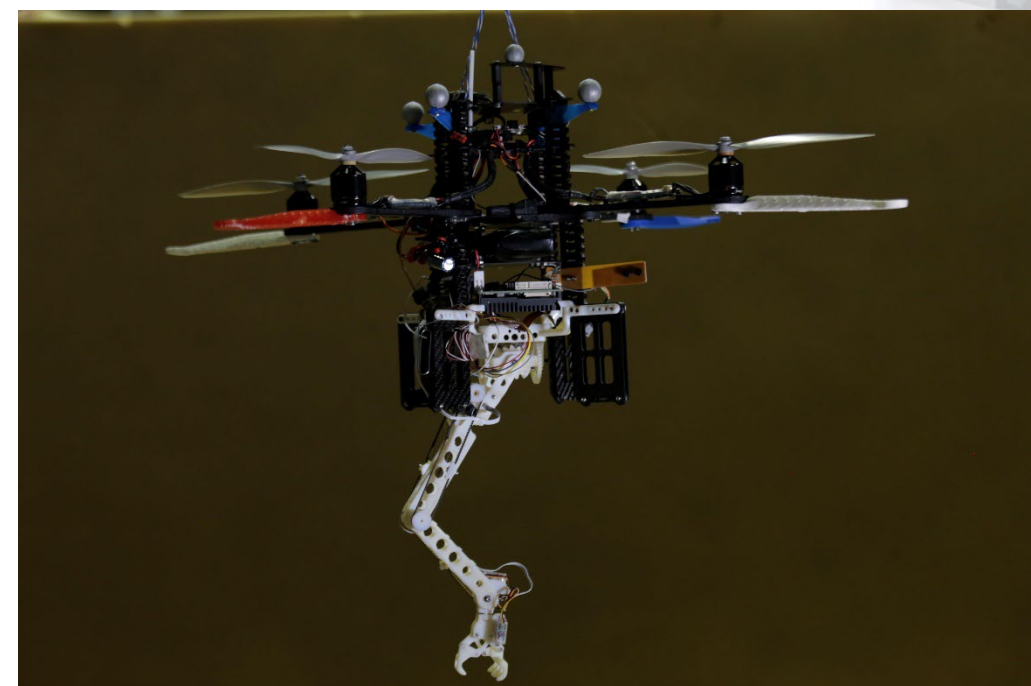


Introduction to Robotics

Bruno Siciliano

*Department of Electrical Engineering
and Information Technology
University of Naples Federico II*

robot



NO robot



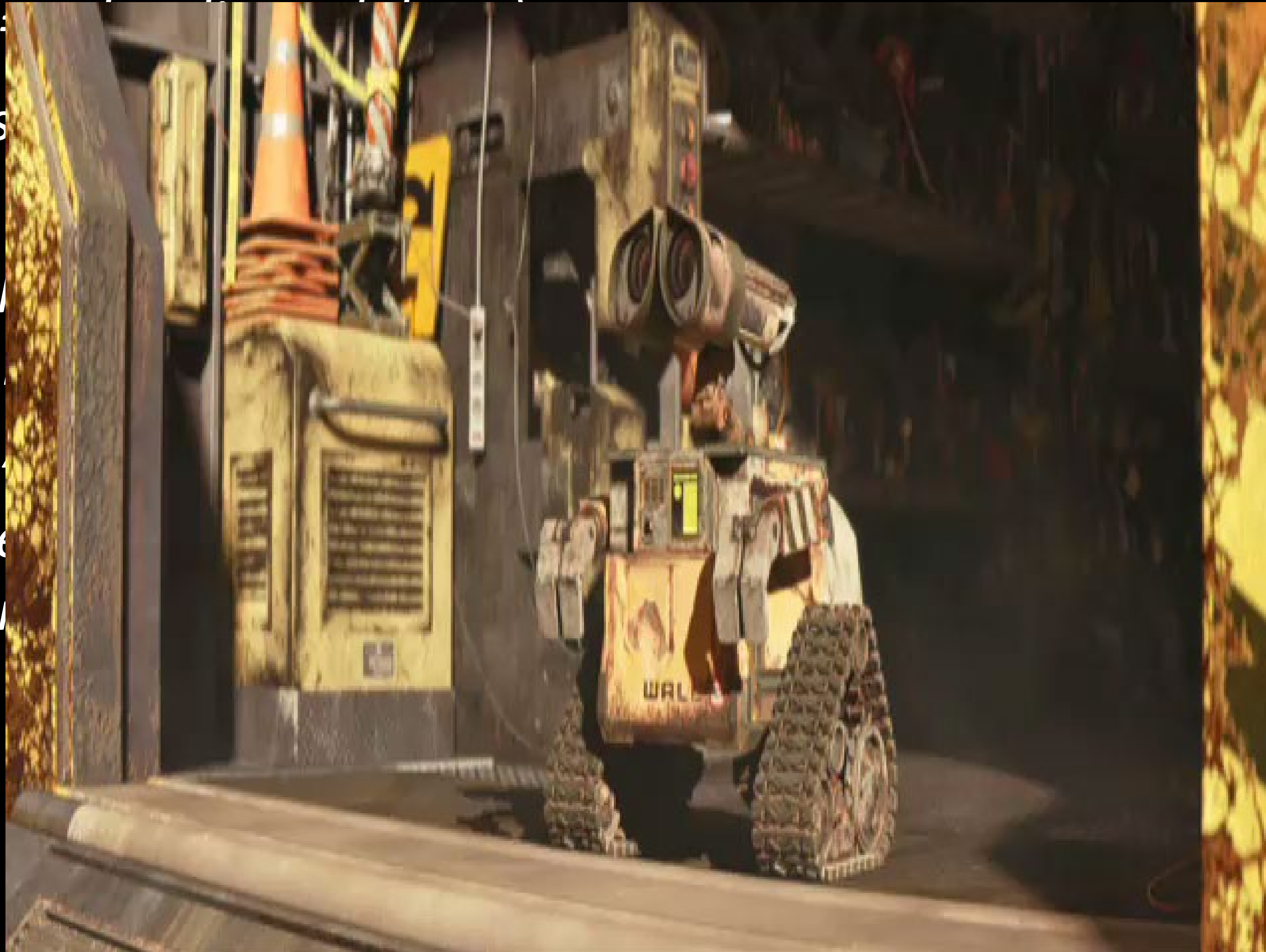
What is a Robot?

Robot (*robota*)

One of humans
(*mythology*)

Common people
walk, see, and
(*science fiction*)

The robot is seen
execute tasks in

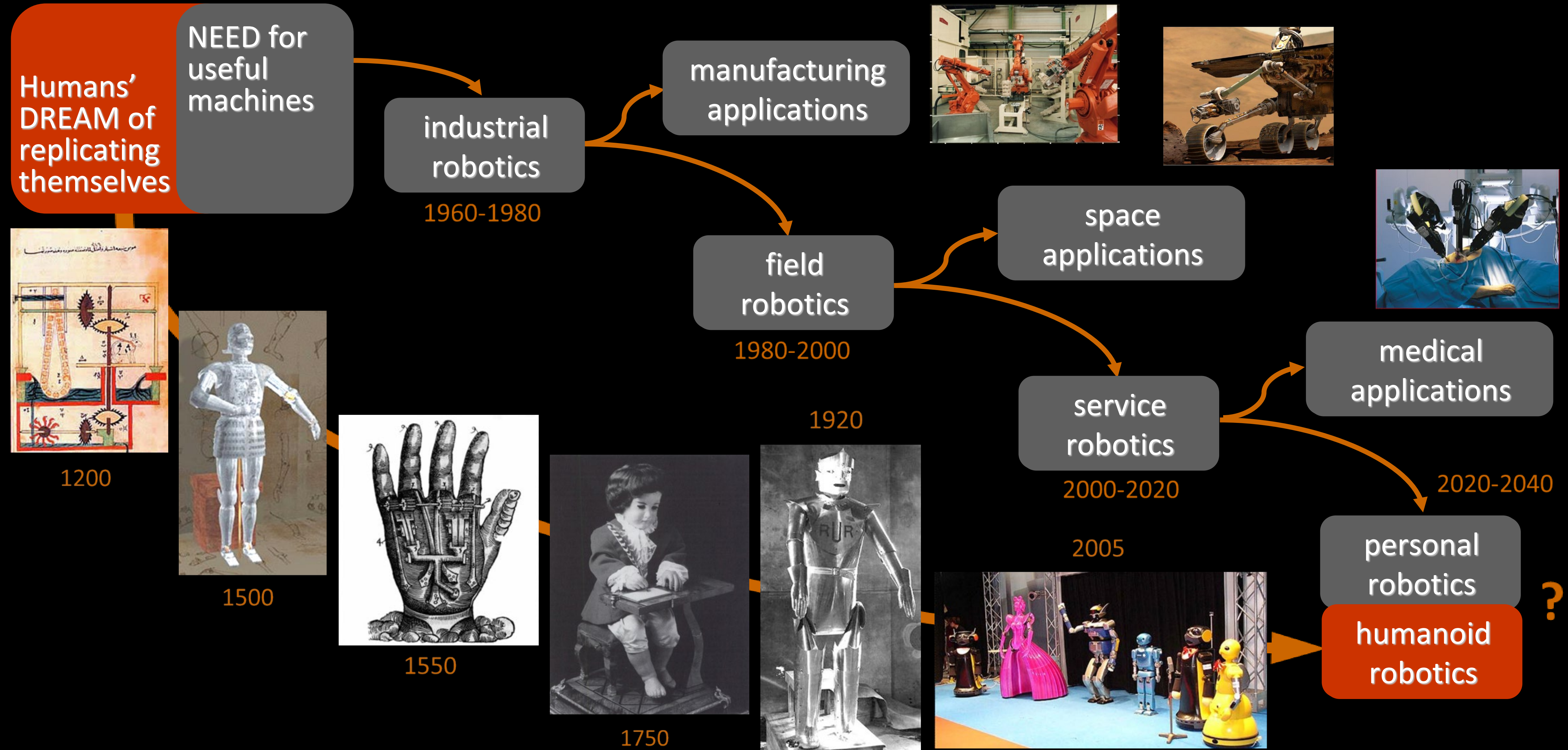


artifacts

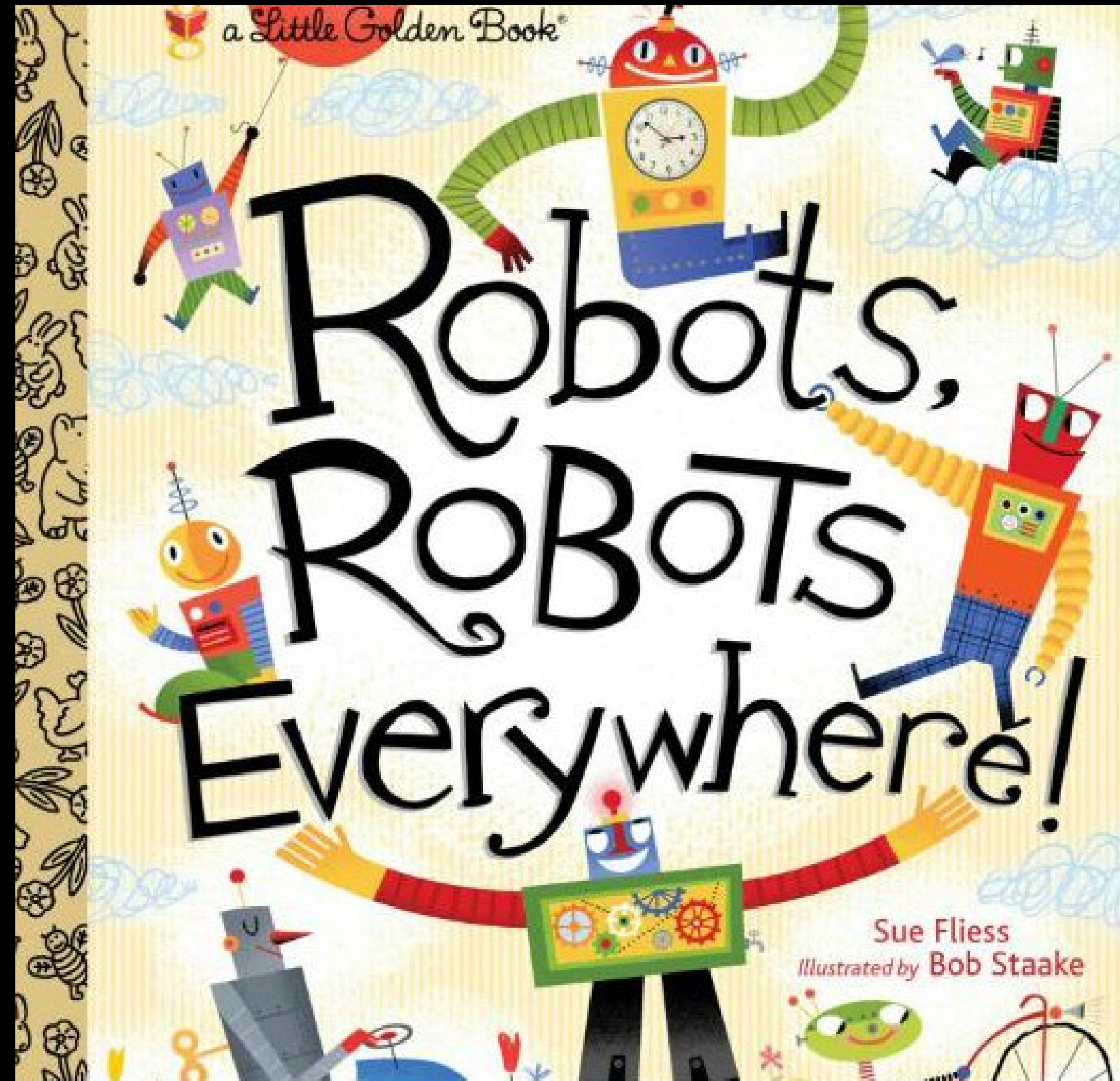
can speak,
mans

is able to
bour (*reality*)

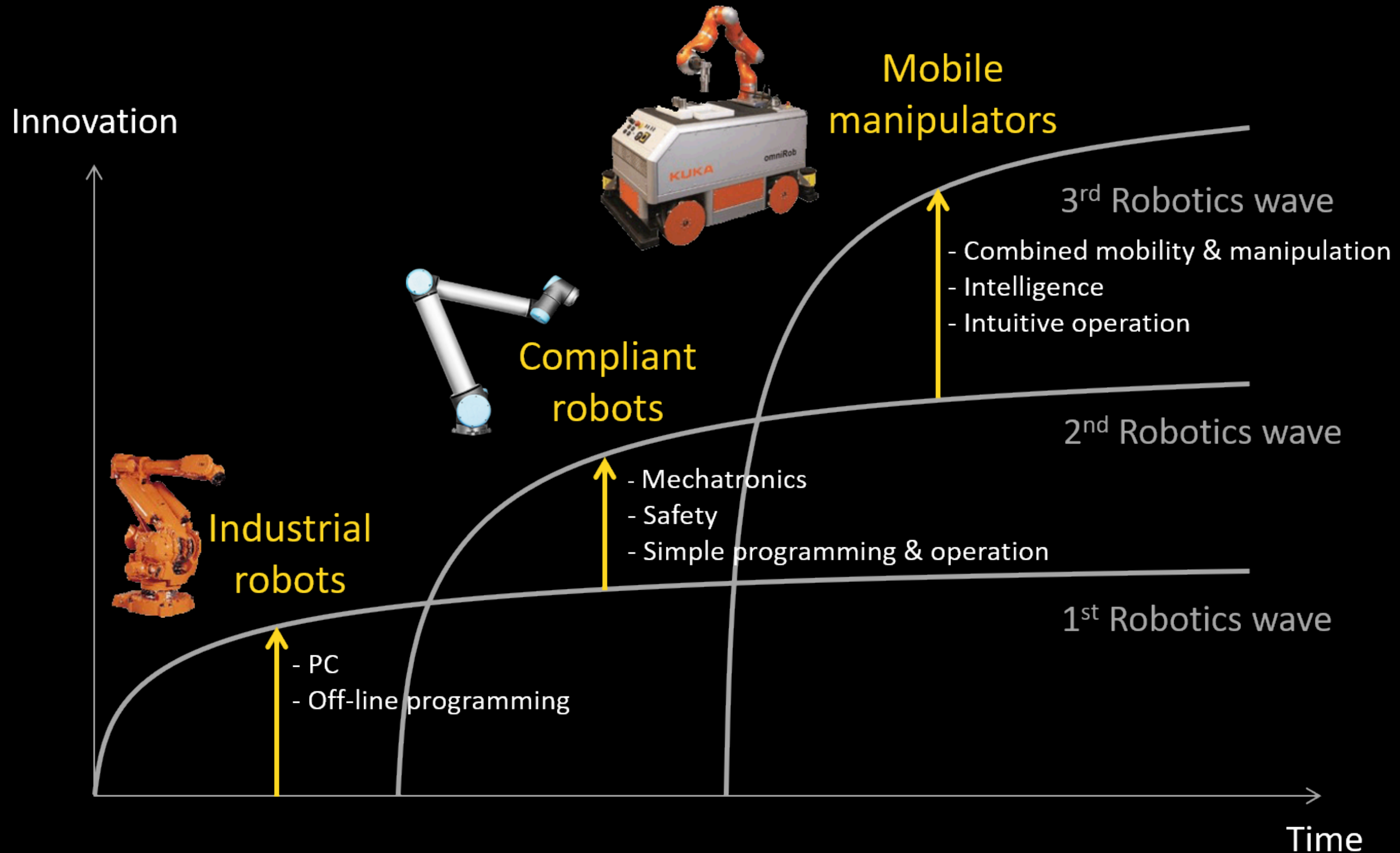
History of Robotics



The Age of Robots

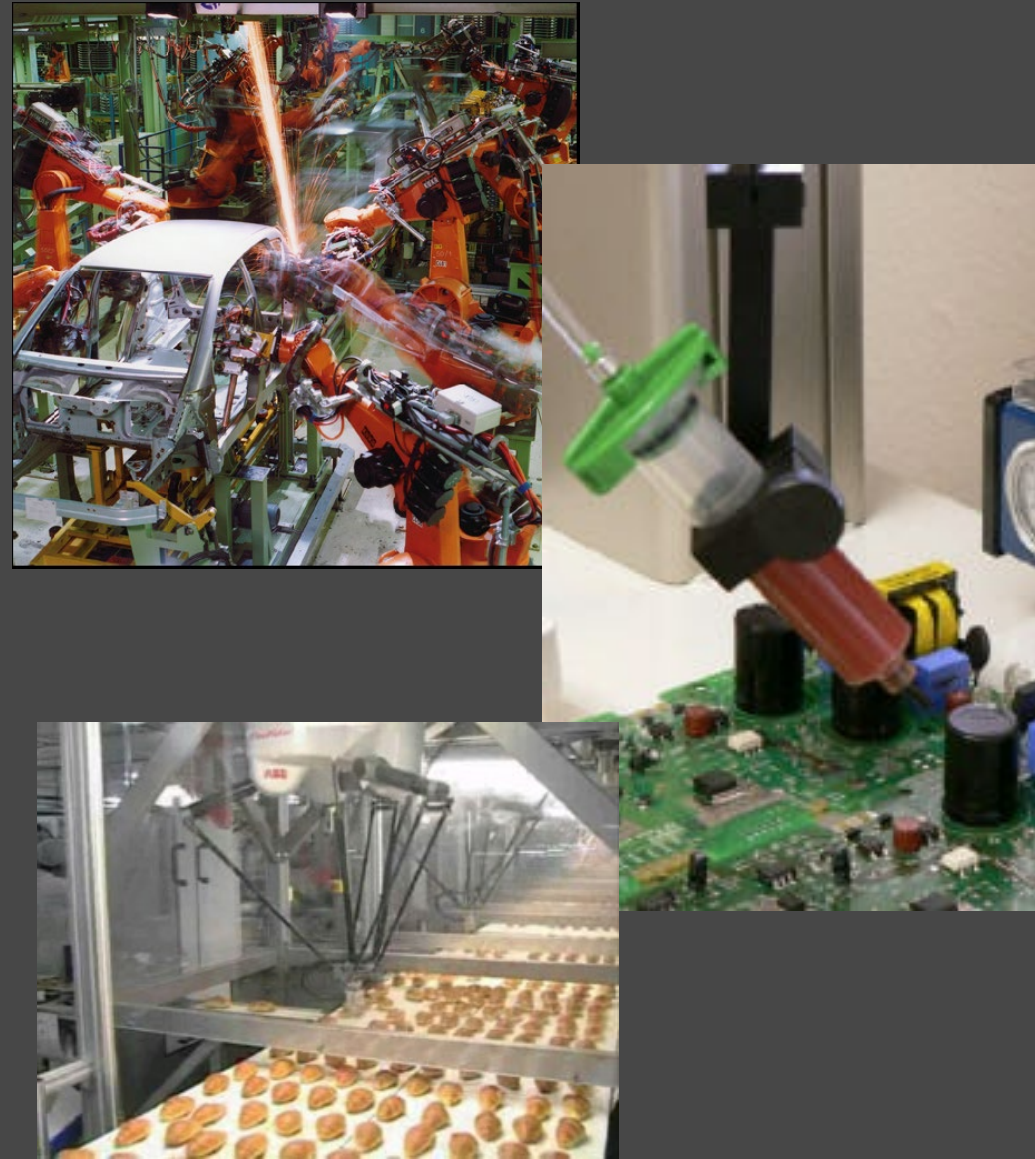


Industrial Robotics Evolution



Robot Classification

Industrial robots



Used for factory automation (mainly manufacturing): automotive, electrical/electronics, metal & machinery, plastic & chemical, food

Service robots

Perform useful tasks for humans or equipment excluding industrial automation

Professional service robots



Used for commercial tasks by trained operators: cleaning public places, delivery in offices or hospitals, fire-fighting, rehabilitation, surgery

Personal service robots



Used for non-commercial tasks by untrained persons: house cleaning, automated wheelchairs, personal mobility assist robots, pet exercising robots

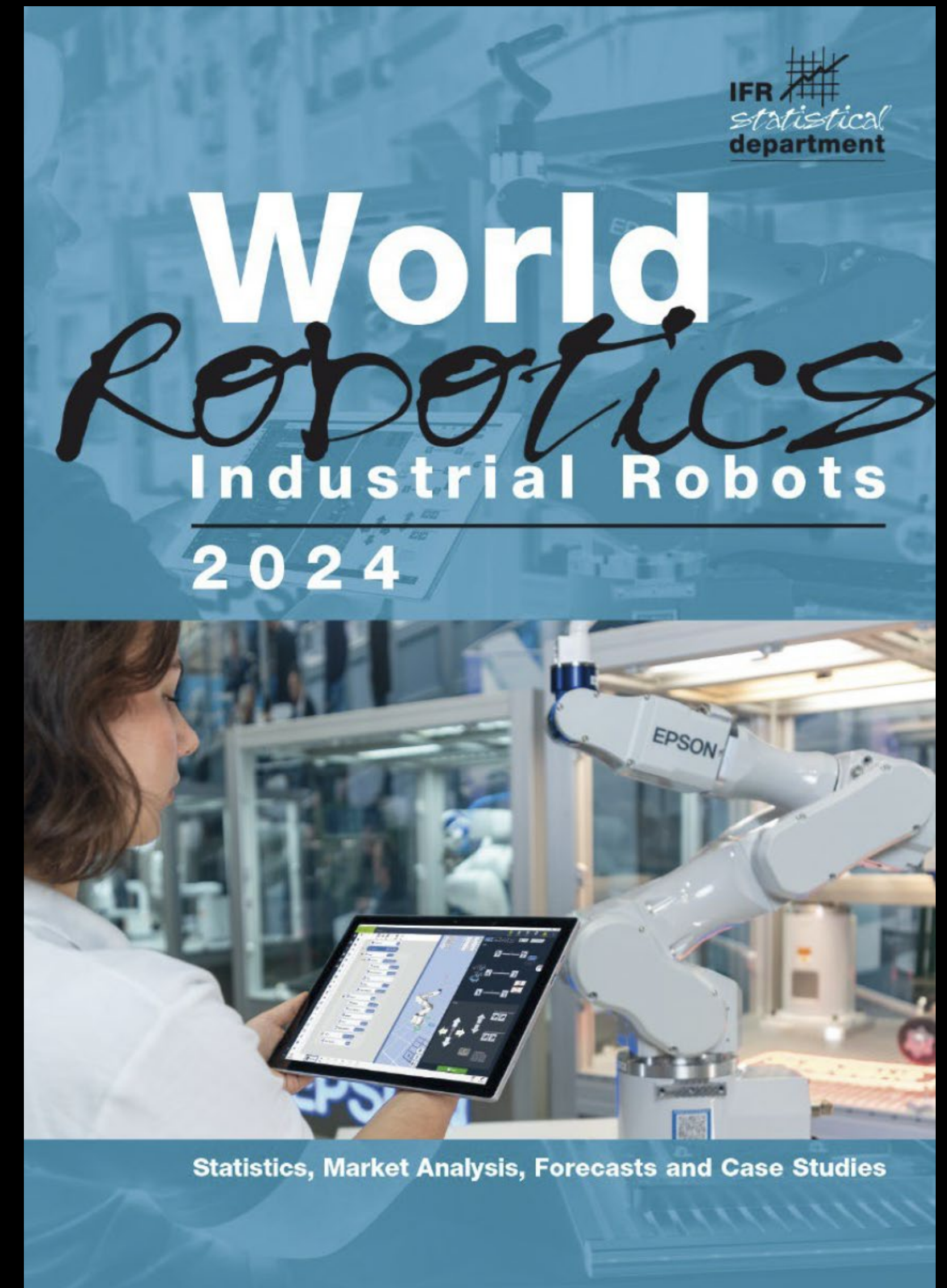
IFR
International
Federation of
Robotics

<https://ifr.org>

👉 *The classification of a robot is done according to its intended application*

World Statistics

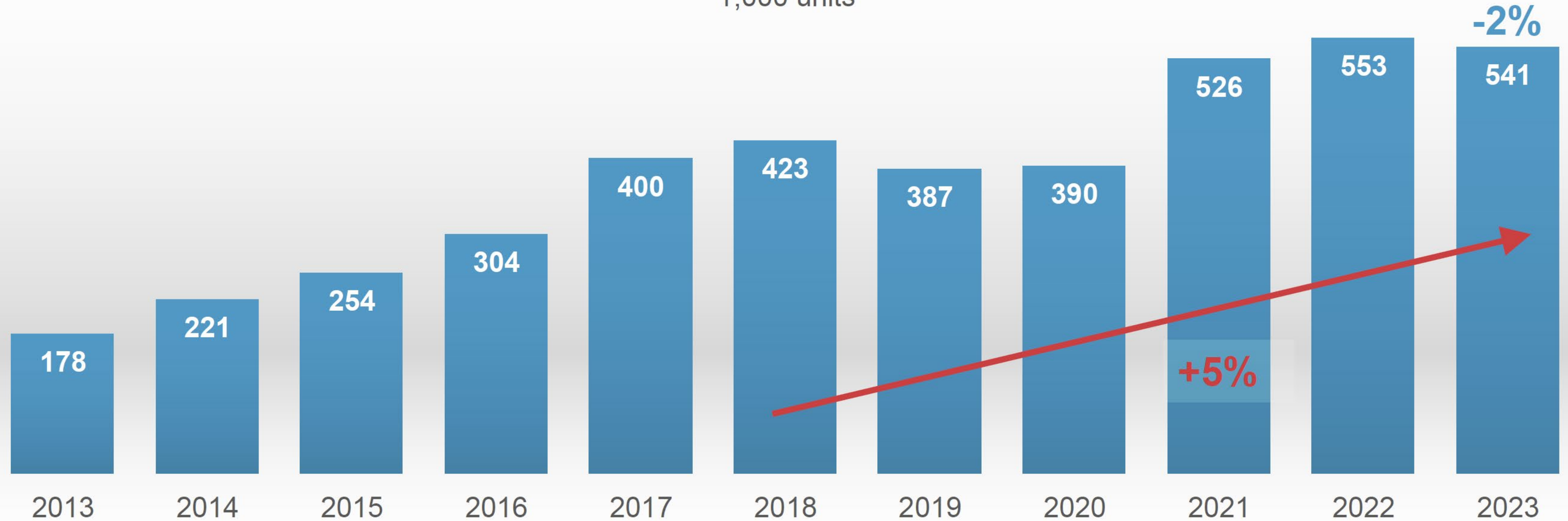
- ✓ *4.3 million of robots @ work worldwide (+10%), CAGR 2018–2023 +12%*
- ✓ *541.000 new installation in 2023 (-2%), CAGR 2018–2023 +5%*
- ✓ *Largest markets: China, Japan, USA, Korea, Germany, Italy (90%)*



Robots At Work

Annual installations of industrial robots - World

1,000 units



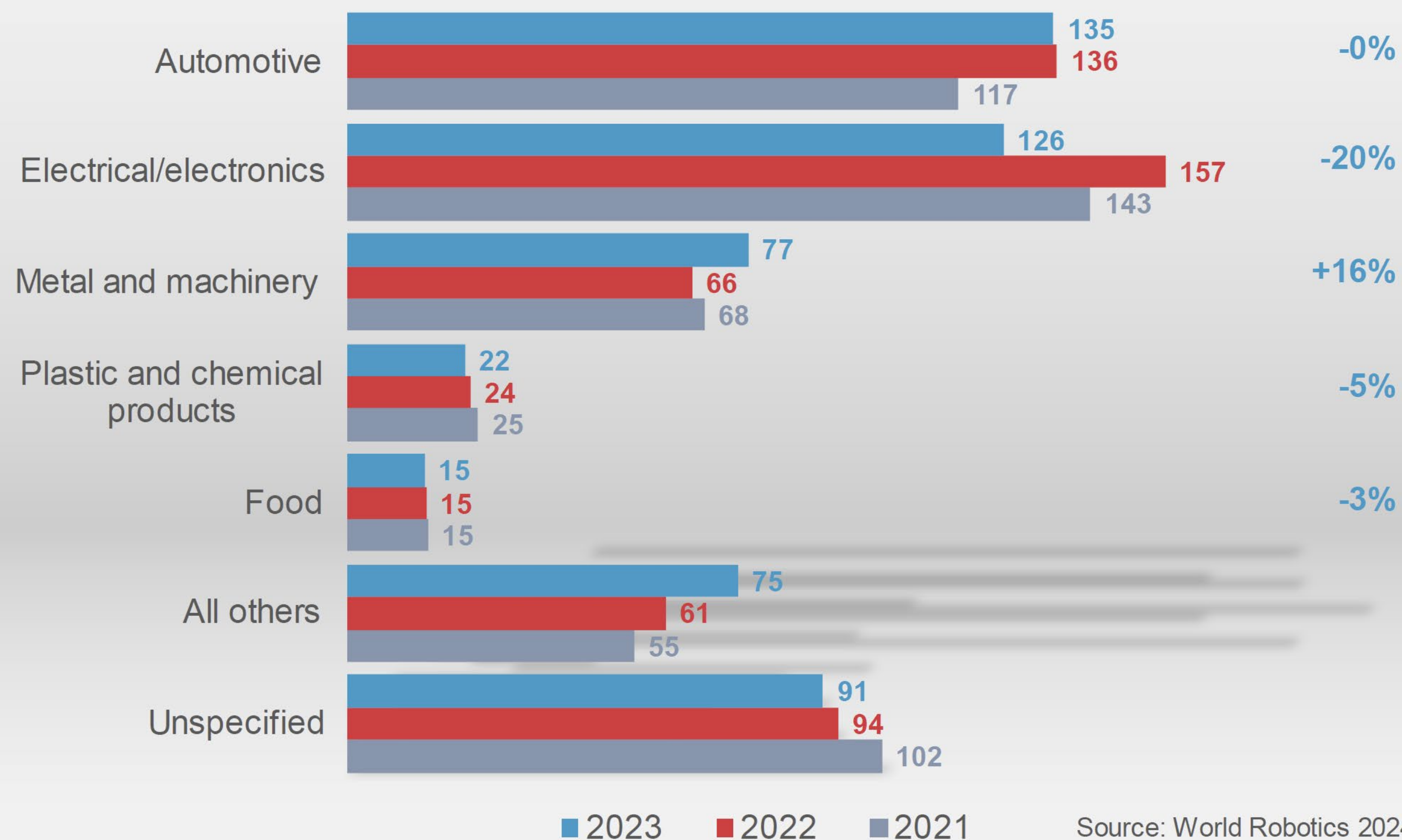
Source: World Robotics 2024

Application Sectors

Automotive main customer due to weak demand from electronics

Annual installations of industrial robots by customer industry- World

1,000 units



Source: World Robotics 2024

Technology Trends

- ✓ *Mobile manipulators* offer new use cases, whenever transportation and handling tasks need to be jointly automated end-to-end in one device
- ✓ Research & development of *humanoid robots* will yield new technological capabilities
- ✓ Improvements in marketable *artificial intelligence* solutions at an incredible pace



Market Trends

- ✓ *Labor scarcity* in many developed economies is driving the demand for automation
- ✓ *Reconsideration of supply chains* and *closeness to customers*
- ✓ *Small and medium sized enterprizes (SMEs)* need *easy access* to automation
<https://go4robotics.com/>



Service Robots

New professional service robots (incl. AMRs)

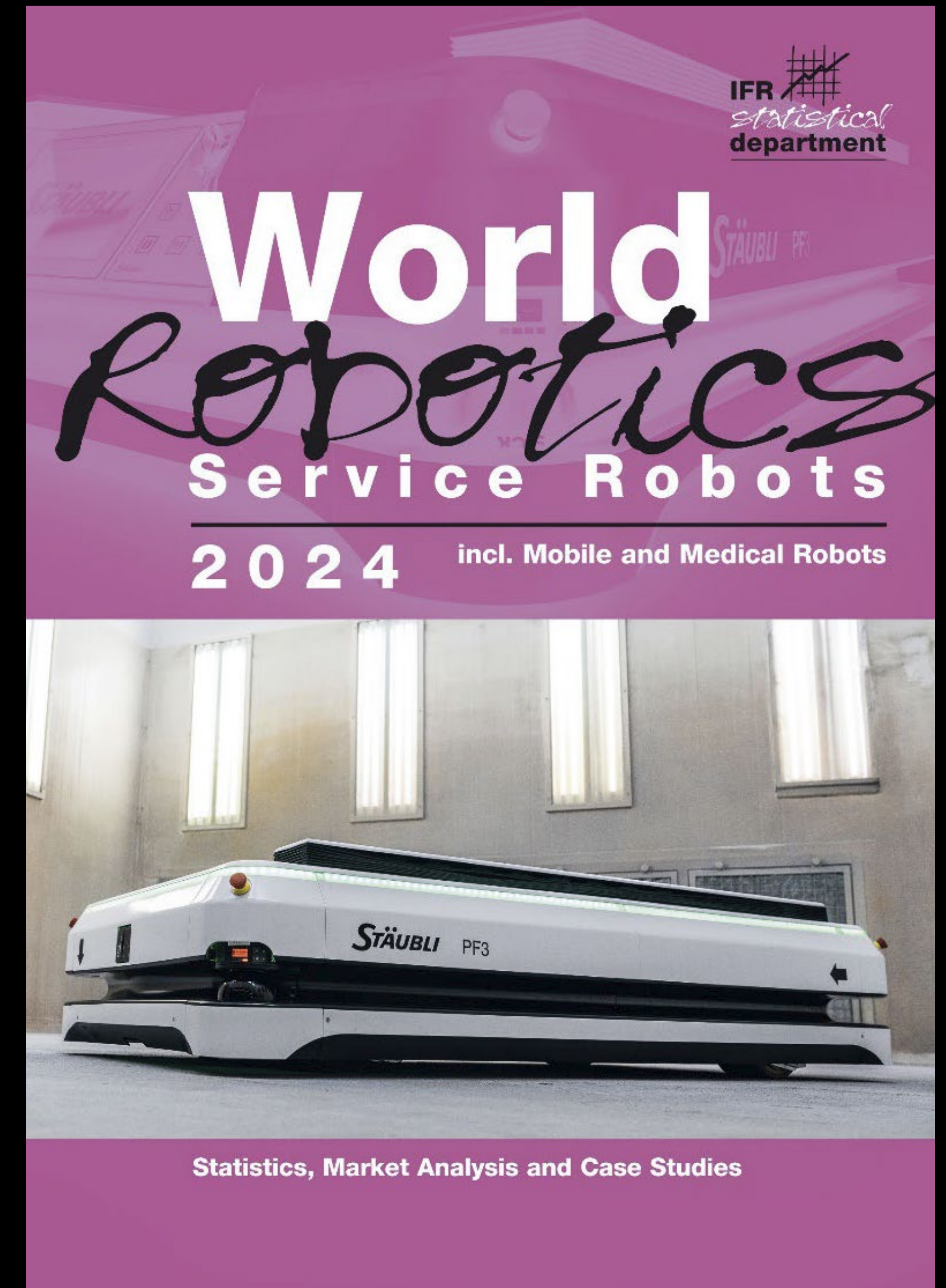
✓ 205,000 units (+30%)

New medical robots

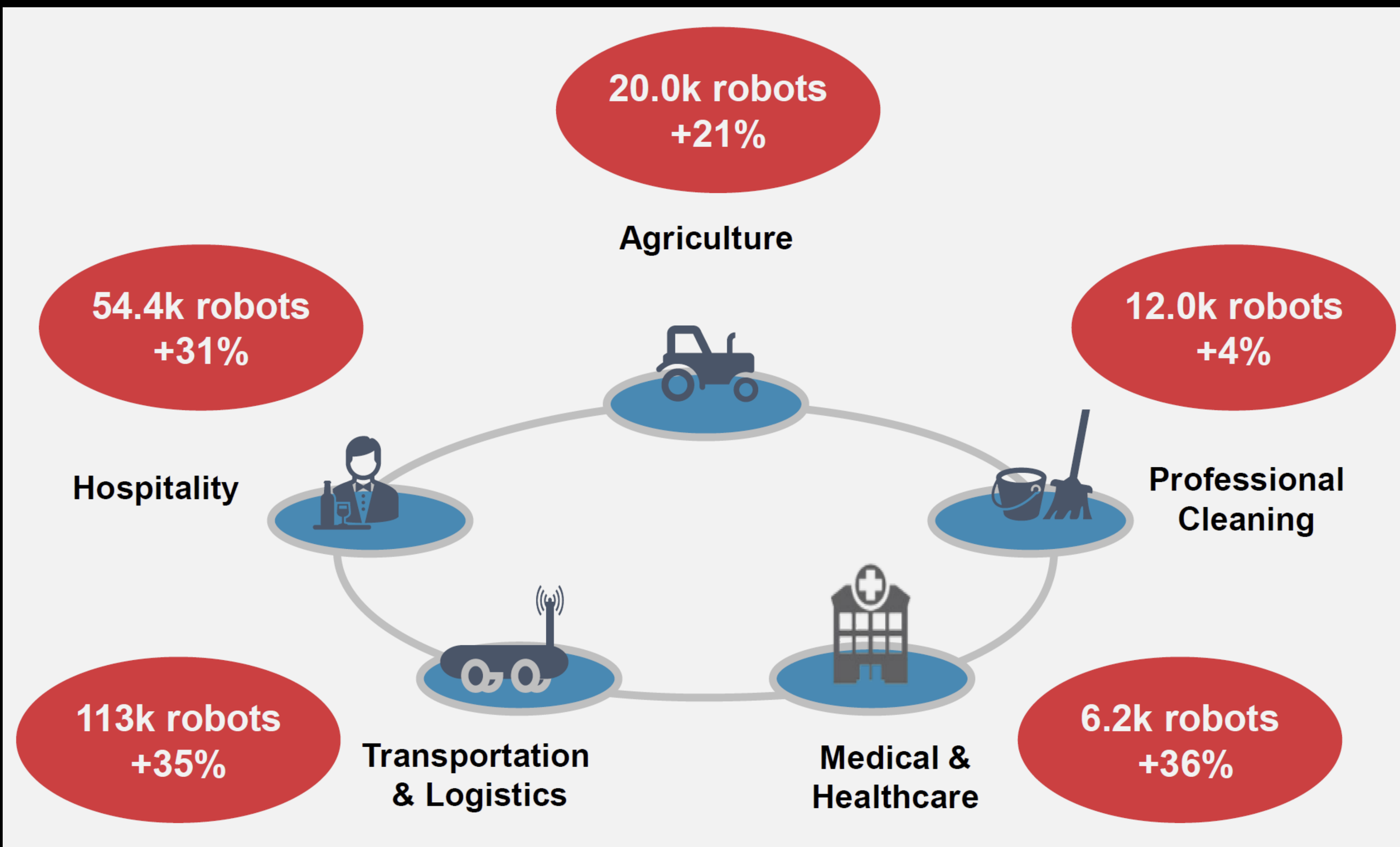
✓ 6,200 units (+36%)

New consumer service robots

✓ 4.1 million units (+1%)



Application Sectors



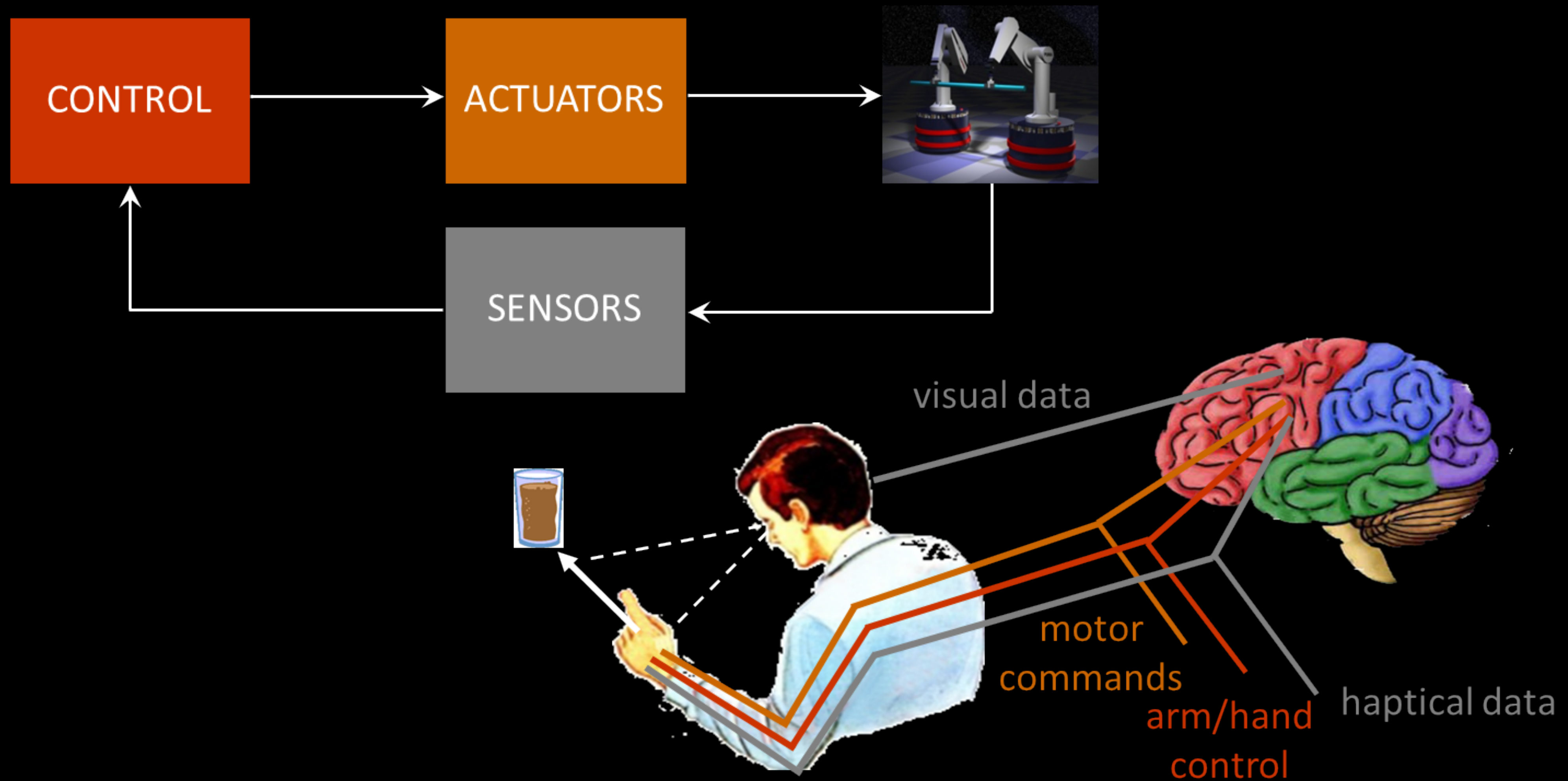
Outlook

- ✓ *Technological advances, e.g. in **generative AI**, improve **robot performance and applicability***
- ✓ ***Demographic change**: scarcity of labor is driving robot demand*
- ✓ *Need for further **standards**, e.g. on **safety***
- ✓ ***Excellent long-term prospects***



Robotics

intelligent connection of perception to action



Components of a Robotic System

Mechanical system

- ✓ *Locomotion apparatus (wheels, crawlers, mechanical legs)*
- ✓ *Manipulation apparatus (mechanical arms, end-effectors, artificial hands)*

Actuation system

- ✓ *Animates the mechanical components of the robot*
- ✓ *Motion control (servomotors, drives, transmissions)*

Sensory system

- ✓ *Proprioceptive sensors (internal information on system)*
- ✓ *Exteroceptive sensors (external information on environment)*

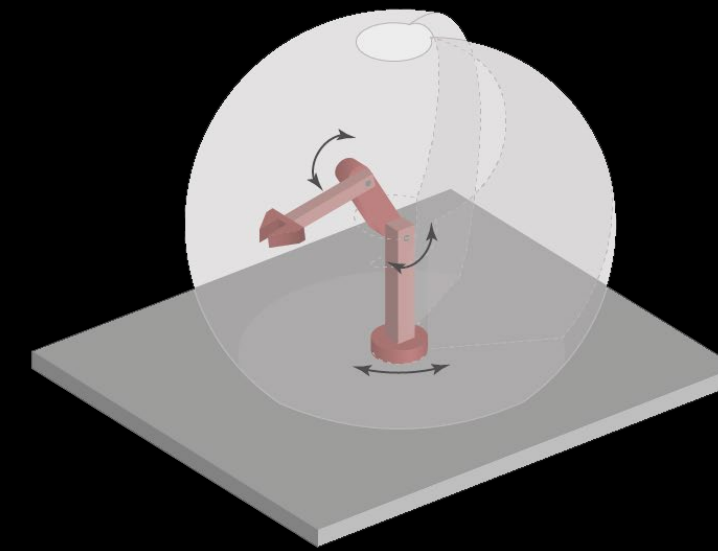
Control system

- ✓ *Execution of action set by task planning coping with robot and environment's constraints*
- ✓ *Adoption of feedback principle*
- ✓ *Use of system models*

Robot Manipulators

Mechanical structure of **robot manipulator**: sequence of rigid bodies (**links**) interconnected by means of articulations (**joints**)

- ✓ **Arm** ensuring mobility
- ✓ **Wrist** conferring dexterity
- ✓ **End-effector** performing the task required of robot

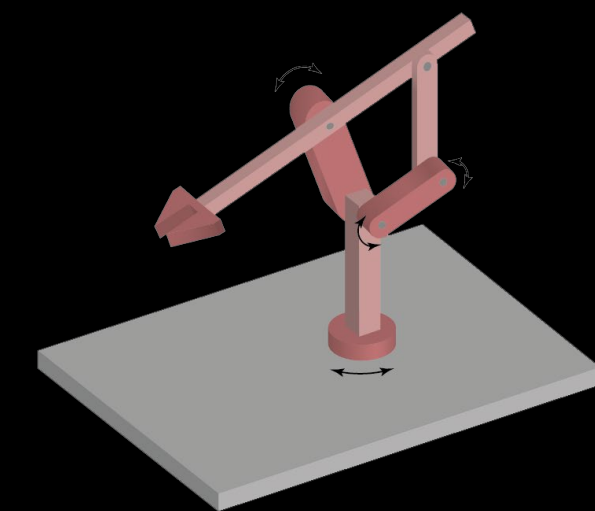
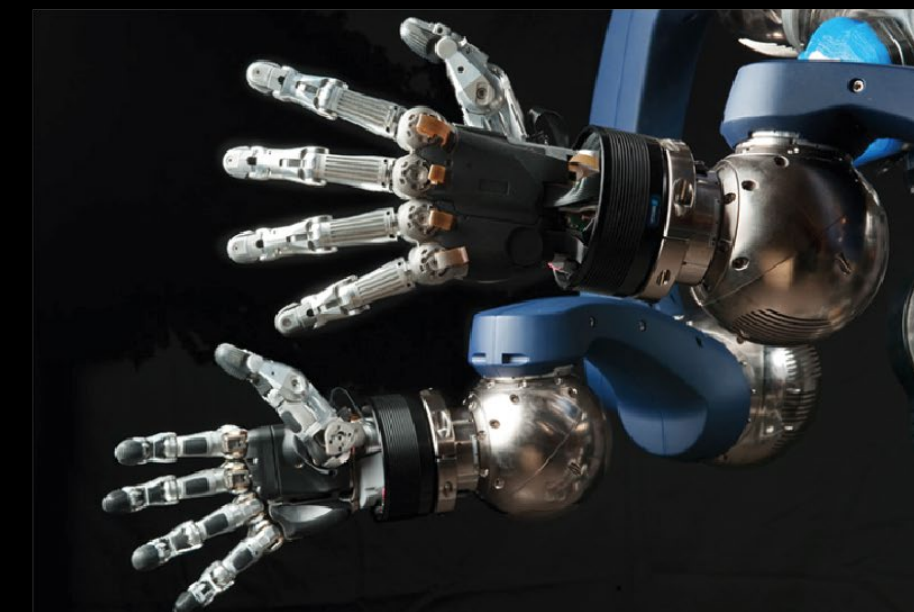
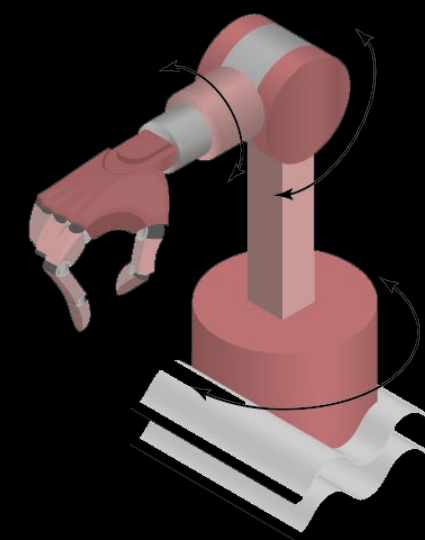


Mechanical structure

- ✓ **Open** vs. **closed** kinematic chain

Mobility

- ✓ **Prismatic** vs. **revolute** joints

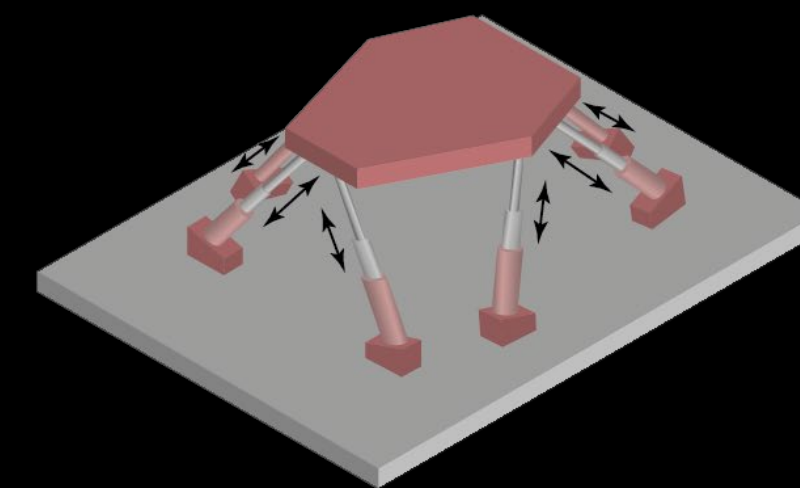


Degrees of freedom

- ✓ 3 for **position** + 3 for **orientation**

Workspace

- ✓ Portion of environment the manipulator's end-effector can access

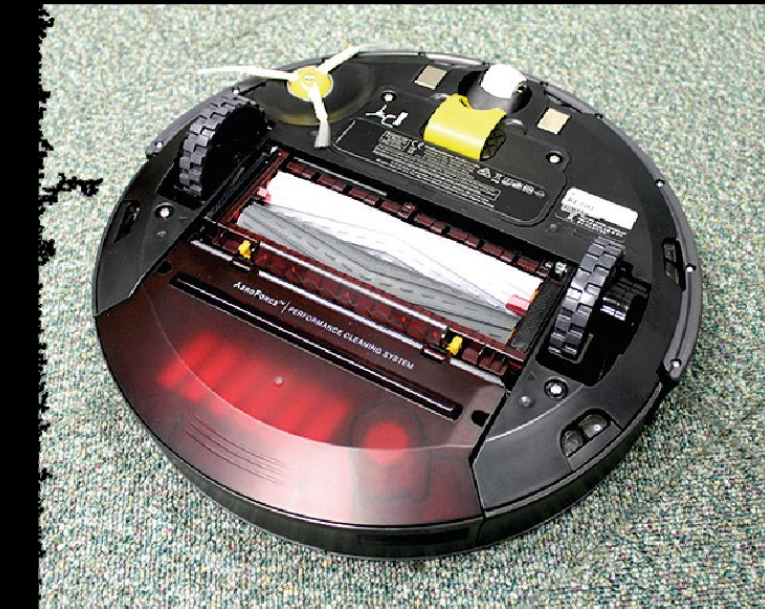
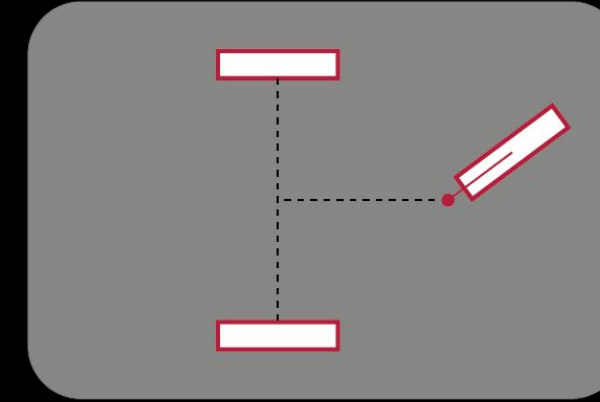


Wheeled Robots

*Mechanical structure of **mobile robot**: set of rigid bodies equipped with locomotion system*

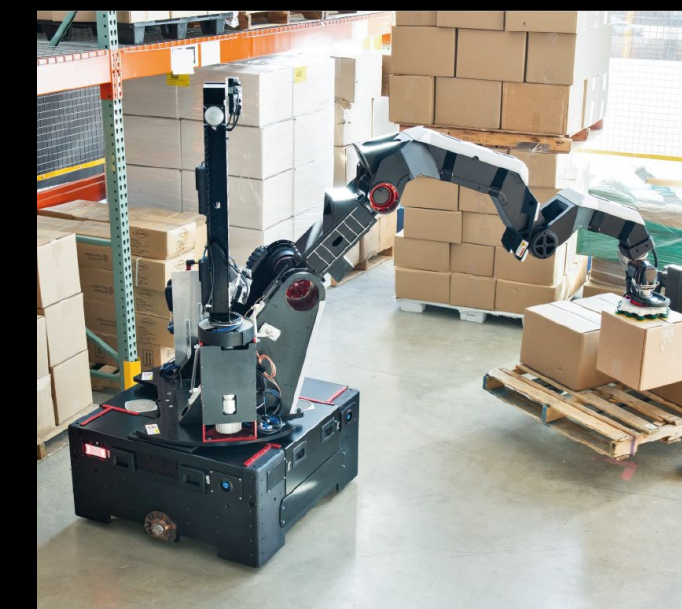
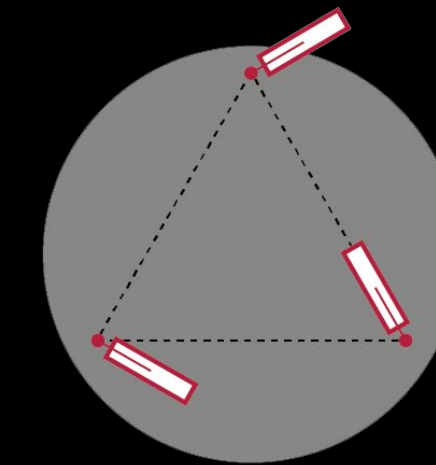
✓ *Mobile robots on **wheels***

- ***Base (chassis)***
- ***Wheels** that move it with respect to the ground*
- *Possible trailers (on wheels)*

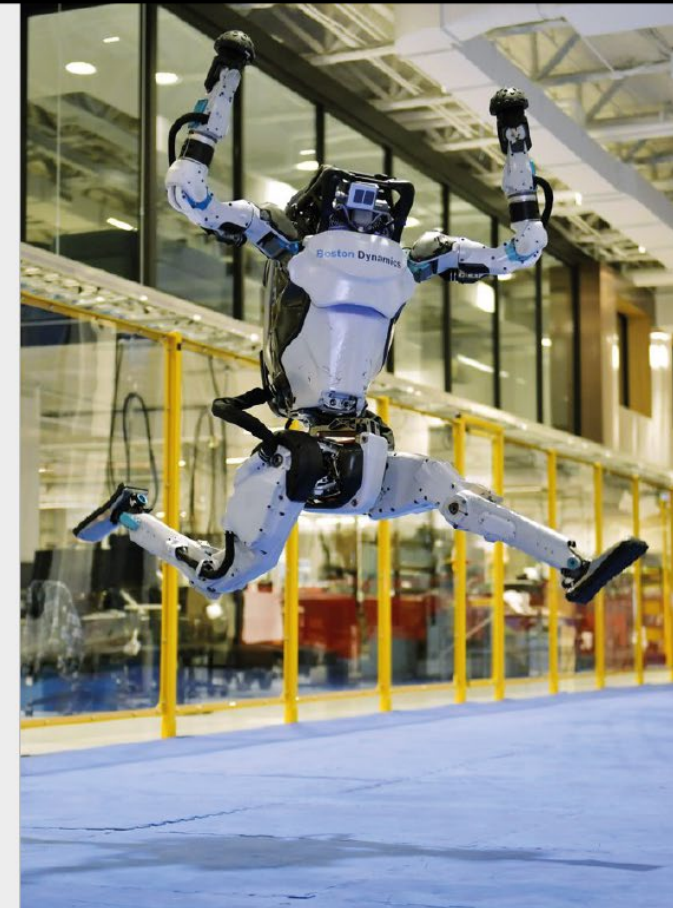
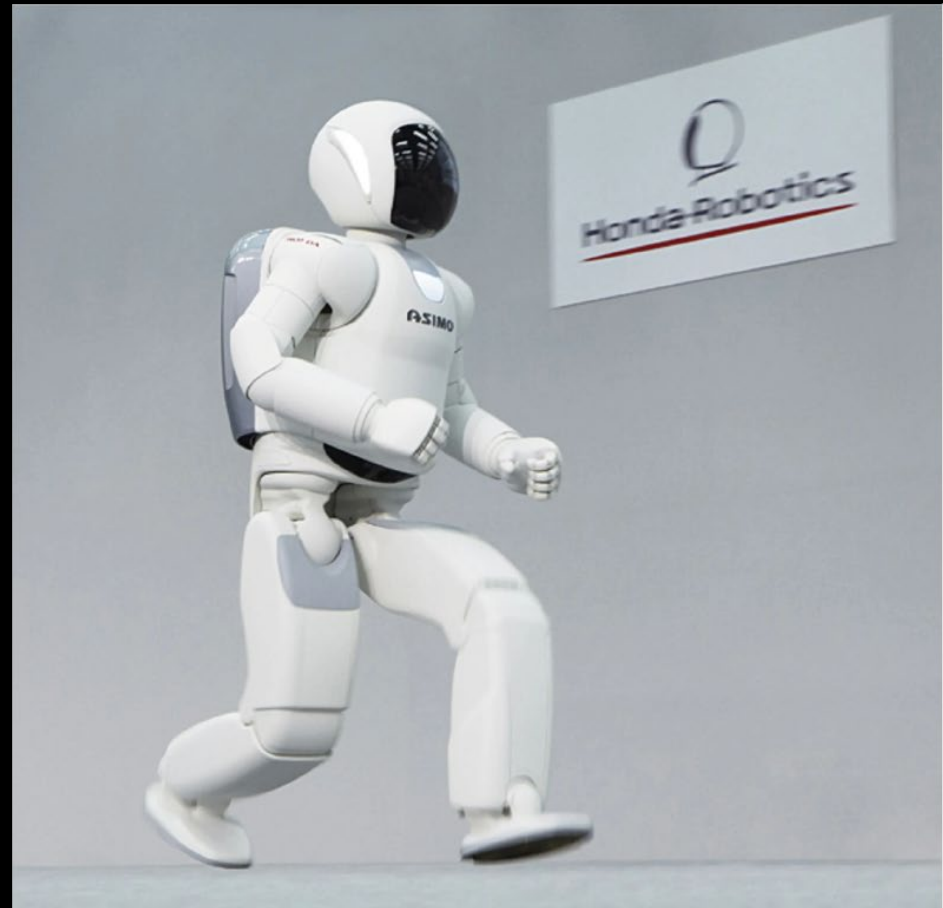


✓ *Mobile robots on **legs***

- *Limbs*
- *Foot periodically in contact with the ground (locomotion)*
- *Project inspired by living organisms (biomimetic robotics)*

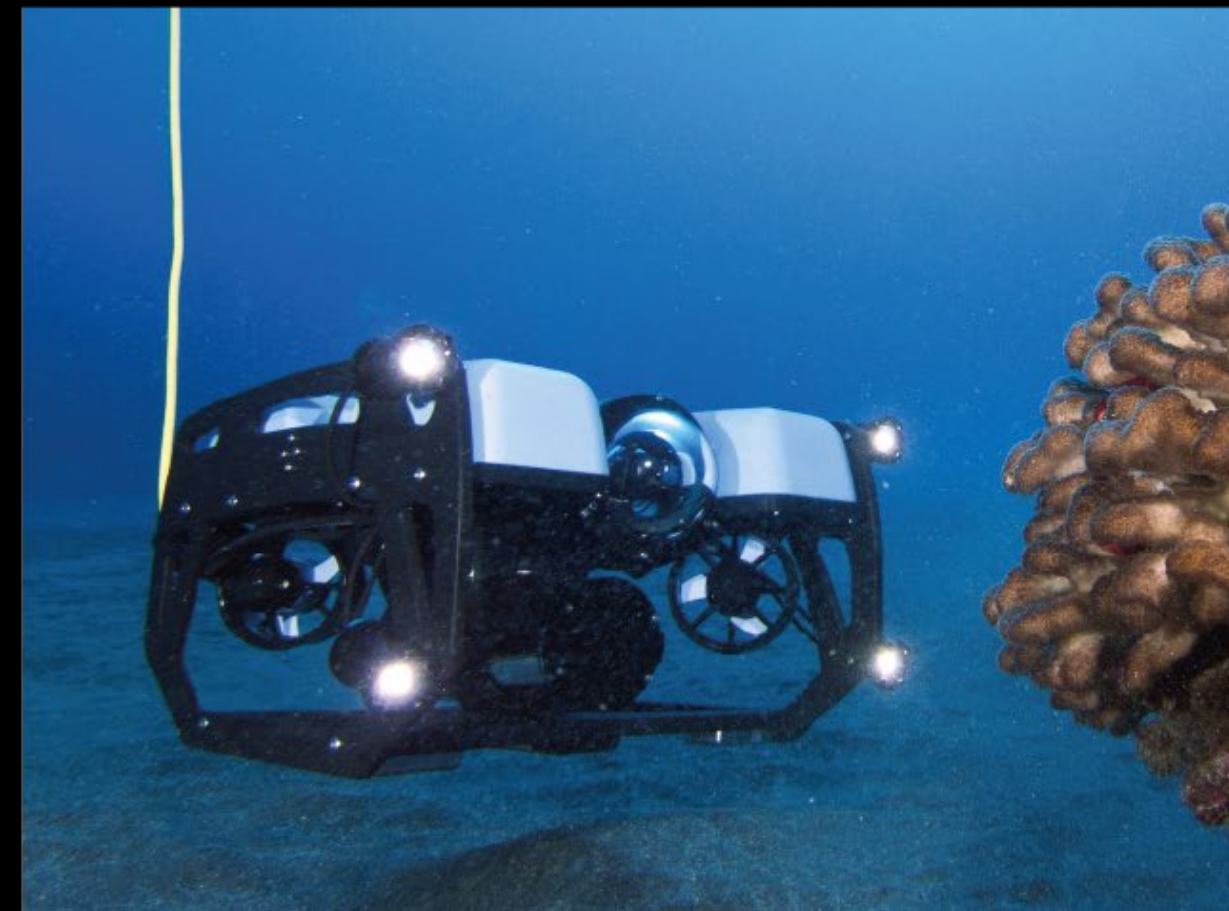


Other Robot Structures



Bipeds

Flying



Walking

Underwater

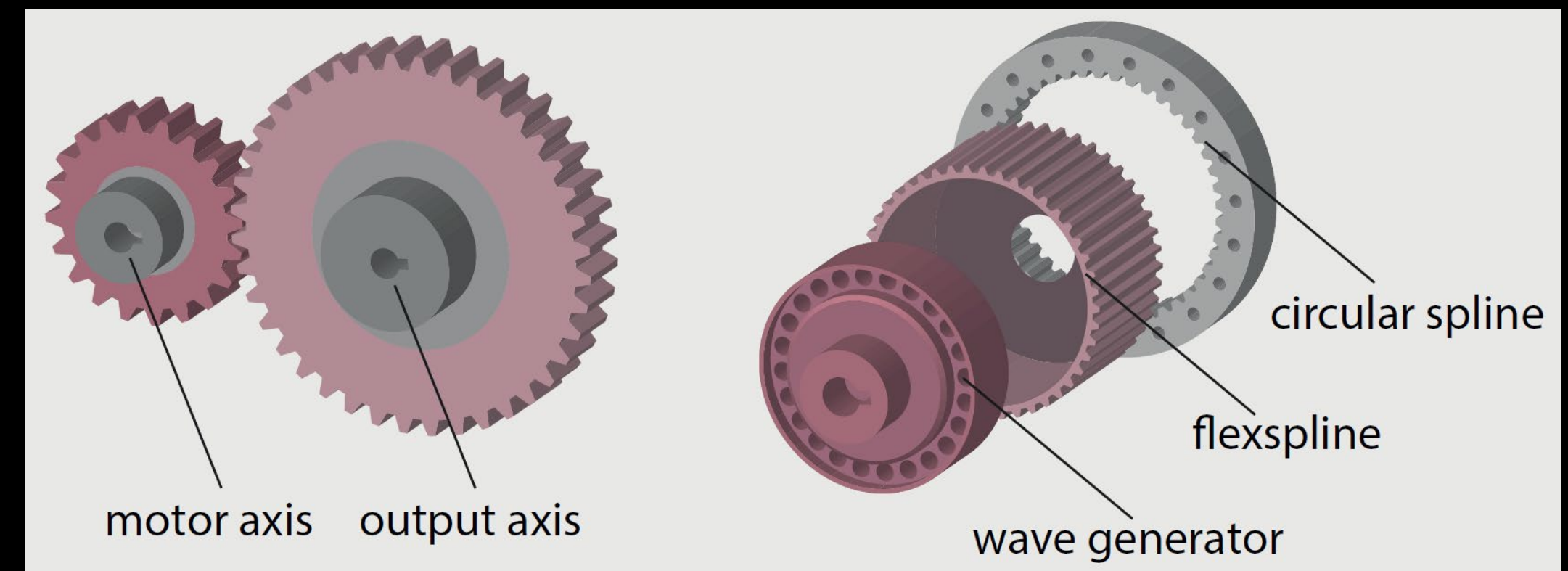
Actuation

Robot actuation is entrusted to motors which allow the realization of a desired motion for the mechanical system

- ✓ ***Electric servomotors** use as primary supply the energy available from the electric distribution system*
- ✓ ***Hydraulic servomotors** transform the hydraulic energy stored in a reservoir into mechanical energy by means of pumps and valves*
- ✓ ***Pneumatic motors** use the pneumatic energy provided by an air compressor and transform it into mechanical energy by means of pistons or turbines*

Transmissions

- ✓ *The execution of joint motions of a manipulator, as well as of wheel rotations in a mobile robot, demand **low speeds** with **high torques***



Harmonic drive

Sensing

*A key component for achieving high performance in robotic systems are **sensors***

Proprioceptive sensors

- ✓ *Joint position, velocity, and torque (in manipulators as well as other robots with revolute joints, e.g., legged robots)*
- ✓ *Angular position or velocity of wheels (in wheeled robots)*
- ✓ *Position, orientation, velocity and acceleration of a body of the robot (in mobile robots)*

Exteroceptive sensors

- ✓ *Forces and moments exerted by the robot on the environment*
- ✓ *Relative distance (range) and orientation (bearing) with respect to workspace obstacles, beacons, and such*
- ✓ *Visual data (images or cues) about the area surrounding the robot*

Control Architecture

*The main component is intelligence, which is implemented as a **control architecture***

Deliberative architecture

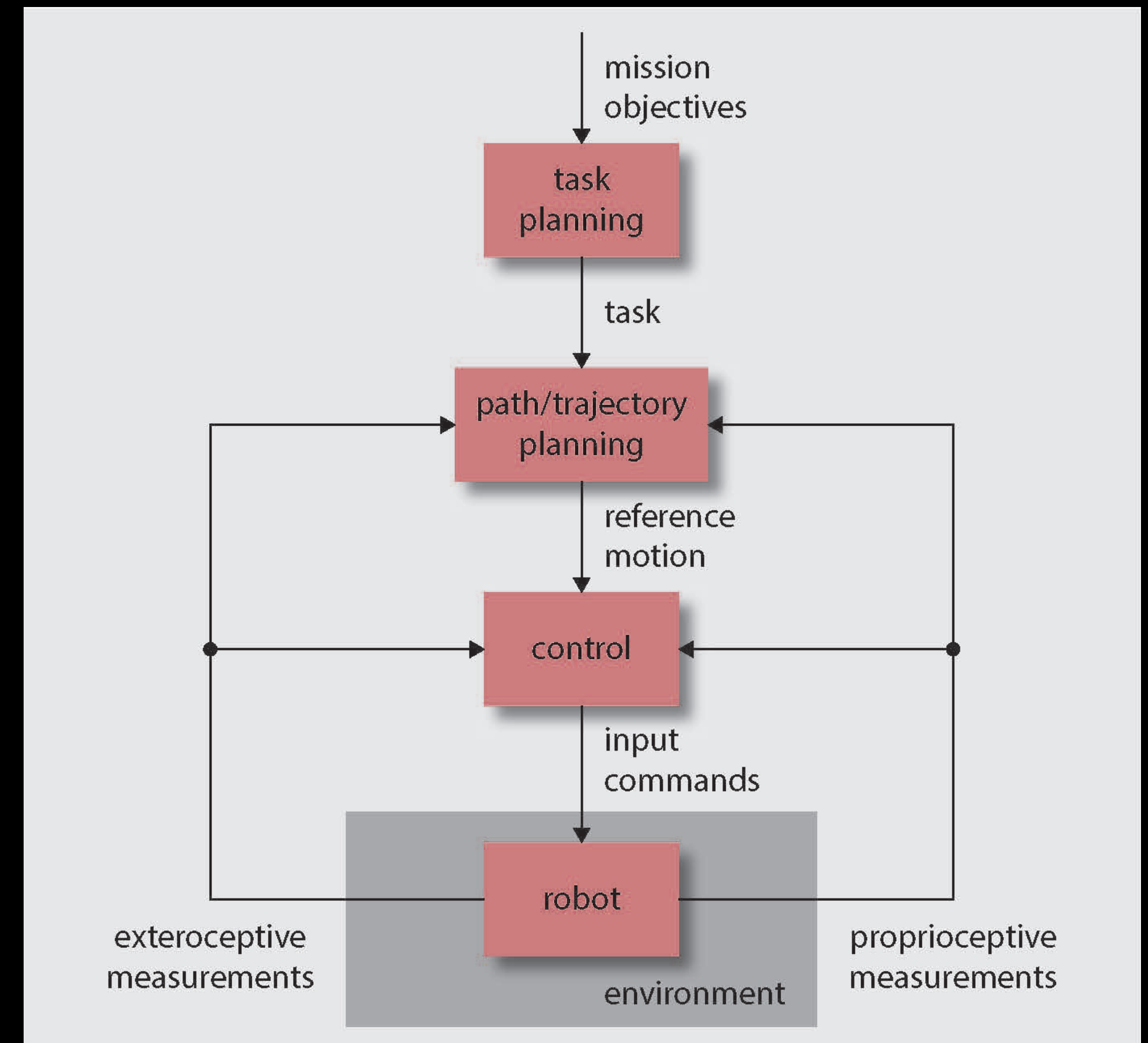
✓ *First Think, then Act*

Reactive architecture

✓ *Don't Think, React (bio-inspired)*

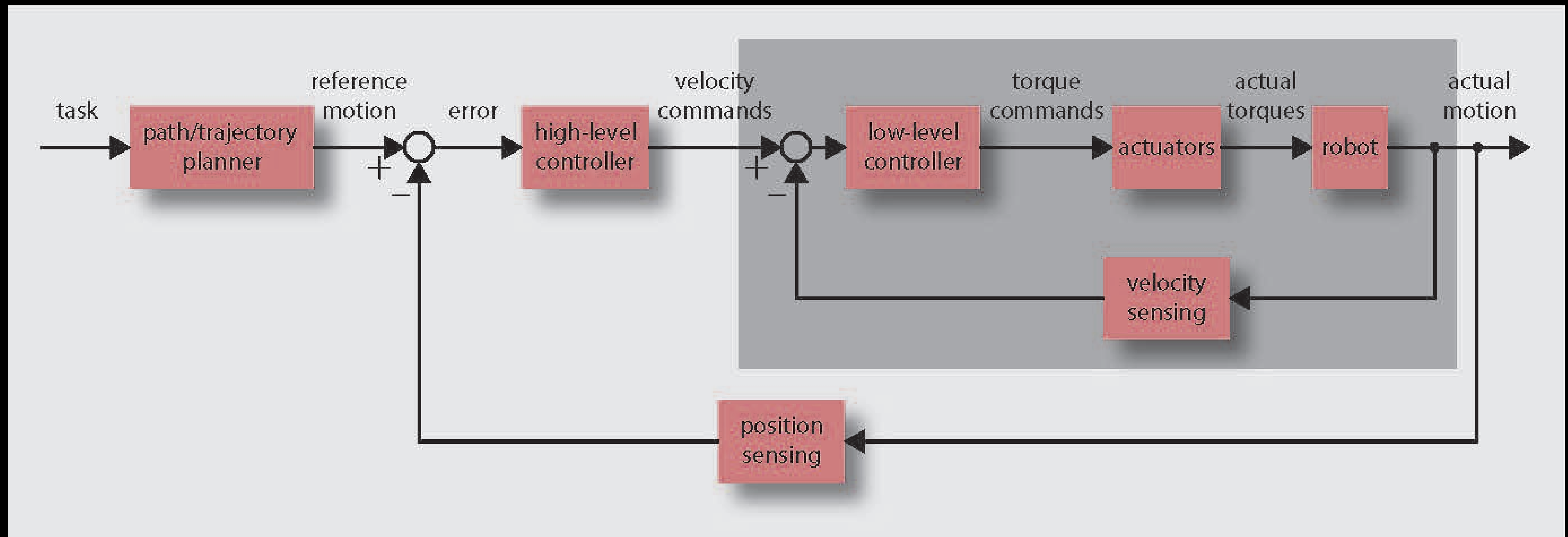
Hybrid architecture

- ✓ *Deliberation at higher level (motion planning)*
- ✓ *Low-level functionalities via reactive modules*



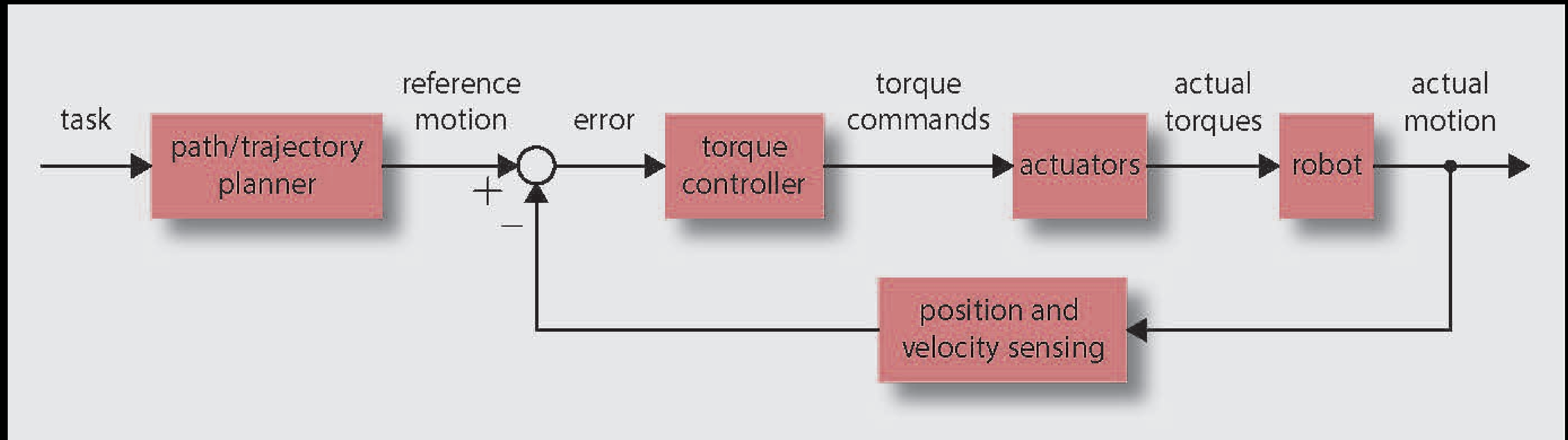
Velocity-Controlled Robots

*Looking at the robot as an essentially kinematic mechanism (**kinematic control**)*



Torque-Controlled Robots

*Accounting for the full dynamics of the robot (**dynamic control**)*



- ✓ *Typical control frequencies for both velocity-controlled and torque-controlled robots range from 100 Hz to 1 KHz*

Artificial Intelligence

*Computers mimicking
functions and logics of
human mind*



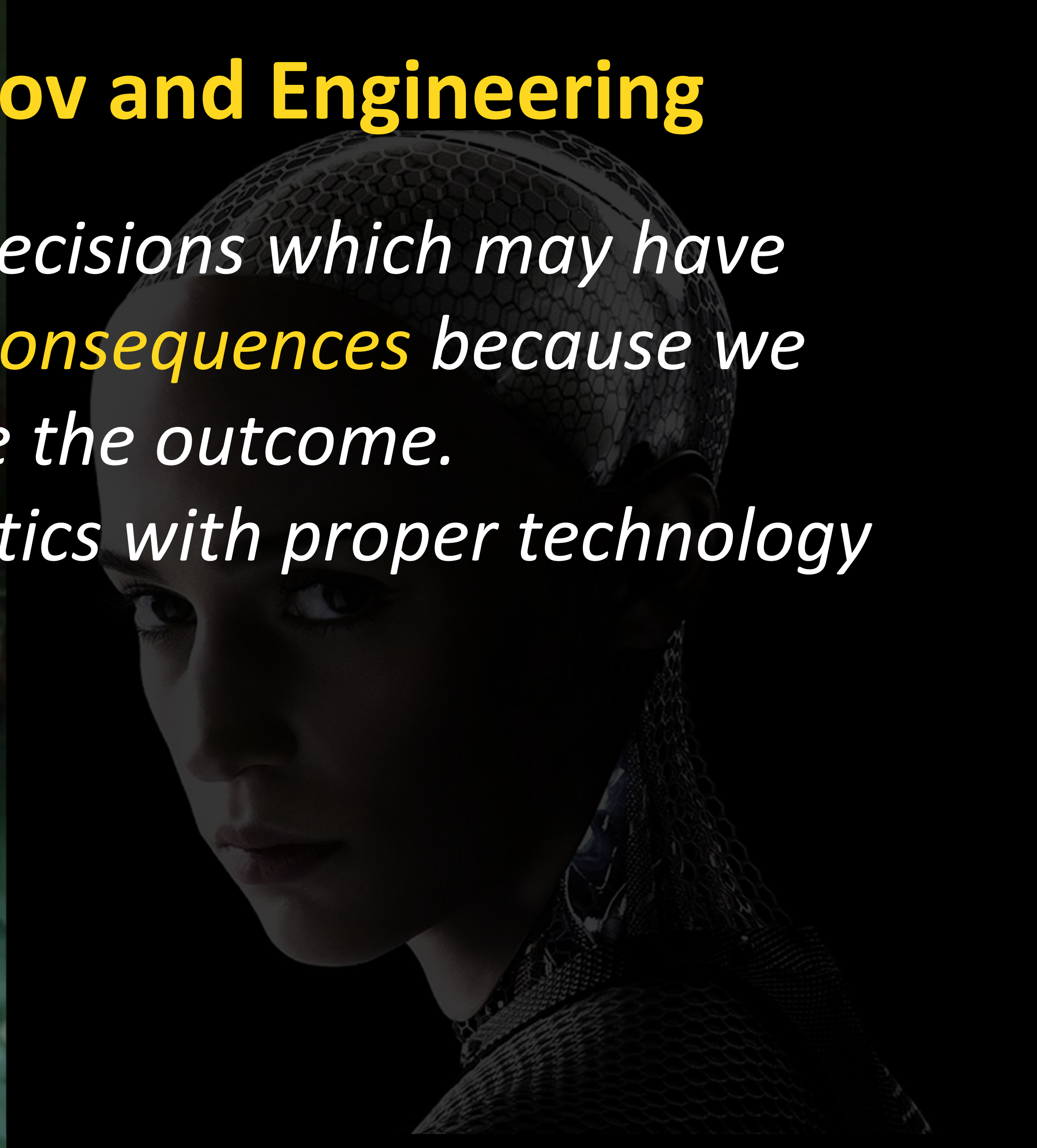
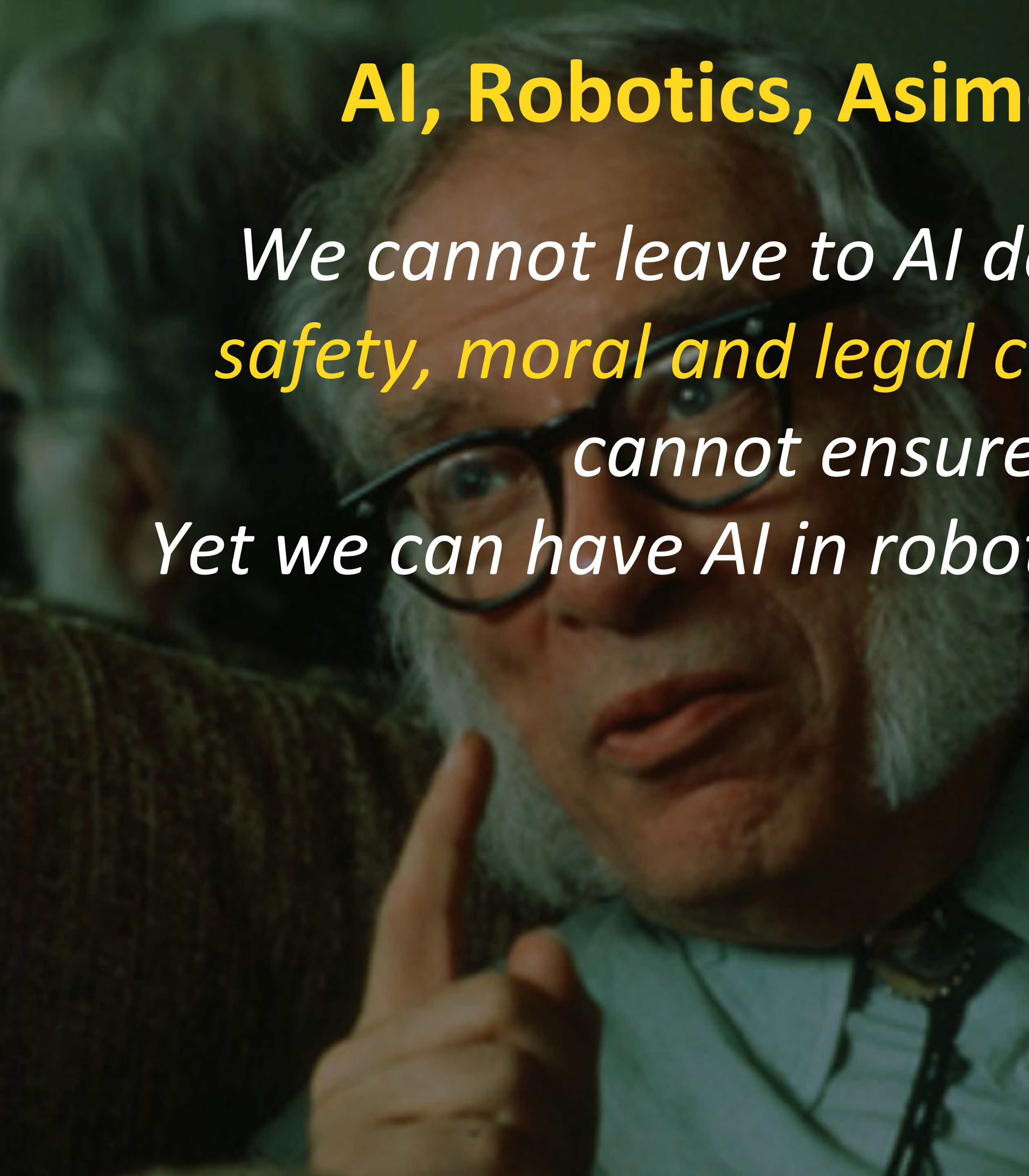
Cortical homunculus



AI, Robotics, Asimov and Engineering

*We cannot leave to AI decisions which may have
safety, moral and legal consequences because we
cannot ensure the outcome.*

Yet we can have AI in robotics with proper technology



The Big Challenge

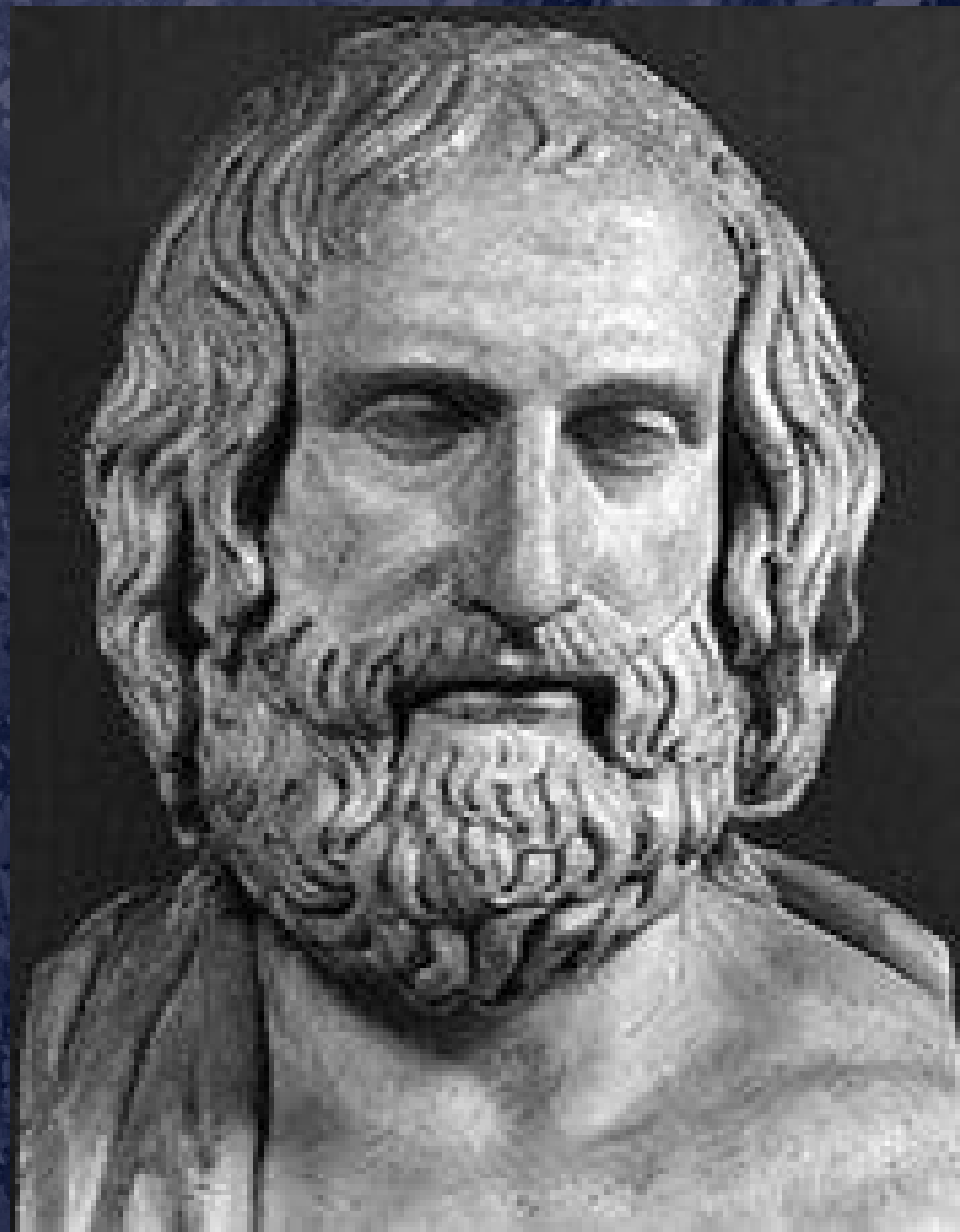


Manipulation

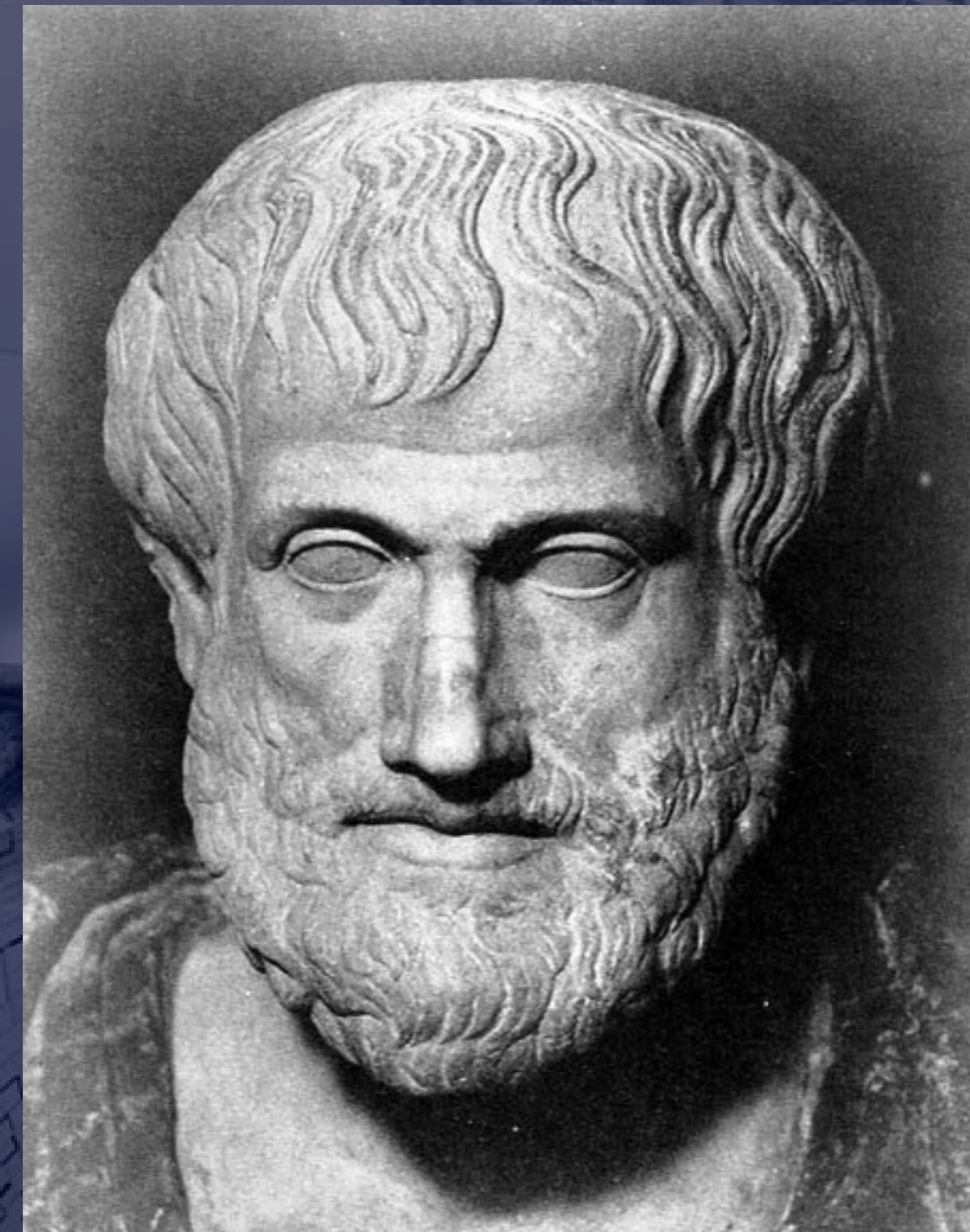


Cognition

Body vs Mind



Anaxagoras



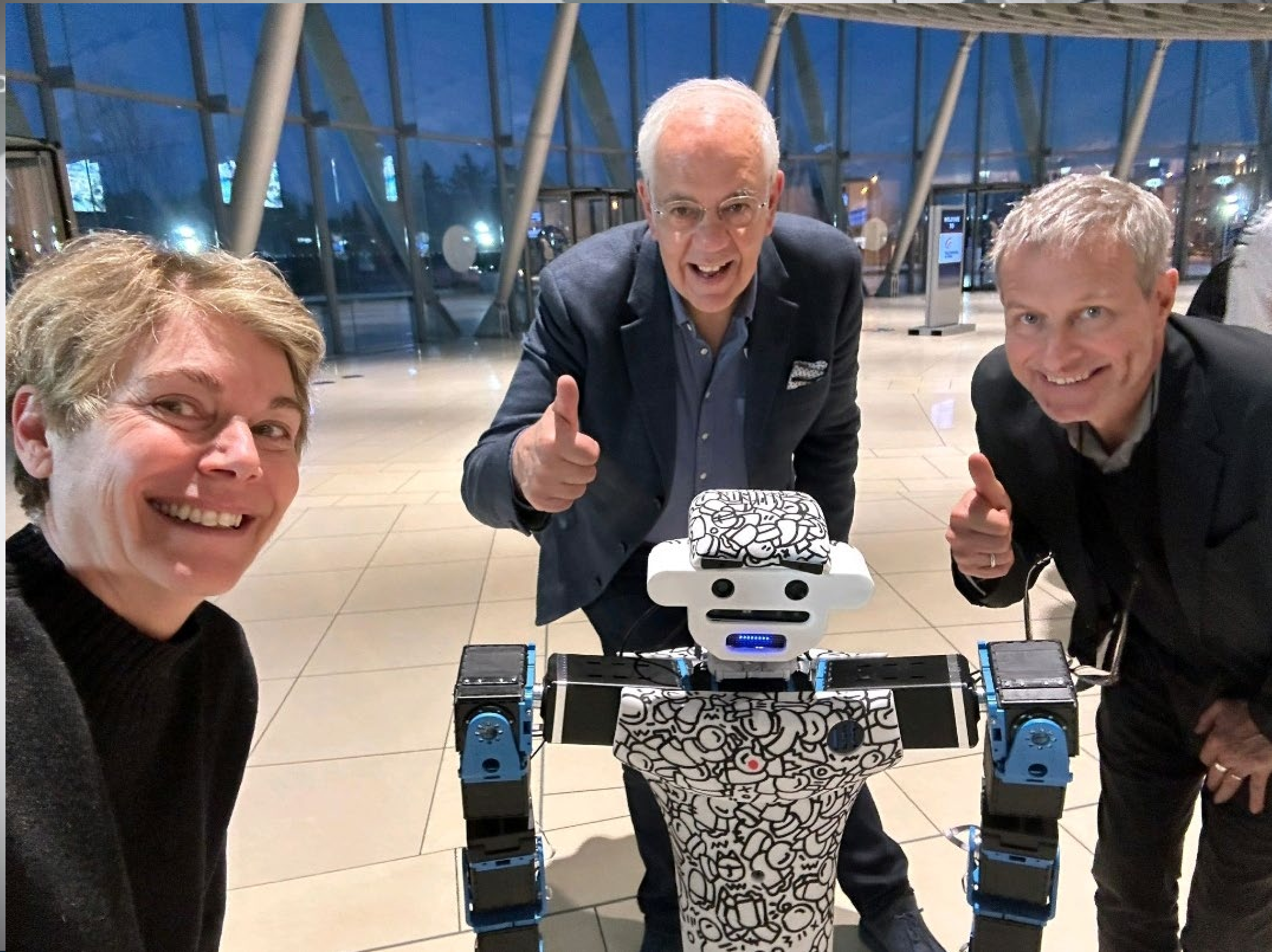
Aristotle



Embodiment

Fleshing out AI

Rai 3 HD



Physical Human–Robot Interaction

*... from Information & Communication Technology (ICT)
to InterAction Technology (IAT)*



Nature Italy, Antonio Bicchi & Bruno Siciliano (2021)

Industry 4.0

In the
new le

1st

Mech
water
stea

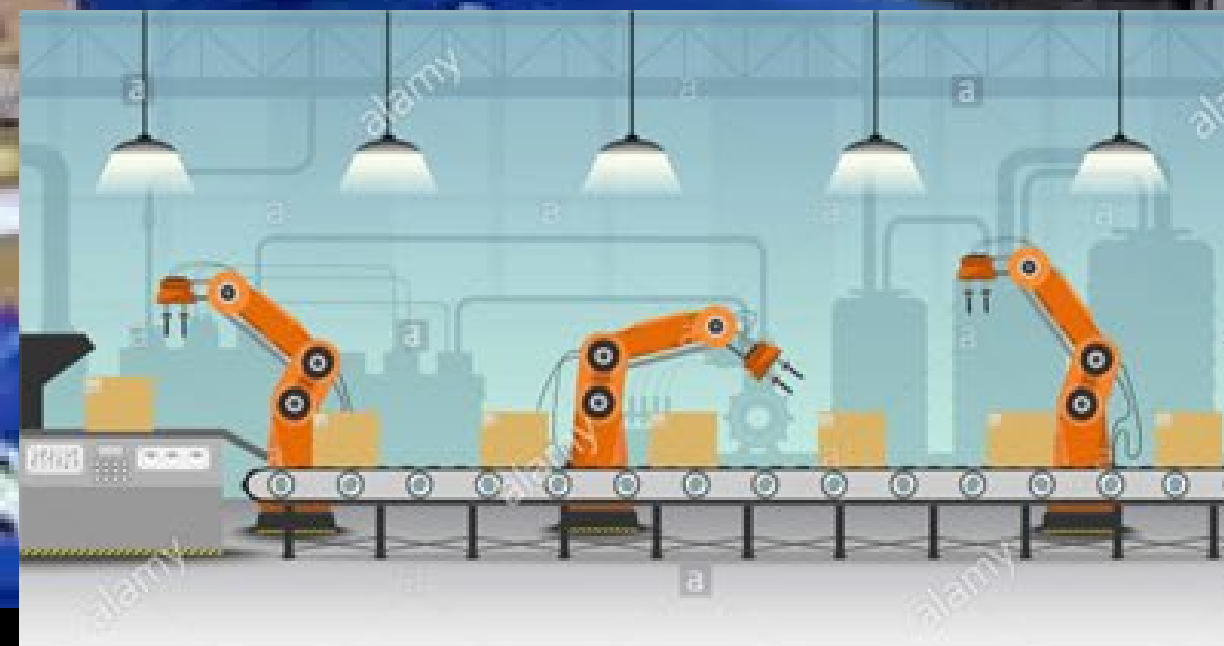


n-Robot
eration
robot)

CRAFT ERA

MASS PRODUCTION ERA

MASS CUSTOMIZATION ERA



Cobot

Collaborative robot (Cobot)

- ✓ *Can be used safely in a space shared with humans*
- ✓ *Special mechanical characteristics, extroceptive sensors, advanced control system*
- ✓ *Intuitive programming and communication interface*
- ✓ *Fast setup, commissioning, and reconfiguration*
- ✓ *Low costs (<20k) and suitable for Small and Medium Enterprises (SMEs)*

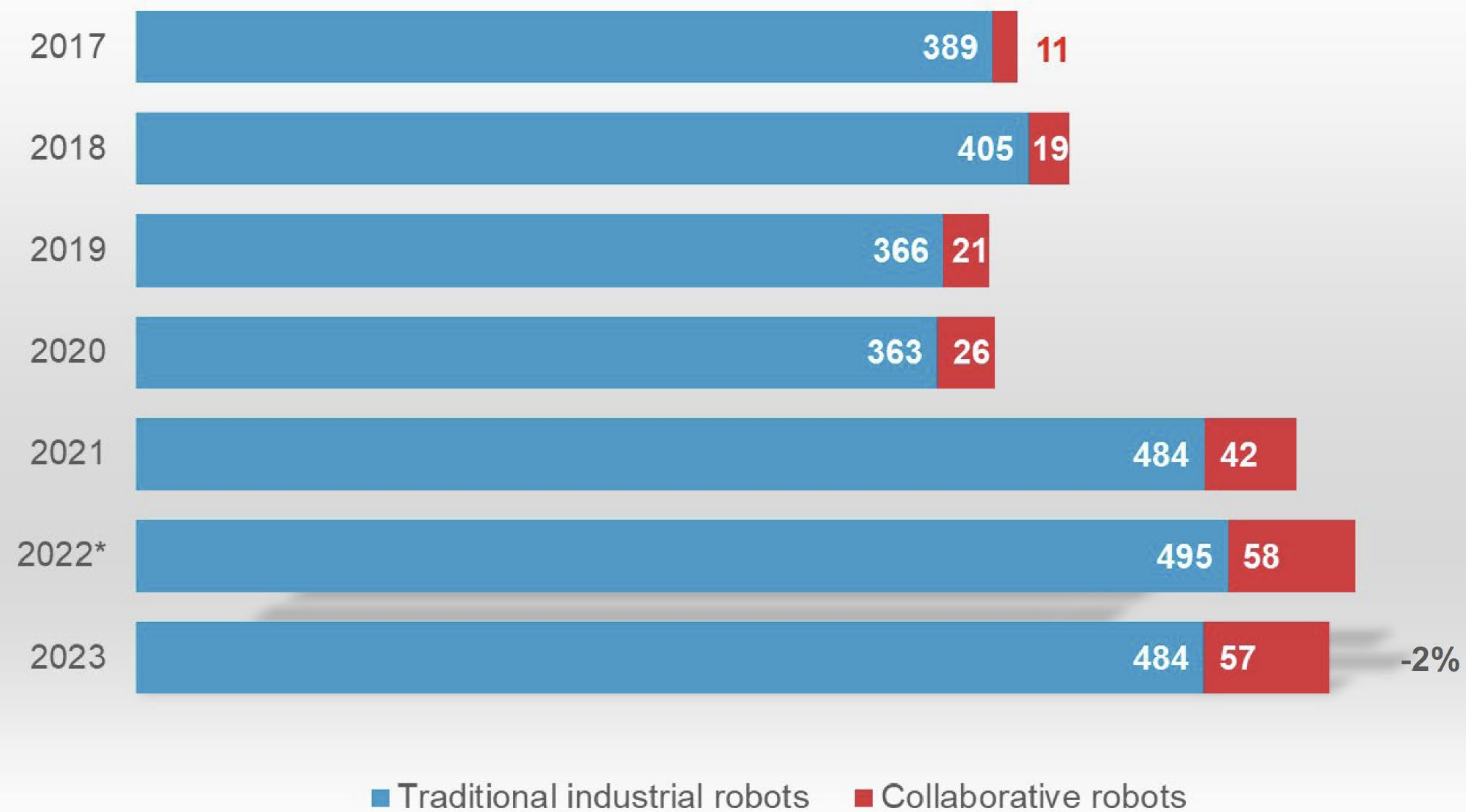


Collaborative vs Traditional Industrial Robots

Collaborative robot installations declining for the first time

Collaborative and traditional industrial robots

'000 units

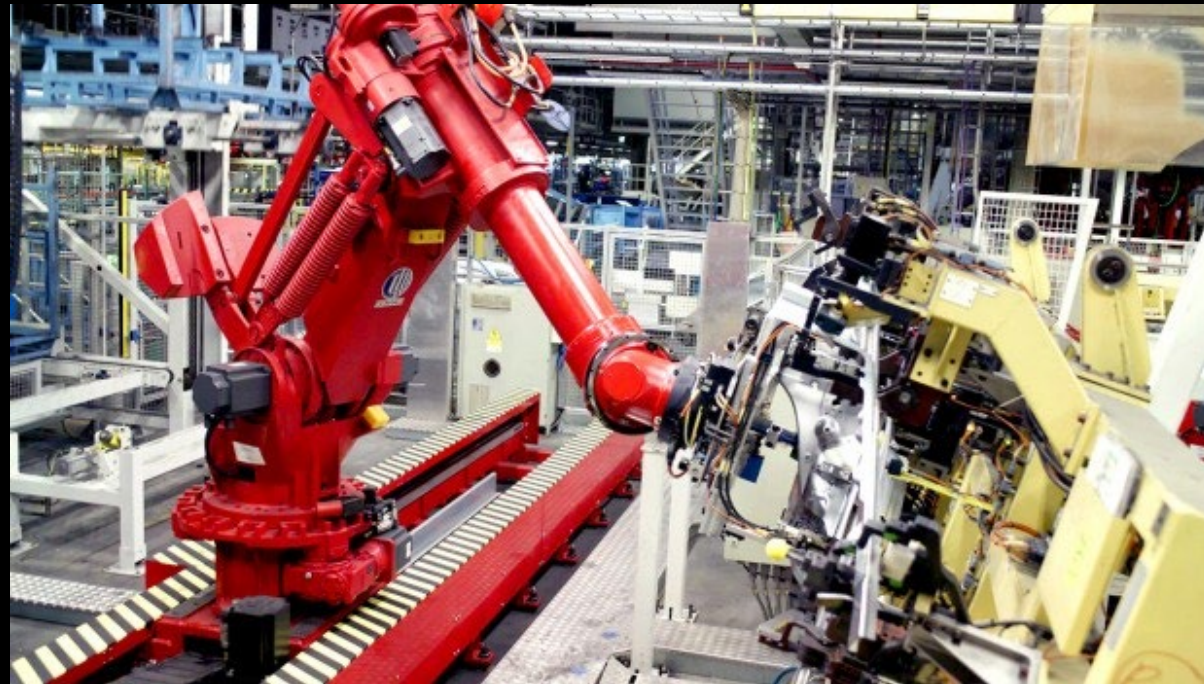


*revised

Source: International Federation of Robotics

From Factories to Our Homes

LEVEL OF AUTONOMY



Automatic machines executing programmed tasks with high levels of accuracy, speed and repeatability in a perfectly known environment



Machines equipped with sensors (vision, distance, force, ...) for perceiving the external environment and with decision-making capabilities



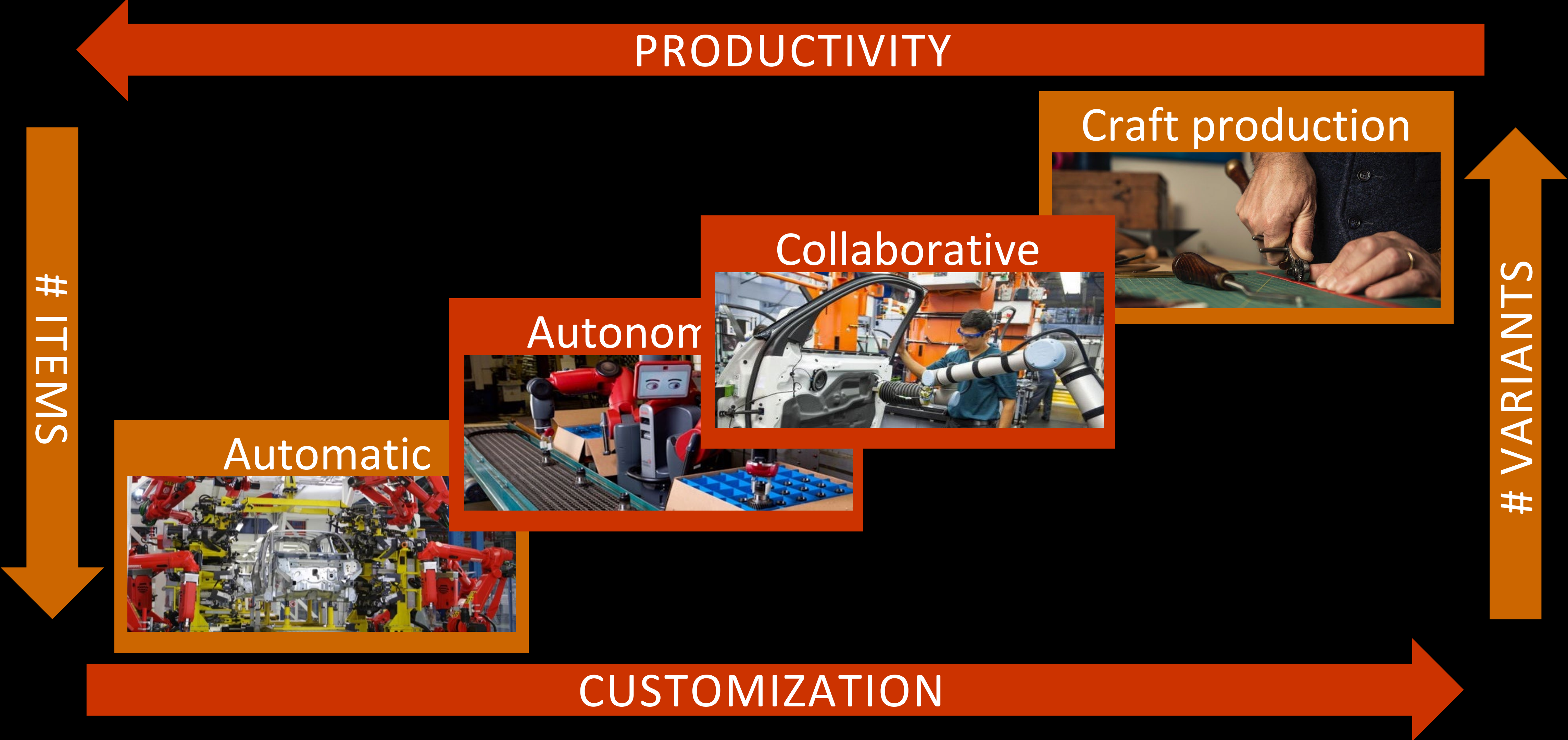
Machines confined in fenced areas, designed to handle the dull, dirty and dangerous tasks in place of human workers



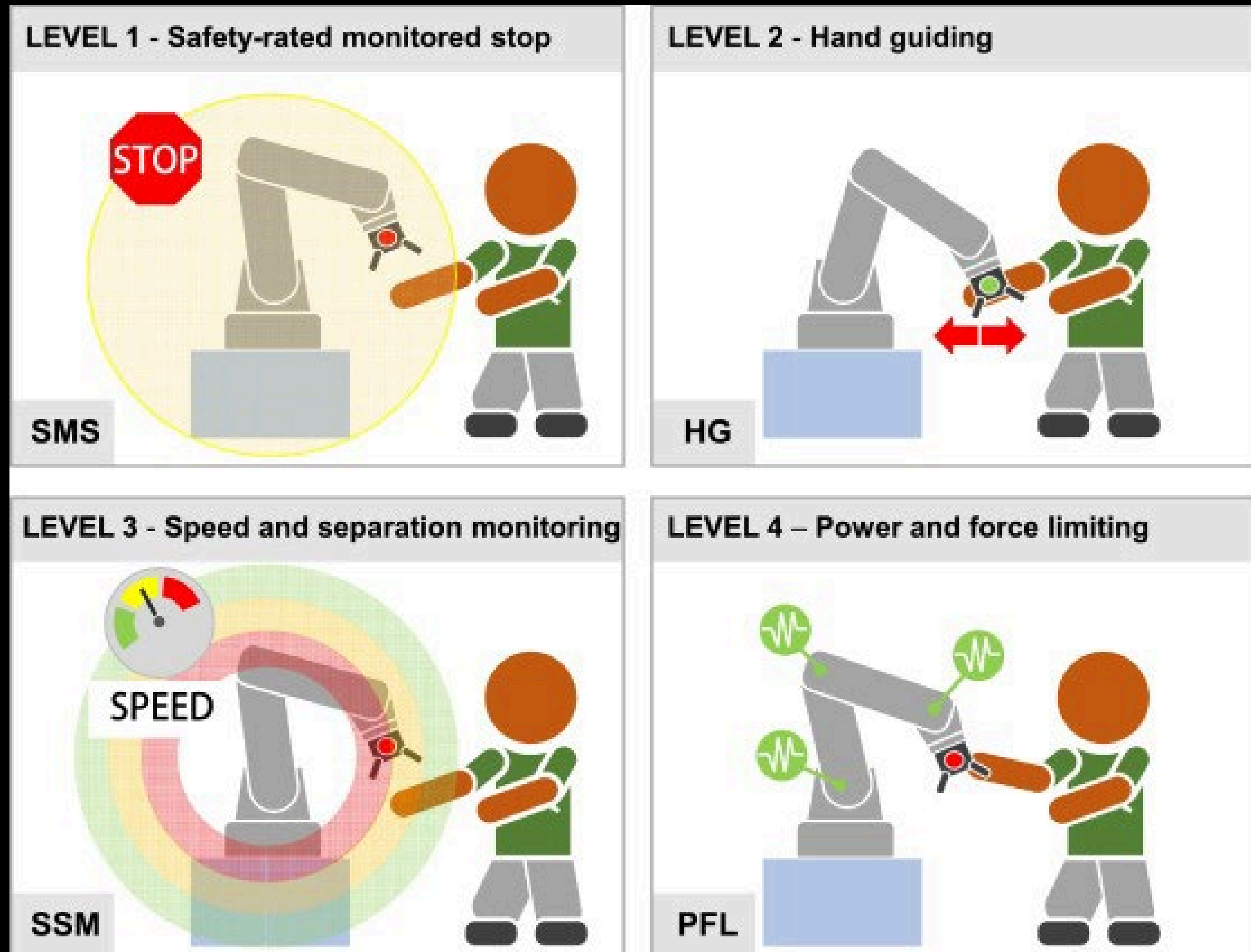
Lightweight machines able to work safely in the same workspace or even physically collaborate with humans

SAFETY AND COLLABORATION CAPABILITY

From Mass Production Towards Mass Customization



Safety



4 levels of collaborative operations

Safety standards

- ✓ *ISO 10298-1/2 --> safety requirements and guidelines for robots in industrial environments*
- ✓ *ISO/TS 15066 --> technical specifications for collaborative robot system safety*

Cobots Hardware & Software

Mechanics

- ✓ *Lightweight*
- ✓ *Redundant/double arms*
- ✓ *Soft covers, no edges*
- ✓ *Elastic joints*

Sensors

- ✓ *Joint torques*
- ✓ *Force/torque at the end-effector*
- ✓ *3D vision*
- ✓ *Sensitive skin*

Control

- ✓ *Compliant, collision detection, collision avoidance*
- ✓ *Coexistence / cooperation / collaboration*



Programming Interfaces

Traditional programming modalities

- ✓ *On-line lead-through (teach pendant)*
- ✓ *Off-line*

Intuitive programming interfaces

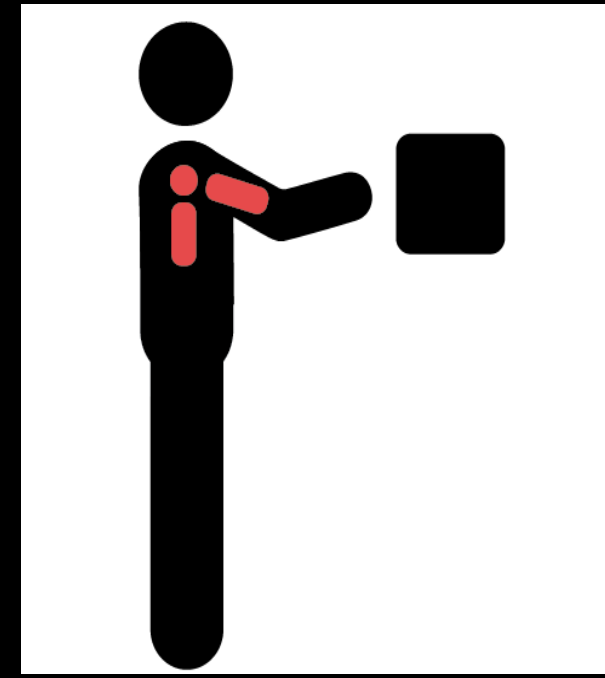
- ✓ *On-line walk-through (manual guidance)*
- ✓ *Training by demonstration*
- ✓ *Virtual and augmented reality*
- ✓ *Multimodal communication (gestures, voice, touch)*



Robots & Humans Working as One

Wearable robots: Exoskeletons

- ✓ *Composed by a frame fitted with (motorised) muscles supporting parts of the human body*
- ✓ *Allow multiplying the strength of its user's or redistributing the weight*
- ✓ *Enable workers to carry out a variety of industrial tasks*
- ✓ *Protect workers from the heavy physical workload, repetitive movements and non-ergonomic postures*



arm support



back support



legs support

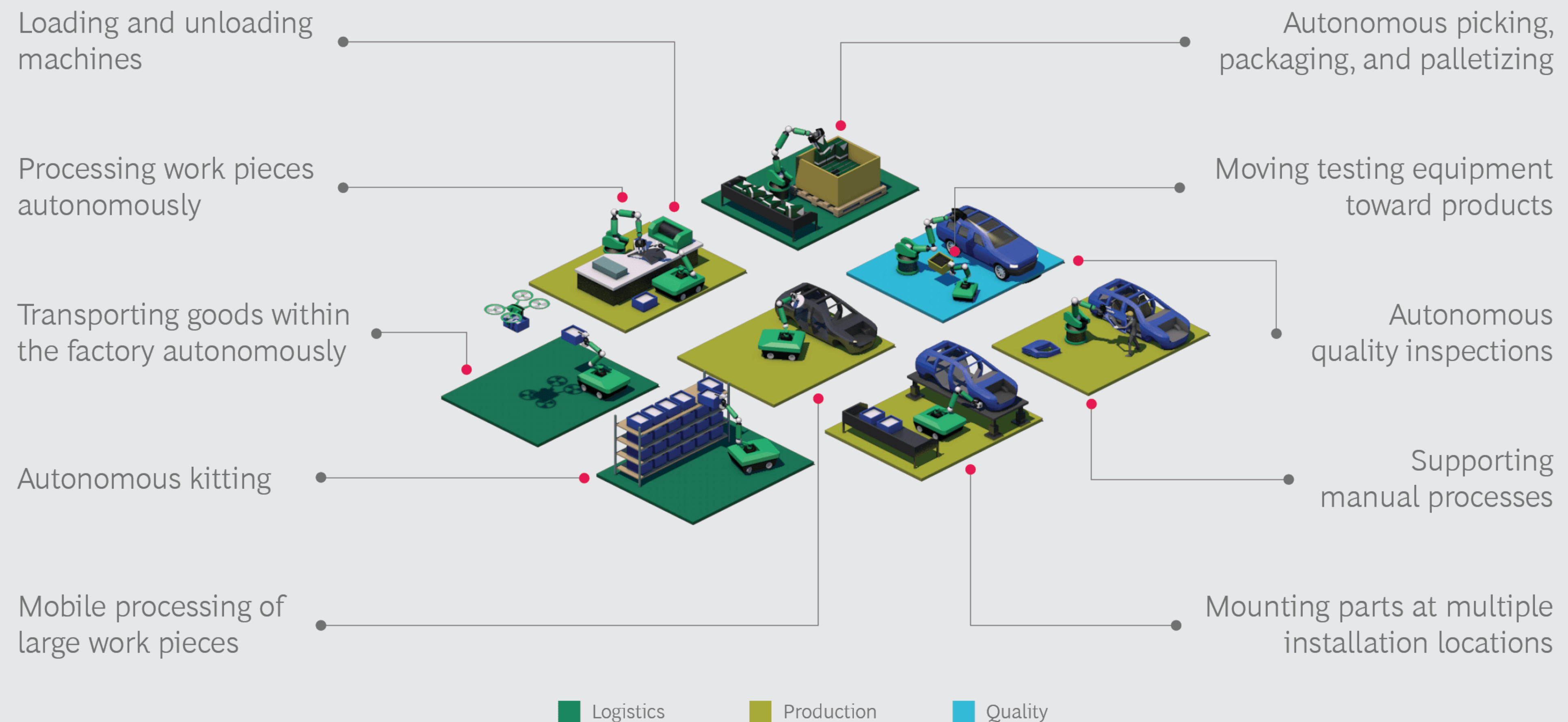


tool holding



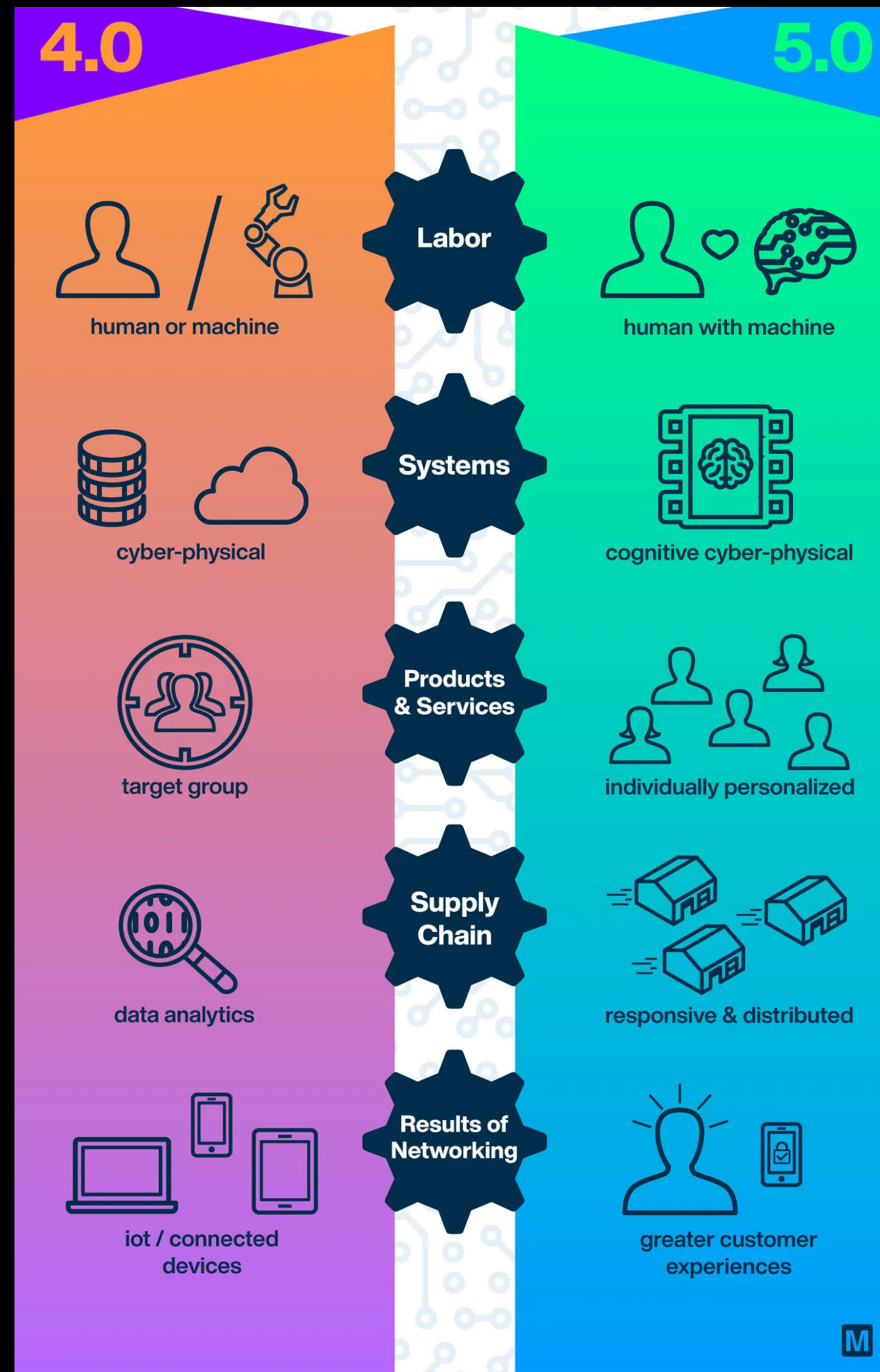
The Factory of the Future

EXHIBIT 3 | Advanced Robotics Has Many Applications in the Factory of the Future



Sources: BCG Global Advanced Robotics Survey, January–February 2019; BCG analysis.

Towards Industry 5.0

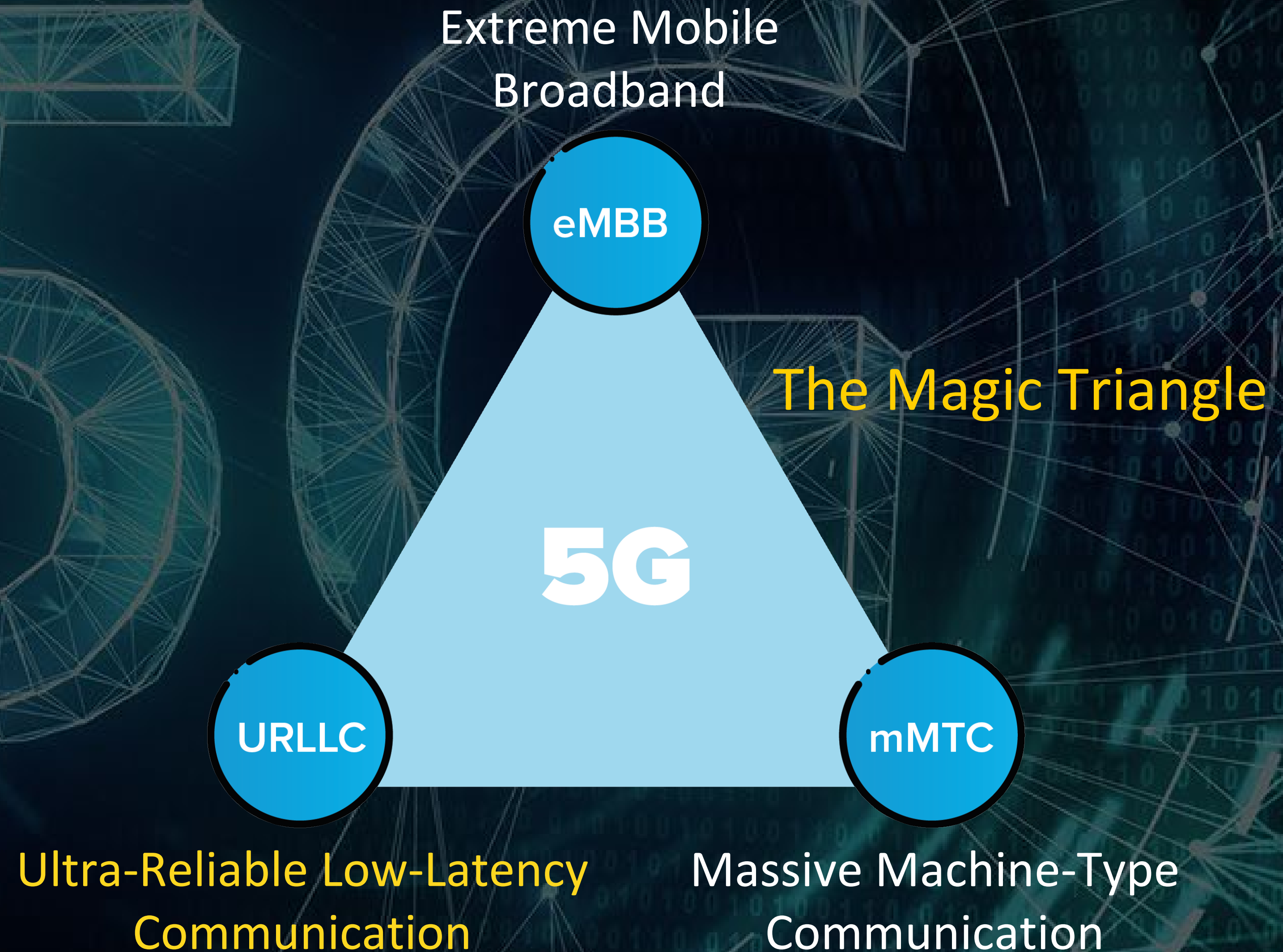


Fifth Generation of Wireless Technology

*5G will pave the way for a
new generation of robots*

*The vast computing and data
storage resources of the **cloud**
is exploited*

*Robots can be controlled
dynamically in real time and be
connected to people and machines
locally and globally*



The Invention Age

*5G-enabled **tactile Internet** — Ultra-reliable and ultra-responsive network connectivity for real-time control and physical tactile experience remotely through suitable haptical equipment*

*... from Internet of Things (IoT)
to **Internet of Skills (IoS)***

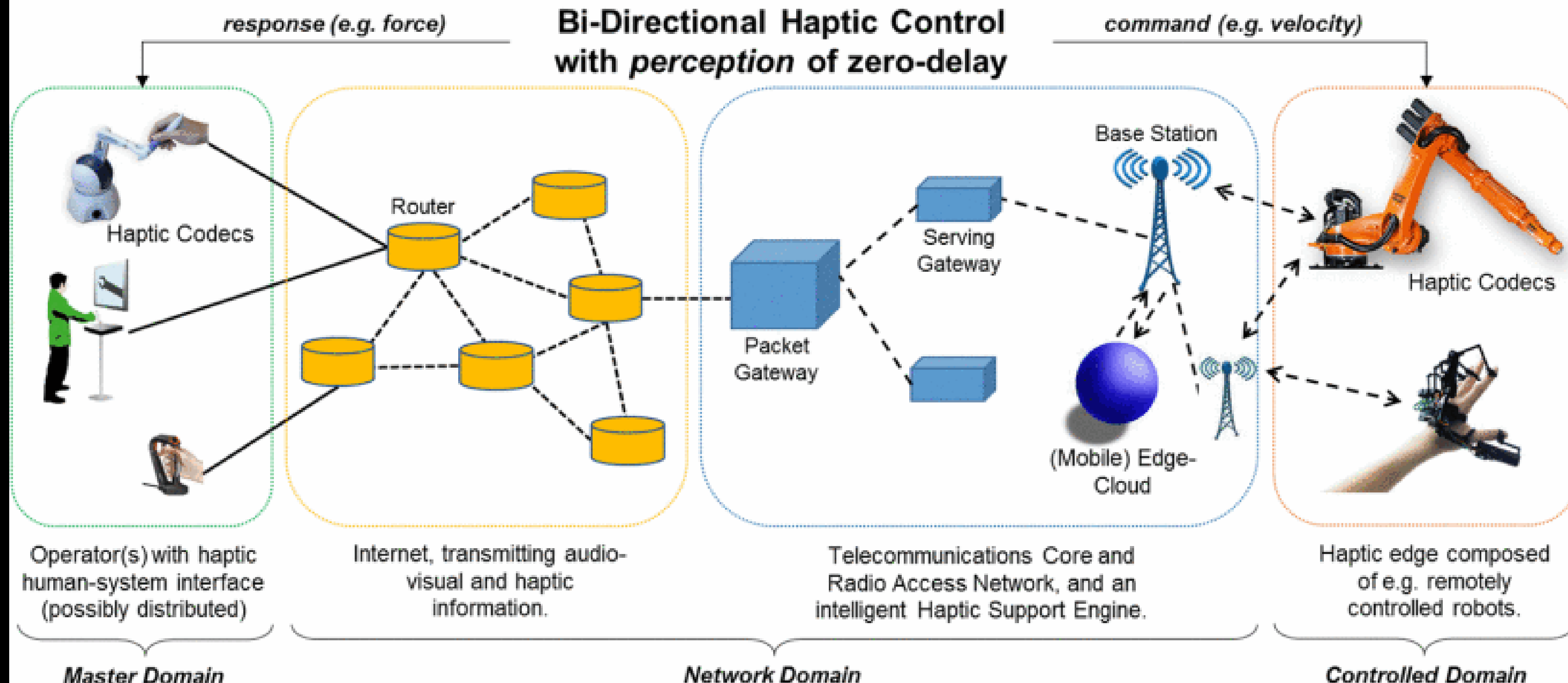
Towards a Digital & Physical Twin — The Phygital

1) Ultra-Fast Networks (Tactile Internet)

2) Haptic Encoders (both kinestaethic & tactile)

3) Edge Artificial Intelligence (to beat light-limit)

Core Technology Enablers of
the “Internet of Skills”



Pillars of Next Generation Robotics



The Factory, Reimagined



NDT, Autonomous



Healthcare, Revolutionized



Robots on the Field, Unthetered



Robots as Job Killers?

*Identify which forms of protection are morally right to put in place to protect workers who will face **technological unemployment** in the short term, but also to deal with possible and unprecedented effects in the long term, if the impact of intelligent machines actually constitutes a **singularity in the history of automation***

[*https://willrobotstakemyjob.com/*](https://willrobotstakemyjob.com/)

Robots as Green Tools?



*Restoration and protection of our **ecosystem** towards the development of a new generation of technologies capable of coexisting harmoniously with the environment*

Reduction of Carbon Footprint

*Modern robots are energy-efficient, thus directly
reducing energy consumption of production*

*Through higher precision, they also produce fewer
rejections and substandard goods, which has a positive
impact on **input/output resources***

*Robots help in the cost-efficient production of
renewable energy equipment, such as photovoltaics or
hydrogen fuel cells*



<https://ifr.org>

Decarbonizing the Built World

*Gecko Robotics, a company at the forefront of using Robotics and AI-powered software to improve the health of the physical world, partnered with Rho Impact, a leading impact analytics firm, to understand the **environmental impact of digitizing critical infrastructures***

*The research findings emphasize the importance of **leveraging robotics, sensors, and digitization** to unlock new industrial efficiencies, reduce waste, and minimize the carbon footprint of the manufacturing sector*

The logo for Gecko Robotics, featuring the word "gecko" in a bold, lowercase, sans-serif font. The logo is black and is set against a white rectangular background.

January 2024

The Impact of Robotics and AI

*Better use of Robotics and AI could result in an impressive **reduction of 853 million metric tons (MMT) annually, equivalent to 18% of U.S. CO2 emissions (CO2e)**, or eliminating more than half (64%) of the gas-powered vehicles on the road*

Through robotics-enabled digitization, the following reductions could be achieved by 2030:

- ✓ *Oil & Gas Pipelines: **556 MMT CO2e***
- ✓ *Baseload Power Plant Reliability: **230 MMT CO2e***
- ✓ *Pulp & Paper Manufacturing: **46 MMT CO2e***
- ✓ *Maritime Transportation: **11 MMT CO2e***
- ✓ *Bridge Inspection & Maintenance: **10 MMT CO2e***

Reduce Fugitive Emissions from Oil & Gas Pipelines

*Fugitive emissions are the unintended release or **leakage of gases**, including greenhouse gases, from equipment including piping, tanks, valves, and more*

*Early detection of corrosion can lead to a **556 MMT CO₂e** per year reduction in fugitive emissions from failed pipelines*

Diminish Forced Outages

*A primary culprit for forced outages is **boiler tube failures**, which increase as industrial assets age*

*Digitization of boiler tubes at energy generation sites could lead to a potential **230 MMT CO₂e** reduction per year, all by keeping more efficient baseload generation online and inefficient backup generation offline*



Optimize Asset Efficiency in Manufacturing

Corrosion is a major problem in the manufacturing industry, causing billions of dollars in damage each year

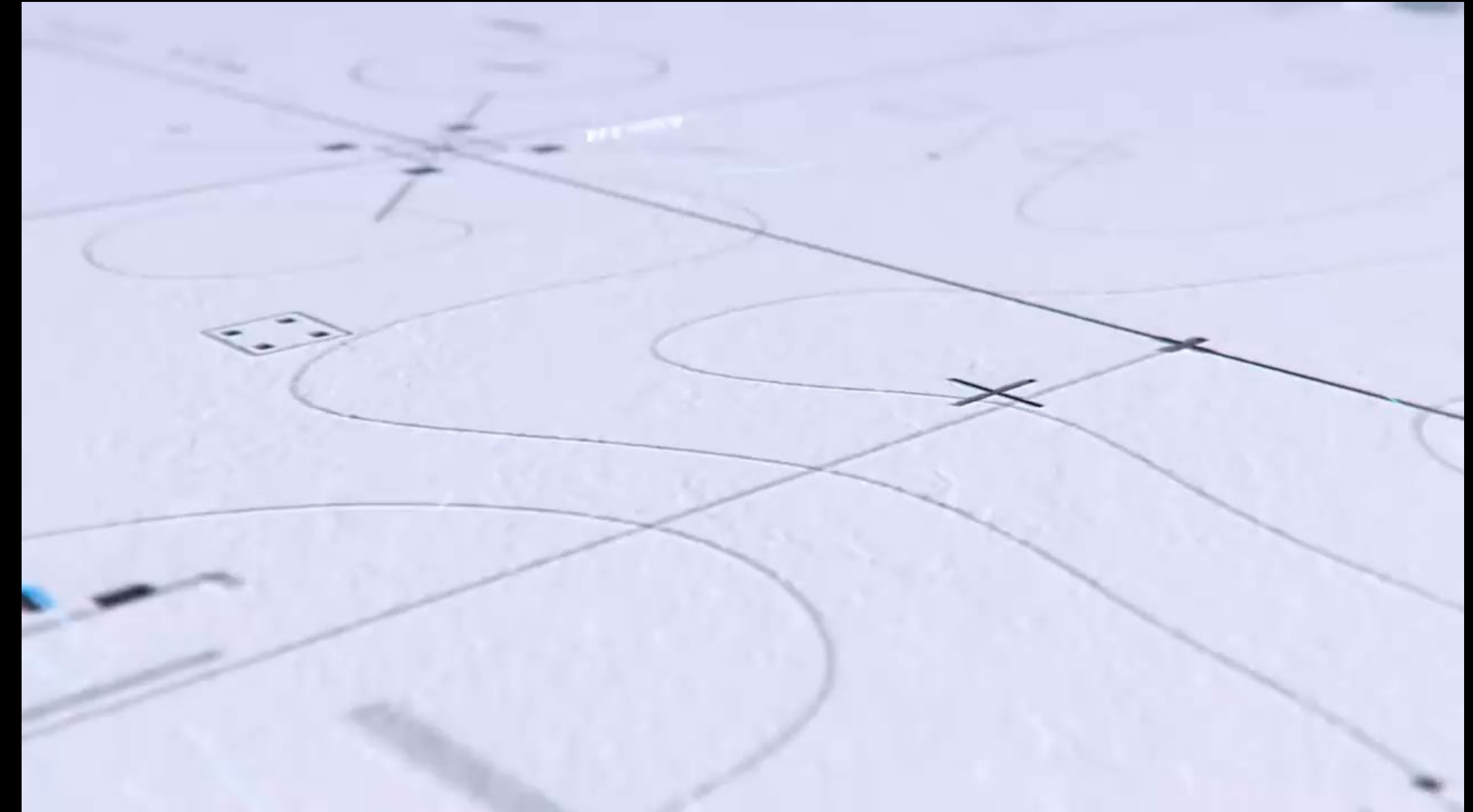
Digitizing key physical assets in the pulp & paper industry could result in an annual reduction of 46 MMT CO₂e



Increase Maritime Vessel Availability

*Load optimization and leak detection present significant opportunities for addressing greenhouse **gas emissions** in maritime shipping*

*Digitization could avoid **11 MMT CO₂e** per year by improving availability of the largest, most efficient shipping vessels*



Decrease Traffic Emissions Through Bridge Digitization

*Transportation agencies advise deploying robots for **inspection and maintenance***

*Inspection digitization ensures better data on bridges, fewer closures, and effective maintenance, potentially reducing traffic-related emissions by **10 MMT CO₂e** yearly*

Towards Climate Neutral, Circular & Digitized Industry

- ✓ Technologies for *continuous learning* and the integration of perception and actuation with natural and artificial intelligence
- ✓ Technologies to improve *intuitiveness, usability and ergonomics of human–robot interfaces*, allowing the effective use of robots by people without specific training
- ✓ Technologies using new materials, smart sensors and actuators, control architectures to ensure *stability and safety*
- ✓ Technologies for *dexterous manipulation and locomotion* in airborne, aquatic, underground environments and on terrains of varied and uneven nature
- ✓ Technologies for *autonomous navigation* to achieve sustainable mobility of self-driving vehicles in urban areas and smart traffic control in extra-urban areas
- ✓ Technologies to improve *energy autonomy and resilience* to imperfect communications in situations realistically encountered in application scenarios
- ✓ Technologies to reduce the *ecological trace of robotic systems* by developing new forms of energy and environmentally friendly materials

Looking Ahead



*The use of **AI-empowered robotics** aimed at **sustainability** can help us fight climate change and lead us towards a better future*

Levels of Autonomy

L0

L1

L2

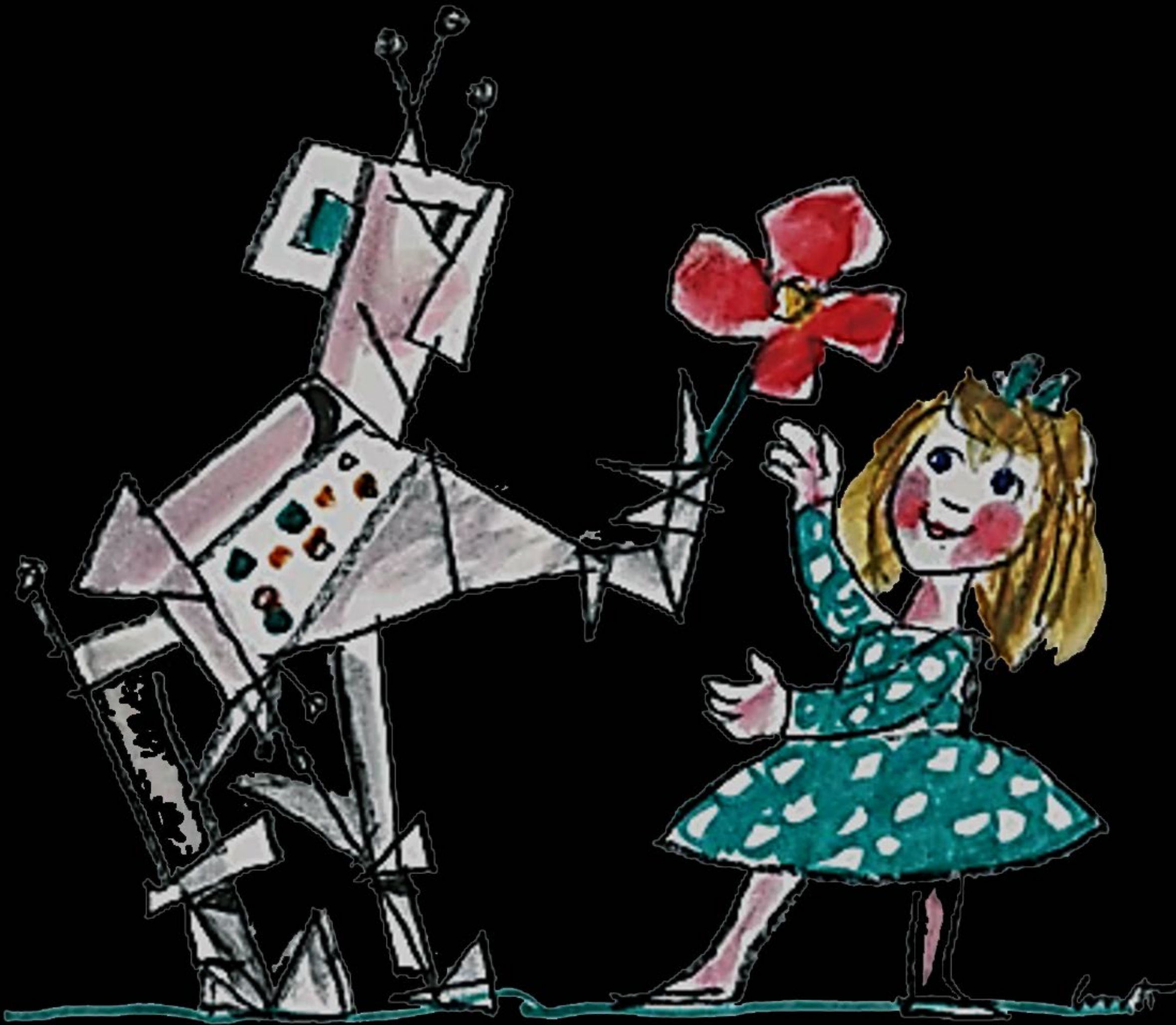
L3

L4

L5

 <p>Operator performs all tasks including monitoring, generating performance options, selecting the option to perform (decision-making), and executing the decision made.</p>	 <p>Operator maintains continuous control of the system while the robot provides certain assistance.</p>	 <p>Operator maintains discrete control of the system, and the robot can perform certain operator-initiated tasks automatically.</p>	 <p>Operator selects and approves a surgical plan, and the robot performs the procedure automatically but with close surgical oversight by human.</p>	 <p>Robot is able to make decisions but under the supervision of a qualified operator.</p>	 <p>No human needs to be in the loop, and the robot can perform an entire surgery.</p>
No autonomy	Robot assistance	Task autonomy	Conditional autonomy	High autonomy	Full automation

Roboethics



Ethical, legal, societal and economic (ELSE) issues for design, construction and use of robots

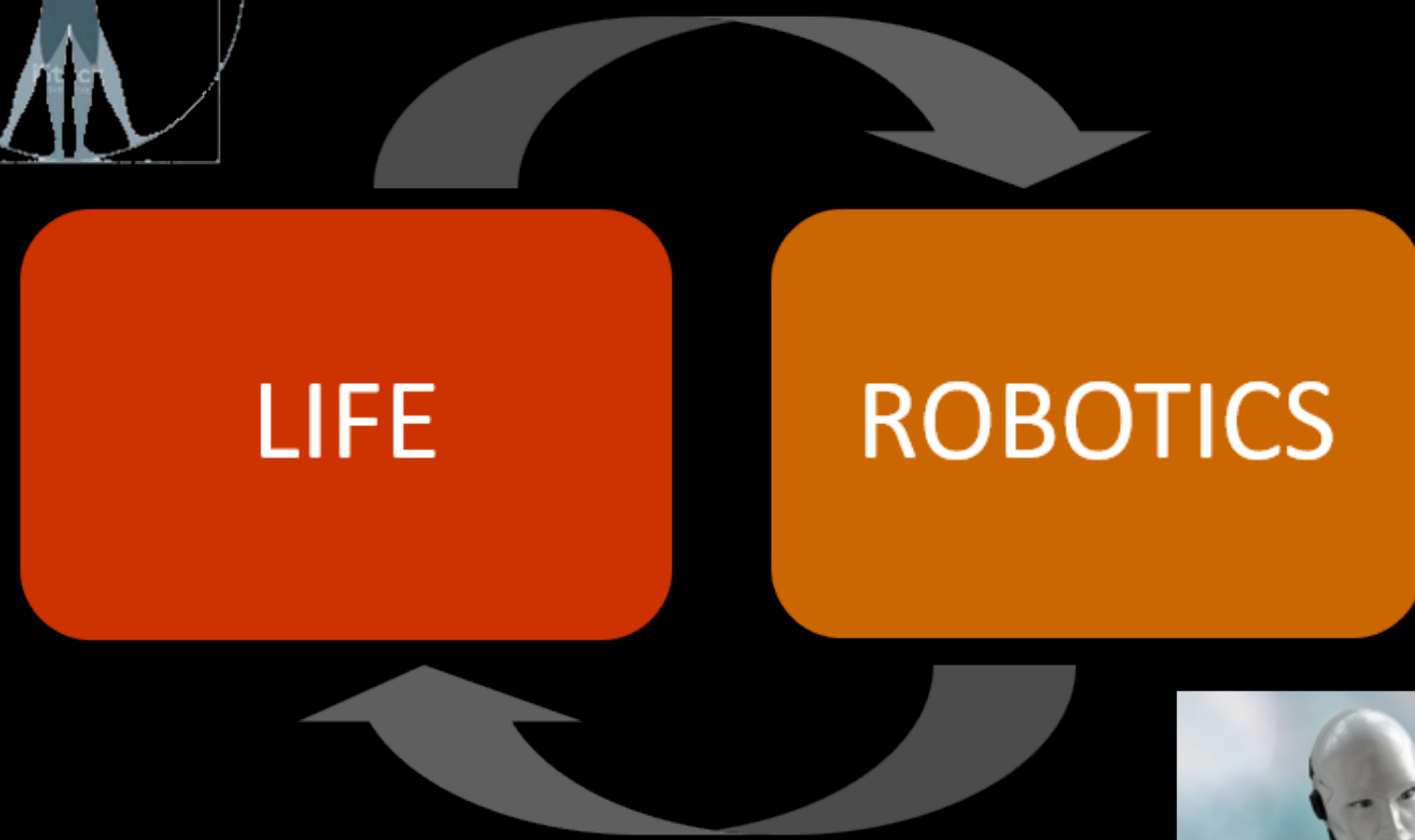
Cohabitation of humans with robots

Fundamental human rights and the moral duties corresponding to them

Robots & Humans

«La scienza m'interessa proprio nel mio sforzo per uscire da una conoscenza antropomorfa; ma allo stesso tempo sono convinto che la nostra immaginazione non possa essere che antropomorfa»

Italo Calvino



A future where **robots** are more **social** than solitary (**robot companion**)

Robots will **enhance human work and life** rather than replace us in our homes, hospitals, factories, farms and freeways



Miroka robot by Enchanted Tools

Biological inspiration in design and learning from nature (**biomimicry** and **bionics**)

Challenges and Outreach

New emerging areas

Biomechanics

Haptics

Neurosciences

Machine learning

Virtual prototyping

Animation

Surgery

Sensor networks

...

New communities of users and developers

*Most striking advances happening at **intersection** of disciplines*

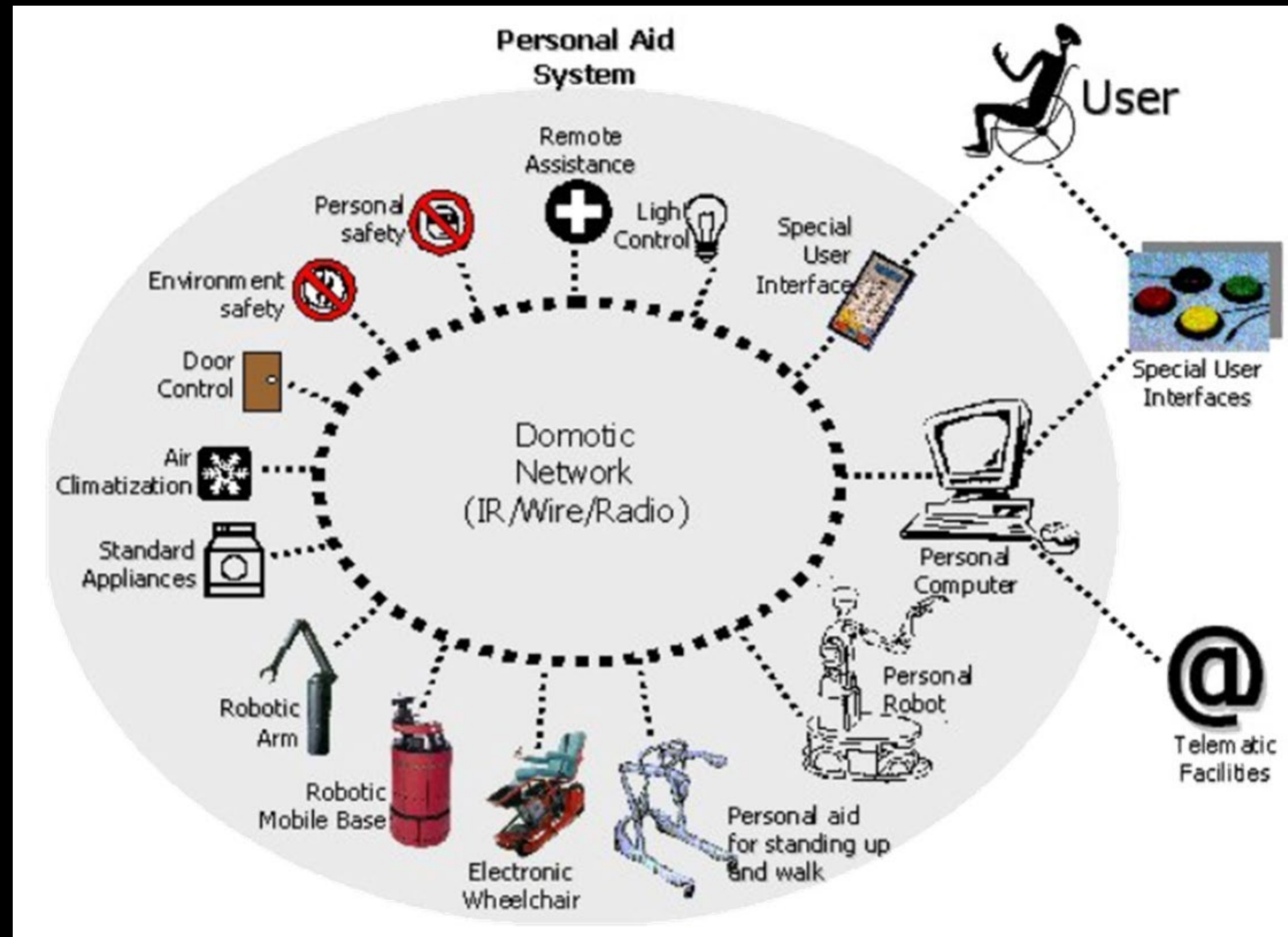
Future developments and expected growth of field largely depending on scientific cooperation

Robotics technology becoming ubiquitous, distributed and embedded into smart environments

Ubiquity & Pervasivity

Integration of robotics, telematics & domotics

Smart environments



Towards a Technological Humanism

«In effetti l'uomo si dimostra essere cosa divina perché dove la natura finisce di produrre le sue spetie l'uomo quivi comincia colle cose naturali a fare coll'aiutorio d'essa natura infinite spetie»

Leonardo da Vinci



*«A distanza di 100 anni dall'ingresso della parola robot nel nostro lessico, la sfida e allo stesso tempo l'opportunità che il mondo della ricerca dovrà rappresentare è relativa a futuri scenari in cui la robotica diventerà un mezzo interattivo per contribuire a migliorare le condizioni di vita. In questa visione, la rivoluzione dei robot potrà aiutarci a riaffermare **la caratteristica meno artificiale del nostro mondo: la nostra umanità**»*

Atlante Treccani, Bruno Siciliano (2020)

Robotics @ PRISMA Lab

- ✓ 3 Full Profs + 3 Associate Profs + 4 Assistant Profs
- ✓ 19 Research assistants + 9 PhDs + 9 Support staff
- ✓ 25 EU projects in last 18 years (incl. 2 ERC Grants)
- ✓ Partnership w/ 180 foreign institutions & companies
- ✓ 10 Patents + 35 Awards in last 20 years

- ✓ Research areas

- ❖ Aerial Robotics
- ❖ AI & Cognitive Robotics
- ❖ Dynamic Manipulation & Legged Robotics
- ❖ Human–Robot Interaction
- ❖ Industrial Robotics
- ❖ Medical Robotics

- ✓ Start-ups

- ❖ Neabotics
- ❖ Herobots



Neabotics
— Service Robotics Solutions —

HEROBOTS



<https://prisma.dieti.unina.it>



<https://www.icaros.unina.it>

Our EU Research Projects



Manipulation & Interaction



Aerial Robotics



Networking & Technology Transfer



Robotics Goes PRISMA

The Textbook

Advanced Textbooks in Control and Signal Processing

Bruno Siciliano · Luigi Villani · Giuseppe Oriolo · Alessandro De Luca

Foundations of Robotics

This textbook explores the foundational principles of robotics, focusing on its core pillars: modeling, planning, and control. Balancing mathematical rigor and physical intuition, a coherent formalism is established and used throughout the book. At the same time, technological challenges and application-driven solutions are given appropriate consideration.

With a general perspective that includes both fixed-base manipulators and mobile robots, the book presents the essential tools for understanding key topics such as kinematics, statics, trajectory planning, dynamics, and motion control. In its second part, more advanced topics are addressed, including wheeled robots, visual control, motion planning, force control, flexible robots and cooperative manipulation.

To support the learning process, appendices provide essential background material on linear algebra, mechanics, differential geometry, control theory, and graph search algorithms. The practical implementation of the methodologies is emphasized throughout, with over 50 worked examples and case studies, many supported by simulations. Additionally, more than 190 end-of-chapter problems are included, with a Solutions Manual available for instructors adopting the book for their courses.

Foundations of Robotics is designed for use as a textbook in both undergraduate and graduate robotics courses within engineering programs, making it an ideal resource for students and educators alike.

Siciliano · Villani · Oriolo · De Luca



Foundations of Robotics

ISBN 978-3-031-85522-1

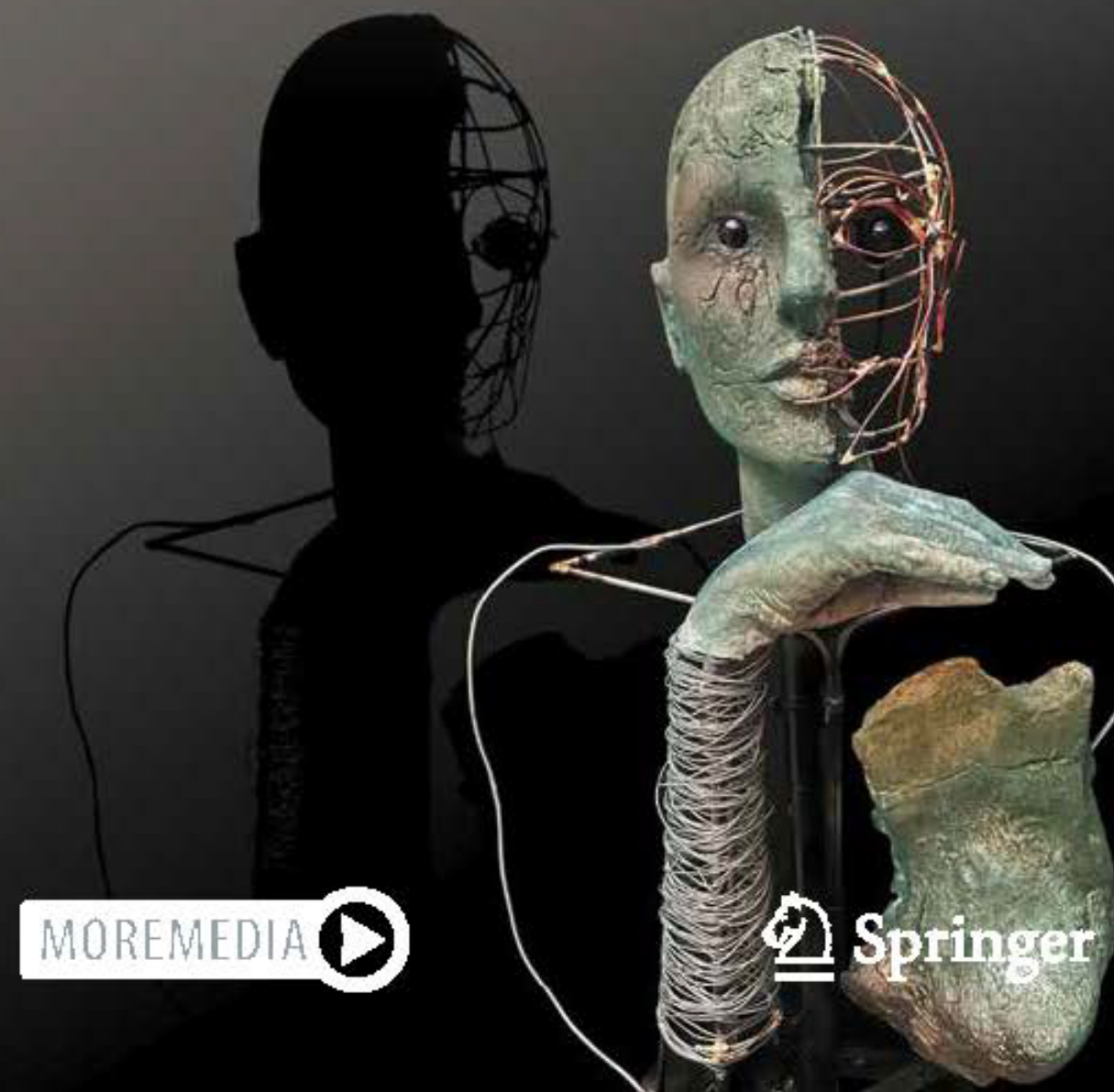


springer.com

Advanced Textbooks in Control and Signal Processing

Bruno Siciliano · Luigi Villani
Giuseppe Oriolo · Alessandro De Luca

Foundations of Robotics

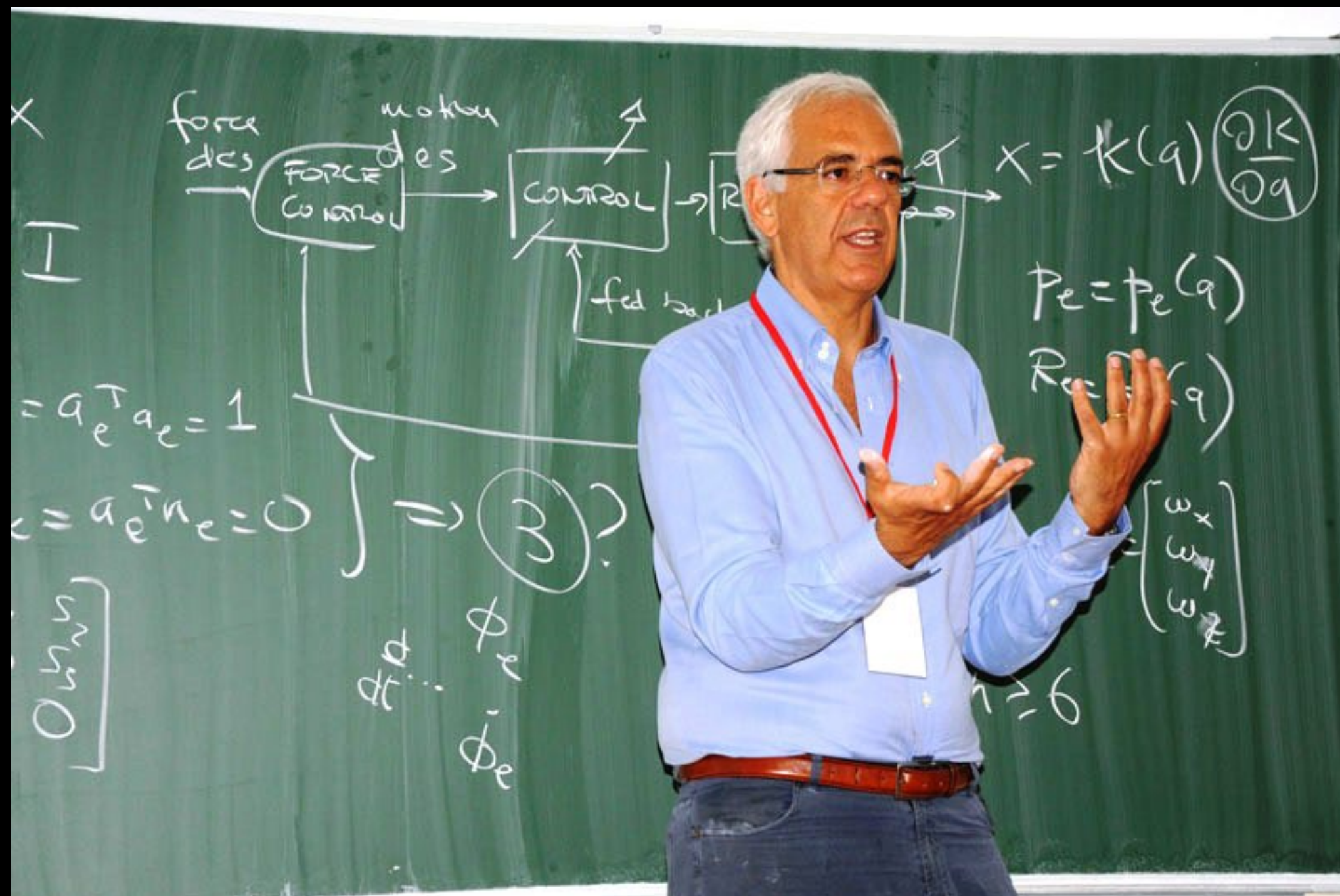


MOREMEDIA



Springer

A New Learning & Teaching Environment: The MOOCs



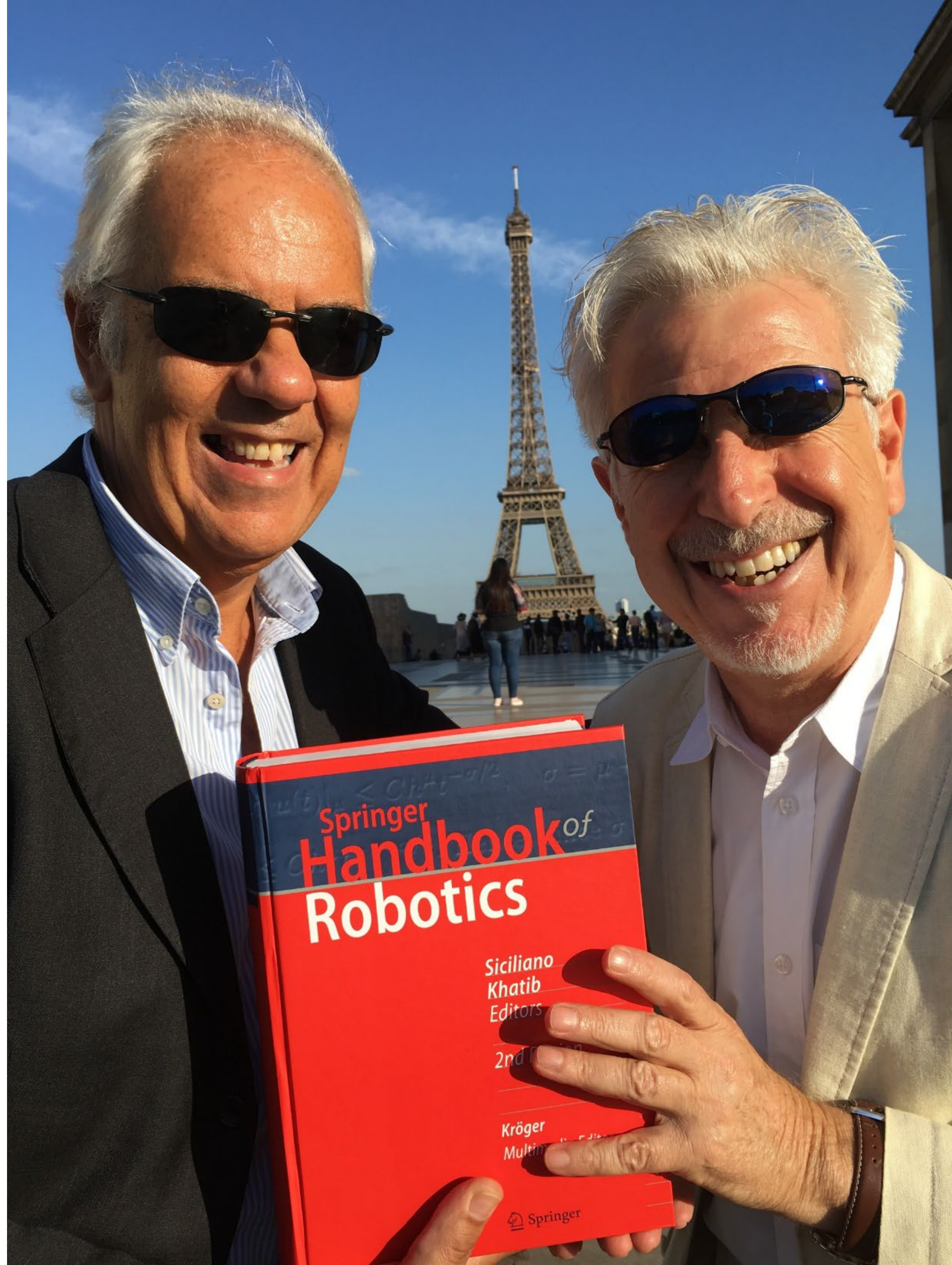
- ✓ **Teaching** is pure adrenaline
- ✓ Robotics is highly interdisciplinary
- ✓ Generations of students **learning** robotics from my textbook

After 25 years of lectures ex cathedra ...

- ✓ Speaking towards the **infinite**
- ✓ No need to provide complementary material, as that is available on the net
- ✓ My video lectures are the **glue** to the technical contents of the slides



✓ **Available on edX**



Bruno Siciliano Editor
Robotics Goes MOOC
Knowledge

The Robotics Goes MOOC project is organized in four volumes devoted to the paradigms of robotics **knowledge**, **design**, **interaction**, **impact**.

The robot "concept" was clearly established by those many creative historical realizations, such as those recalled above. Nonetheless, the emergence of the "physical" robot had to await the advent of its underlying technologies of mechanics, controls, computers, electronics and sensors — in one word, mechatronics — during the course of the twentieth century. As always new designs motivate new research and discoveries which, in turn, lead to enhanced solutions and thus to novel concepts. This virtuous circle over time produced that **knowledge** and understanding which gave birth to the field of Robotics, properly referred to as the science and technology of robots.

To make robots and intelligent machines useful to humans it is necessary to have a broad and tight interaction between Robotics and AI. Sophisticated mathematical models are needed that enable the robot from a physical point of view, as well as intelligent algorithms capable of correlating all the information coming from the use of technologically advanced sensors with the data available from experience. It is expected that the synergy of model-based techniques with data-driven approaches will contribute to increasing the level of autonomy of robots and intelligent machines in the near future.

The first book of the Robotics Goes MOOC project starts with the journey of robotics in the introductory chapter by Khanh, who has pioneered our field of robotics and has ferried it to the third millennium. Sensing is crucial for the development of intelligent and autonomous robots, as covered in Chapter 2 by Nüchter et al. Model-based control is dealt with in Chapter 3 by Kroeger et al. along with motion planning, as well as in Chapter 4 by Villani and Chapter 5 by Chaumette to handle force and visual feedback, respectively, when interacting with the environment. Resorting to AI techniques is the focus of the last part of the book, namely, Chapter 6 by Peters et al. on learning, Chapter 7 by Beetz et al. on knowledge representation and reasoning, and Chapter 8 by Burgard et al. on graph-based SLAM.

The content published here is linked to the MOOC course Robotics & Robots available at <https://www.federica.eu/federica-pro/robotics-and-robots> specifically created by Federica Web Learning, the Center for Innovation, Experimentation and Dissemination of Multimedia Education of University of Naples Federico II. You can access the related content via our app: download the Springer Nature More Media app for free, scan the link and access directly to the online course on your smartphone or tablet.

The image on the cover metaphorically illustrates the **knowledge** paradigm of robotics through a hand trying to catch an apple.



springer.com

Siciliano Ed.



Robotics Goes MOOC

Bruno Siciliano
Editor

Robotics Goes MOOC

Knowledge



Springer

Bruno Siciliano Editor
Robotics Goes MOOC
Design

The Robotics Goes MOOC project is organized in four volumes devoted to the paradigms of robotics **knowledge**, **design**, **interaction**, **impact**.

A robot's appearance and its way of interacting with humans is of fundamental importance. Until a few years ago there was a clear asymmetry between the typically excellent performance of industrial robots and their ugly and disharmonious bodies, with crude ways and potentially very dangerous movements for the human environment. A modern artifact can be as harmonious and beautiful as a complex biological machine or a work of plastic art and thus it should be clear how **design** plays a key role for robot technology to become a part of our everyday life and change it essentially in a responsible and beneficial manner. It is designers who shape the interface between humans and machines and, as such, they will contribute to make robots as customizable and intuitively useful to inexperienced users according to a plug-and-play mode.

The new concept of robotonics as the mechatronics approach to designing advanced robotics is the focus of the first chapter of the second book of the Robotics Goes MOOC project by Asfour et al. The main issues for robot manipulator design are covered in the subsequent material, namely redundant robots in Chapter 2 by Maciejewski et al. and parallel robots in Chapter 3 by Müller, where widely adopted kinematic solutions are presented. Then, the adoption of flexibility, as opposed to the rigid mechanics paradigm, is discussed in Chapter 4 by Malzahn et al. with reference to elastic robots and in Chapter 5 by Laschi focused on soft robotics. Somewhat speculating on the previous two design solutions comes Chapter 6 by Outokoski dealing with bioinspired robots. The last part of the book is devoted to robot locomotion, namely, Chapter 7 by Vendittelli on wheeled robots and Chapter 8 by Harada on biped humanoid.

The content published here is linked to the MOOC course Robotics & Robots available at <https://www.federica.eu/federica-pro/robotics-and-robots> specifically created by Federica Web Learning, the Center for Innovation, Experimentation and Dissemination of Multimedia Education of University of Naples Federico II. You can access the related content via our app: download the Springer Nature More Media app for free, scan the link and access directly to the online course on your smartphone or tablet.

The image on the cover metaphorically illustrates the **design** paradigm of robotics through a hand firmly grasping an apple.



springer.com

Siciliano Ed.



Robotics Goes MOOC

Bruno Siciliano
Editor

Robotics Goes MOOC

Design



Springer

Bruno Siciliano Editor
Robotics Goes MOOC
Interaction

The Robotics Goes MOOC project is organized in four volumes devoted to the paradigms of robotics **knowledge**, **design**, **interaction**, **impact**.

With the massive and pervasive diffusion of robotics technology in our society, we are heading towards a new type of a new type of AI, which we call physical AI at the intersection of Robotics with AI, that is the science of robots and intelligent machines performing a physical action to help humans in their jobs of daily lives. Physical assistance to disabled or elderly people, reduction of risks and fatigue at work, improvement of production processes of material goods and their sustainability, safety, efficiency and reduction of environmental impact in transportation of people and goods, progress of diagnostic and surgical techniques are all examples of scenarios where the new Interaction Technology (IAT) is indispensable.

The **interaction** between robots and humans must be managed in a safe and reliable manner. The robot becomes an ideal assistant, like the tool used by a surgeon, a craftsman, a skilled worker. The new generation of robots will co-exist — the robots — with humans not only in the workplace but, gradually, in homes and communities, providing support in services, entertainment, education, health, manufacturing and care.

As discussed above, interaction plays a crucial role for the development of modern robotic systems. Grasping, manipulation and cooperative manipulators are covered in the first part of the third book of the Robotics Goes MOOC project, respectively in Chapter 1 by Prattichizzo et al., Chapter 2 by Kao et al., and Chapter 3 by Cacavale. Specific interaction issues along with the development of digital and physical interfaces are dealt with in Chapter 4 by Marchal et al. and in Chapter 5 by Croft et al. respectively. Interaction between robot and human also means that a robot can be worn by a human as presented in Chapter 6 by Vitello et al. A different type of interaction at a cognitive and planning level is the focus of Chapter 7 by Lima devoted to multi-robot systems and Chapter 8 by Song et al. on networked, cloud and fog robotics, respectively.

The content published here is linked to the MOOC course Robotics & Robots available at <https://www.federica.eu/federica-pro/robotics-and-robots> specifically created by Federica Web Learning, the Center for Innovation, Experimentation and Dissemination of Multimedia Education of University of Naples Federico II. You can access the related content via our app: download the Springer Nature More Media app for free, scan the link and access directly to the online course on your smartphone or tablet.

The image on the cover metaphorically illustrates the **interaction** paradigm of robotics through a hand dexterously manipulating an apple.



springer.com

Siciliano Ed.



Robotics Goes MOOC

Bruno Siciliano
Editor

Robotics Goes MOOC

Interaction



Springer

Bruno Siciliano Editor
Robotics Goes MOOC
Impact

The Robotics Goes MOOC project is organized in four volumes devoted to the paradigms of robotics **knowledge**, **design**, **interaction**, **impact**.

It is often read in the media that AI and Robotics are the primary cause of technology unemployment. AI and machine learning techniques are expected to take over lower-level tasks, while humans can spend more time with higher-level tasks. In perspective, it can be said that jobs requiring boring, cognitive tasks or repeatable and dangerous physical tasks will be considerably shored up by automation thanks to the wide adoption of AI and Robotics technology to replace humans, while jobs requiring challenging cognitive tasks or unstructured physical tasks will be suitably re-engineered with the progressive introduction of AI and Robotics technology to assist humans.

From the discussion above, it should be clear that in a world populated by humans and robots issues arise that go beyond engineering and technology due to the **impact** resulting from the use of robots in various application scenarios. The anthropization of robots cannot ignore the resolution of those ethical, legal, social, economic (ELSE) problems that have so far slowed their spread in our society.

The final book of the Robotics Goes MOOC project enlightens the impact of using robotic technology in the main fields of application, namely, industrial robots as in Chapter 1 by Bischoff et al., medical robotics as in Chapter 2 by Dario et al., aerial robots as in Chapter 3 by Ollero et al., orbital robotics as in Chapter 4 by Lampariello, underwater robots in Chapter 5 by Antonelli, and rescue robots as in Chapter 6 by Murphy. The last part is devoted to the open dilemmas of using and accepting robots in human co-habited environments which is addressed in Chapter 7 on social robotics by Pandey and the very final chapter by Tamburrini on the important issues raised with robot ethics.

The content published here is linked to the MOOC course Robotics & Robots available at <https://www.federica.eu/federica-pro/robotics-and-robots> specifically created by Federica Web Learning, the Center for Innovation, Experimentation and Dissemination of Multimedia Education of University of Naples Federico II. You can access the related content via our app: download the Springer Nature More Media app for free, scan the link and access directly to the online course on your smartphone or tablet.

The image on the cover metaphorically illustrates the **impact** paradigm of robotics through a hand holding bitten an apple.



springer.com

Siciliano Ed.



Robotics Goes MOOC

Bruno Siciliano
Editor

Robotics Goes MOOC

Impact



Springer

