:

- From carefully hand-designed solutions to the systematic production of embodied solutions
- Adaptation to the environment, exploitation of the complex dynamical coupling between body and environment
- Possibility to discover and suggest elaborate solutions, beyond the skills and creativity of human designers (human-competitive design)

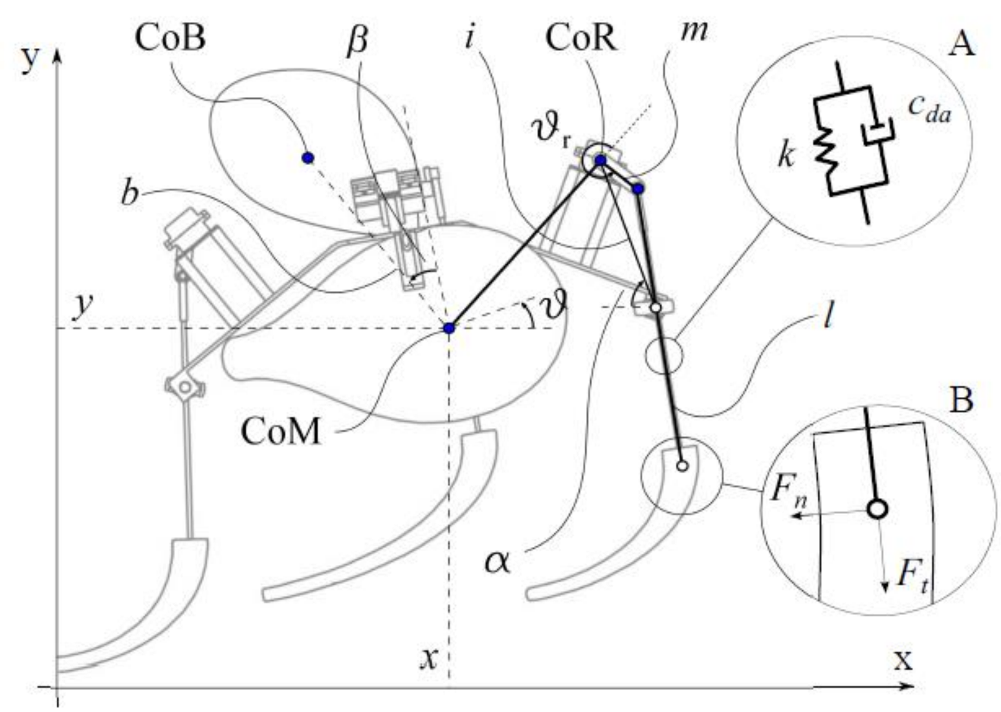
Morpho-functional robot:

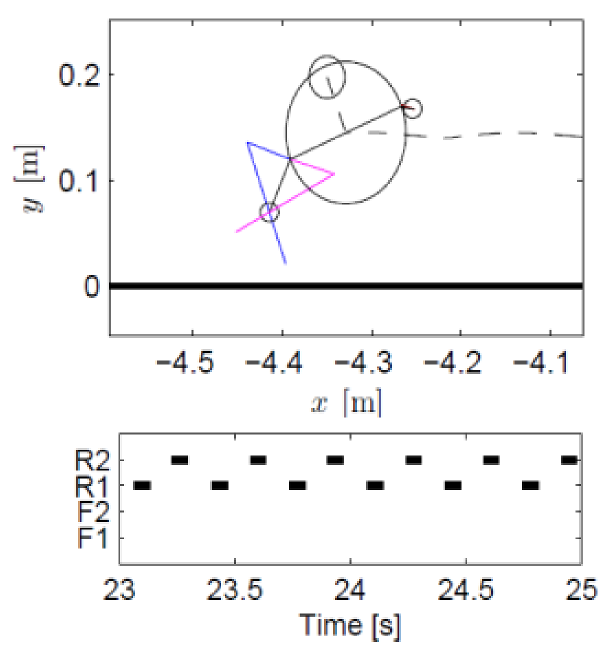
- Possibility to control slight morphological changes to achieve a diversity of behaviors

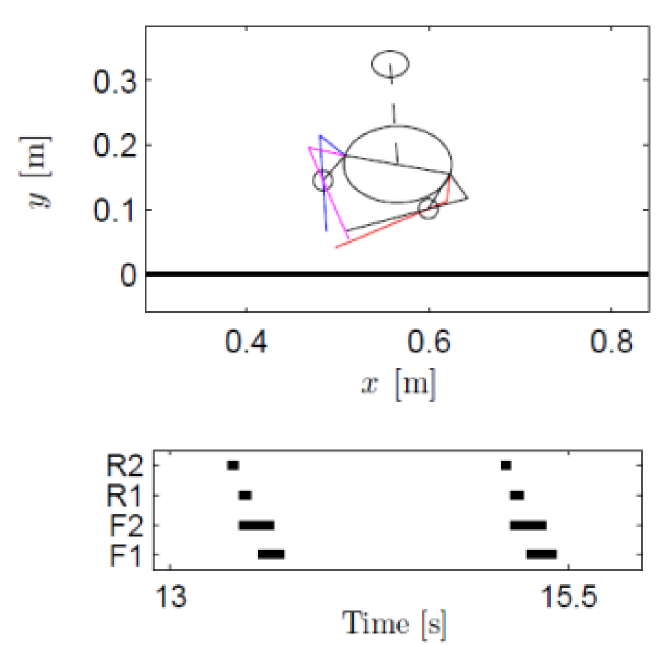


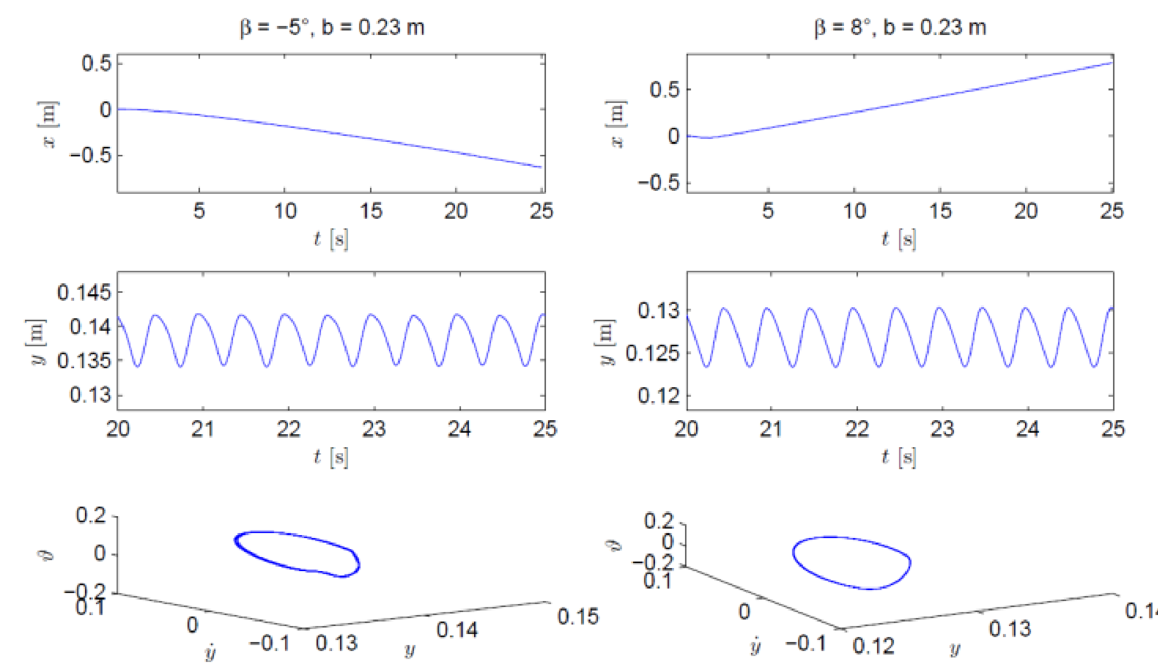
Self-stabilized locomotion

- Evolutionary algorithms are applied to discover interesting morphologies capable of highly dynamic gaits
- Elaborated behaviors are produced, featuring a highly dynamic coupling with the environment
- It is possible to switch among different gaits by controlling slight morphological changes
- e.g. by changing just one morphological parameter, the speed and the direction of the locomotion can be









Corucci, F., Calisti, M., & Laschi, C. (2014). Evolutionary discovery of self-stabilized dynamic gaits for a soft underwater legged robot (under review)

Calisti, M., Corucci, F., & Laschi, C (2014). Underwater legged locomotion of a bio-inspired robot (unpublished)

Calisti, M., Corucci, F., Arienti, A., & Laschi, C. (2014). Bipedal Walking of an Octopus-Inspired Robot. In *Biomimetic and Biohybrid Systems* (pp.

Programma del corso

- Meccanica e cinematica dei robot, sensori per la robotica, controllo di robot, architetture per il controllo del comportamento, tecniche di navigazione robotica
- Visione robotica
- Sensi bioispirati
- Robotica umanoide, neurocontrollori, computing neuromorfo
- Embodied intelligence e soft robotics
- Algoritmi evolutivi applicati in robotica

Svolgimento del corso e modalità di esame

- Lezioni frontali fino alla fine di aprile
- Progettino in laboratorio fino alla fine di maggio

- Esame = Presentazione del progettino + Esame orale
- Voto = media dei 2 voti

- Compitino alla fine delle lezioni (inizio di maggio), che può sostituire l'orale, se lo studente accetta il voto.

Informazioni pratiche

Inviare una mail a:

cecilia.laschi@sssup.it

con subject: Corso Robotica

Materiali del corso:

http://didawiki.cli.di.unipi.it/doku.php/magistraleinformatica/rob/start