

A study of Embodied Intelligence and its Embedding in Manufactures



A presentation in support of a FET Flagship in

Embodied Intelligence

by

Alin Albu Schaeffer (DLR, Munich)

Massimo Bergamasco (S.Anna, Pisa)

Antonio Bicchi (Univ. Pisa)

Rainer Bischoff (KUKA)

Oliver Brock (TU Berlin)

Etienne Burdet (Imperial College, London)

Darwin Caldwell (IIT, Genoa)

Alessandro De Luca (U. Roma)

Giuseppe De Maria (SUN, Naples)

Danilo De Rossi (Univ. Pisa)

Marc Ernst (MPI-BC, Tübingen)

Claudio Galletti (Univ. Bologna)

Gerhard Grunwald (DLR, Munich)

Vincent Hayward (UPMC, Paris)

Henrik Jörntell (Univ. Lund)

Soenke Kock (ABB)

Kostas Kyriakopoulos (NTU Athens)

Dirk Lefeber (VUB, Bruxelles)

Chris May (Univ. Saarland)

Claudio Melchiorri (Univ. Bologna)

Martin Nilsson (SICS, Kista)

Geoff Pegman (RUR Robotics, UK)

Domenico Prattichizzo (Univ. Siena)

Marco Santello (ASU & Univ. Pisa)

Bruno Siciliano (Univ. Napoli)

Stefano Stramigioli (Univ. Twente)

Roko Tschakarov (SCHUNK)

Support from

- A Multidisciplinary but Coherent Community
- Mathematics & Physics
- Clinical & Research Medicine
- Psychology and Cognitive Science
- Social Sciences
- Neuroscience
- Material Science
- Computer Science
- Engineering
- + Industry

The idea:

Study Intelligence *per* its Embodiment



[...] man is the most intelligent of animals because he has hands...

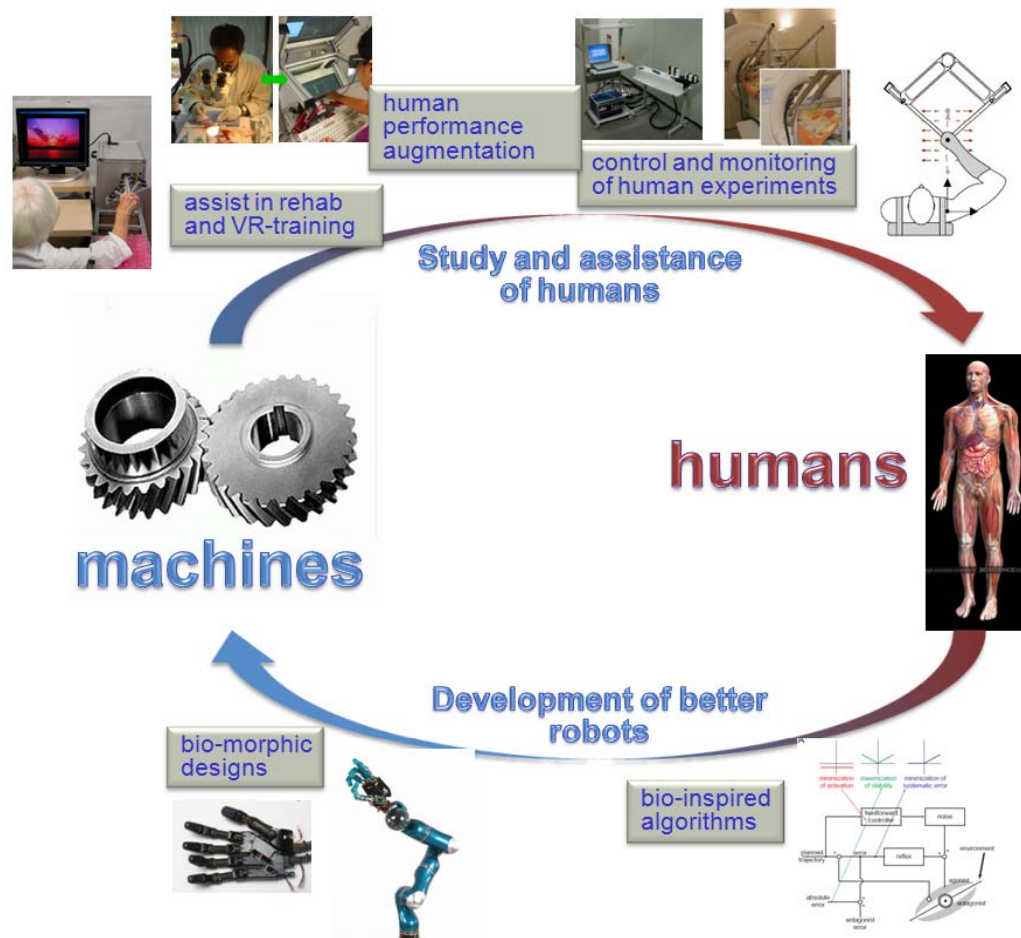
Anaxagoras,
cited by Aristotle,
De partibus animalium

- ❑ The Body as the Organ of Cognition
- ❑ How the constraints due to embodiment **affect and determine** learning and control
- ❑ What is the **conceptual structure and the geometry** of such *enabling constraints* (aka *synergies*)
 - ❑ **Understanding by building**
 - ❑ Trying to reproduce functionality to understand
 - ❑ Musculo-skeletal system
 - ❑ Biomechanics
 - ❑ Sensory motor control
 - ❑ Perception
 - ❑ Cognition
 - ❑ ... and their interplay
 - ❑ **Re-creating**, one of the basic approaches for human learning – used by children and scientists alike
 - ❑ **Motor Synergies** in redundant body mobility
 - ❑ **Sensor Synergies** in redundant receptors and the five + senses
 - ❑ **Sensorimotor Synergies**: How can *the* brain *organize and control* such a complex system as the body, and how could *our mind emerge* out of it
 - ❑ **Social Synergies**
 - ❑ **Human-Robot Interaction** coexistence and cooperation
 - ❑ **Robot-Robot Interaction** rules for a Society with Robots



The ambition: A new Science

- ❑ Can there be a Mind without a Body?
- ❑ Anatomy of the Body does not tell much about the Mind – nor would a mere “Xerox” approach to artificial life do



[...the universe is a book which ...] cannot be understood if one does not learn the language and the symbols in which it is written....These are triangles, circles, and other geometric figures, without which means man cannot understand a single word in that book. Without these, it is just wandering in vain in an obscure labyrinth.

Galileo Galilei, Il Saggiatore, 1623



- ❑ Build a Science of Embodied Intelligence
- ❑ Abstract the insight from nature in terms of mathematical models
- ❑ Apply the new theory to achieve the technology our Society is asking for

The impact: Dreams that Deliver

- ❑ Strategically crucial to political sustainability of FET-Flagship is evidence of **impact *along the way*** – no leap of faith warranted
- ❑ Where can Embodied Intelligence impact our Society:
 - ❑ **Existing:** Industrial, Rehabilitation, Medical, Home
 - ❑ **New:** Affordable Personal Assistants (companions), at work and at home
 - ❑ **Beyond:** A tremendous **pull for new technologies** – which then get embedded in everyday products
 - ❑ **New materials, new sensors, new actuators**, new system concepts
 - ❑ Safe, effective, intuitive, and ethical **human-machine interaction** – both physical and cognitive
 - ❑ **Advanced perception** (sensors and processing algorithms) **and action** (programming, planning, artificial reasoning paradigms)
- ❑ **Success stories** with robotics technologies integrated in everyday devices and services ("**the disappearing robot**"): Assisted Drive and Self-Parking cars, Probabilistic Mapping (Google StreetView), Human(oid) dynamics in SEGA 3D engine, ...
- ❑ **Two economic avenues**
 1. To enable European companies to build and maintain world leadership in robotics markets
 2. To create new markets and new businesses



*“Si nous pouvions nous dépouiller de tout orgueil, ... nous ne dirions peut-être pas **Homo sapiens**, mais **Homo faber**.”*

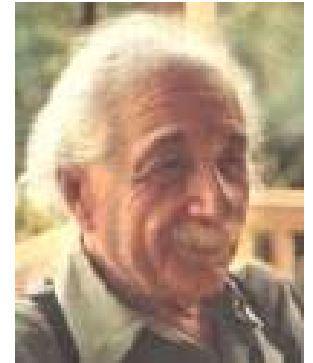
En définitive, l'intelligence... est la faculté de fabriquer des objets artificiels, en particulier des outils à faire des outils.”

Henri Bergson, L'Évolution créatrice (1907)

Integration: the name of the game

(Embodied Intelligence: a new Science of Integration)

- ❑ Re-creating to understand the **Body and the Mind** is a daring concept
- ❑ A vast effort is needed, federating Science with Engineering , Mathematics with Physiology, Psychology and Philosophy
- ❑ **If this has a chance to happen, it will happen in Europe** where the culture has broader multidisciplinary bases
- ❑ As an outcome , **a new scientific domain will result**, establishing unprecedented synergies between domains and reorganizing traditional fields
- ❑ The enormous **social and economic impact** will also **cement integration with other crucial stakeholders** – political and economic
 - ❑ **Revamp European manufacturing** through introduction of advanced, safe robotics as a productivity booster
 - ❑ Take advantage of robotics technology in all aspects of life: **affordable assistance to the ageing European population** and the disabled, in nursing and in household chores
 - ❑ Further **empower European industry with new technology**



*God does not care about our mathematical difficulties.
He integrates empirically.*

*— Albert Einstein
in Quest (1942), L. Infeld*

Plausibility: Invest where Europe is Already a Leader

- ❑ This proposal capitalizes upon the vision formulated by a large academic and industrial community in the **European Robotics Strategic Research Agenda** (going well beyond 2020)
- ❑ According to May 2010 DG-ENTR/JRC-IPTS study on **Future Competitiveness of EU ICT Industry**, Robotics is *the* emerging opportunity, with EU research strongholds in
 - ❑ **Safety** – Europe has introduced first quantitative assessment for safe physical Human-Robot Interaction, a major ethical concern and acceptability enabler
 - ❑ **Robots for SMEs** – Robot companions in the factory, in touch with human co-workers, to boost manufacturing productivity
 - ❑ **Soft Robotics** – A quantum leap in performance and safety from new generation of muscle-like, variable compliance actuators

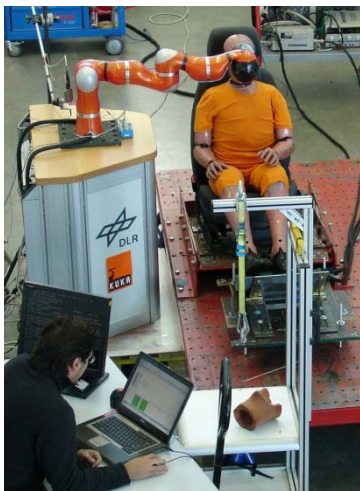


“A robot may not injure a human being or, through inaction, allow a human being to come to harm.”

Isaac Asimov, Runaround, (1942)

The world is catching up:

- 1) Korea Giant Robot Theme Park
- 2) Newest DARPA call “M3” on Variable Compliance Actuation
- 3) US Congress audition on Safe, Soft Robots for Manufacturing



Robots vs. Humans
What a difference a body makes!

