



ELTE | FACULTY OF
INFORMATICS

Embodied Intelligence - L01

Introduction to Robotics and Embedded Systems

by Márk Domonkos



Meet the Team



János Botzheim
Dept. AI
Head of dept.
Cognitive Robotics



Balázs Nagy
Dept. AI
Assistant professor
Signal Processing



Beáta Korcsok
Dept. of Ethology
Assistant Research Fellow
Ethologically inspired robotics



Márk Domonkos
Dept. AI
PhD Student
Embedded Systems /
Practice /
Administration

Structure of this course - Lectures

- Module 1 – Embedded Systems by Márk Domonkos and Balázs Nagy
 - L01 – *Course introduction; Definitions; Embedded systems ; History of robotics*
 - L02 – Signal Processing
 - L03 – Sensors
 - L04 – Actuators
 - L05 – Controlling units

Mainly used sources:

1. The Mechatronics Handbook (2nd ed.) by Robert H. Bishop
2. Mechatronika alapjai (HUN) by Péter Horváth
3. Beágyazott rendszerek (HUN) by Ivor Dülk



Structure of this course - Lectures (cont.)

- Module 2 – Ethologically inspired robotics by Beáta Korcsok
 - L06 – Ethorobotics 1
 - L07 – Ethorobotics 2
 - L08 – Biologically inspired robotics



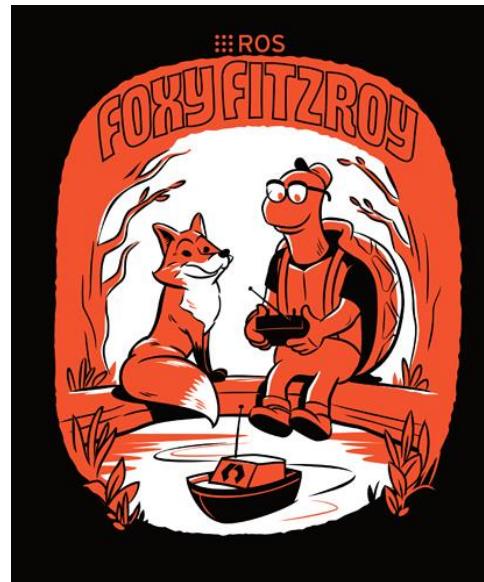
Structure of this course (cont.)

- Module 3 – Intelligent robotics *by János Botzheim*
 - L09 – Cognitive robotics 1
 - L10 – Cognitive robotics 2
 - L11 – Evolutionary robotics 1
 - L12 – Evolutionary robotics 2
 - L13 – Robot locomotion



Practice

- On the Practice You will learn ROS2
 - How to establish a project in ROS2
 - How to make custom computational units in it
 - How to make these units to communicate each other in different forms
 - How to model a robot in ROS2
 - How to control a robot with ROS2 in a simulation



How You will get Your grade

- You will have 1 HW project (team work) [40 %]*
- Last practice - presentation [Go-NoGO]
- 2 short HW from practice [7.5 - 7.5 %]
- Exam in the exam period [45 %]

*Grading of the project HW

- 20 % - Supervisor's opinion
- 20 % (+ 20 % max) – Decision by the jury based on the presentation



Project HomeWork

- You will receive a list of topics – [start of 1st week]
- You will need to form groups (2 - 4 members), all member need to work around 25 – 35 hrs (consultation meetings and presentation making included) in the project.
- You choose a project OR You can bring Your own project proposals as well (approval needed from supervisor AND Márk Domonkos). – [end of 2nd week]
- Concluding meeting before the last practice. → Points from supervisor
- Mini conference on last practice → depending on the amount of groups 15+5 or 12+3 minutes for each presentation
 - Grading = supervisor (20 %) + jury (20 % + 20 % max)



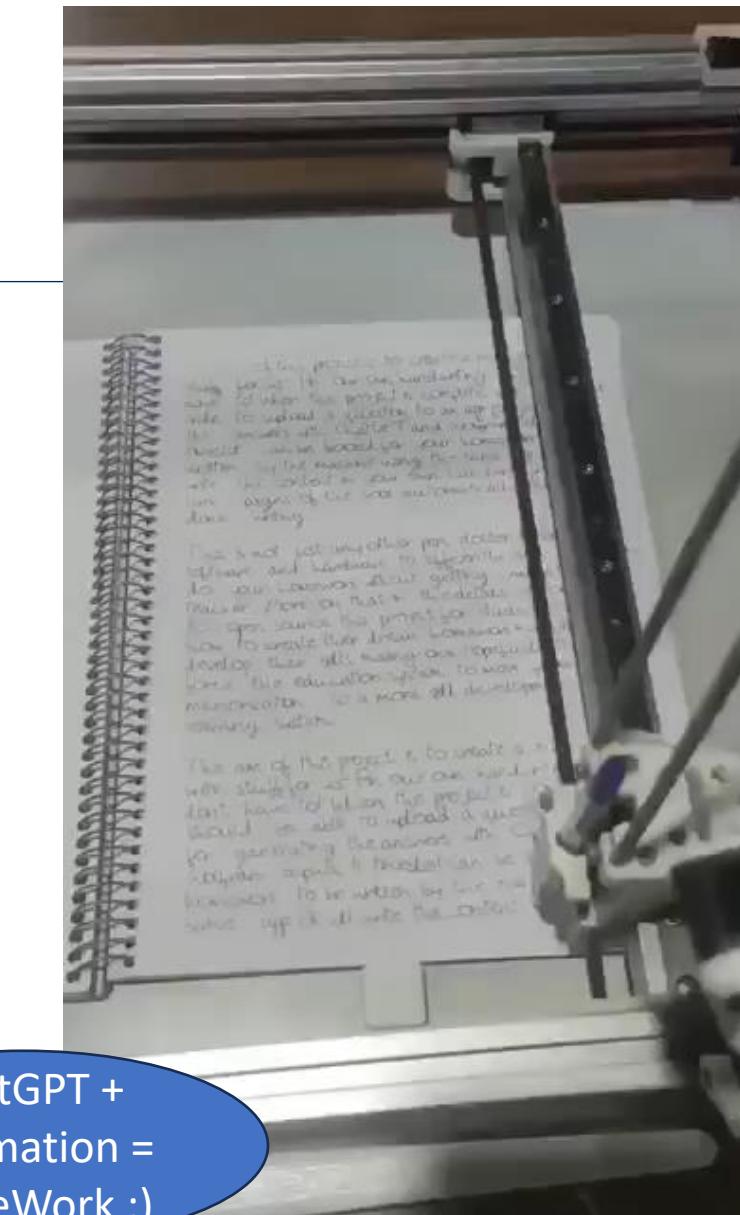
Join our MS Teams group

- We will post the important info there.
 - You are welcome to ask questions there as well.
 - We will post the materials used as well.
-
- Enter code: qlgjnrm



Why do You need this course?

- Widen Your knowledge (hopefully), from the solely informatics domain. (embedded systems)
- Learning some things outside of the simulation (physical systems and robotics).
- Robotics is always fun. ;)
- AI and Robotics (alongside with intelligent gadgets) will have more and more common domain.
- You will not be limited to work in the world inside the computer.



ChatGPT +
automation =
HomeWork ;)



Embedded systems

Embedded systems; Definitions; Mechatronics



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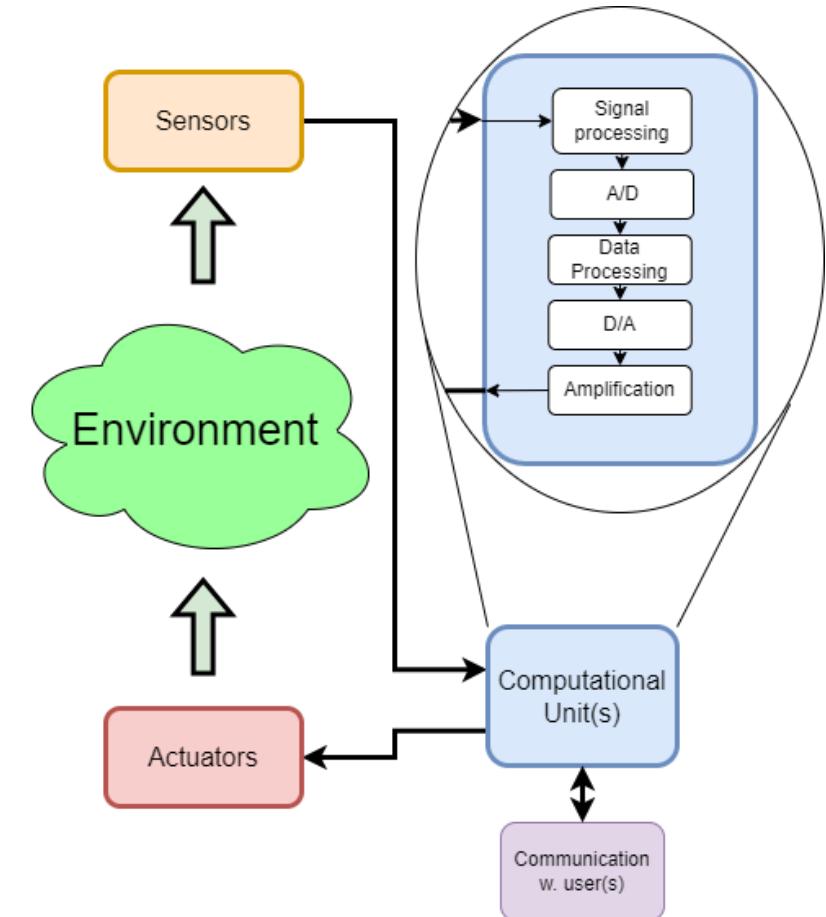
Embedded systems - definition

- Satellites
- GPS systems in cars
- Tempomat in cars
- Dish washers
- Automatic water pumps
- Air conditioners
- Robot vacuum cleaner
- Industrial Robots
- Automated irrigation systems
- Washing machines
- What are the common in these devices?



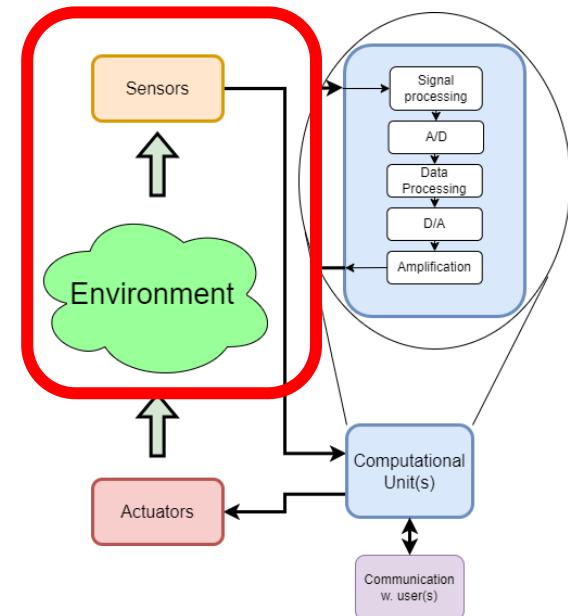
Embedded system – definition (cont.)

- An embedded system is a system, that mostly has an ***intensive information changing connection with its environment***, usually based on a ***microcontroller or other operation execution unit***, which is designed and built ***to perform well-defined task***. This formulation also implies that ***functionality is defined at the design stage*** and is non-flexible or can be only slightly modified during operation.



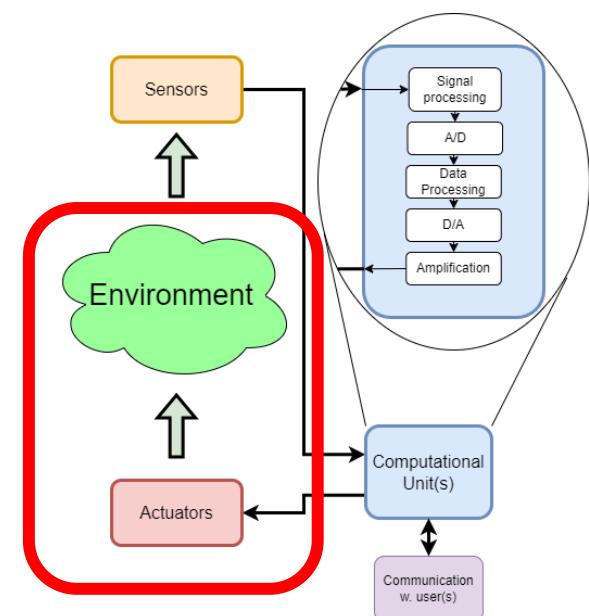
From the L03 lecture - Sensors

- In its broader definition, the purpose of a sensor is to ***detect a certain event, process or change in the environment and produce a corresponding output signal.***
- Human sensory inputs:
 - Vision
 - Audio
 - Smelling
 - Taste
 - Tactile
 - Temperature
 - ... etc.
 - FUN FACT: We can't sense whether something is wet or not (no humidity sensors in our skin)



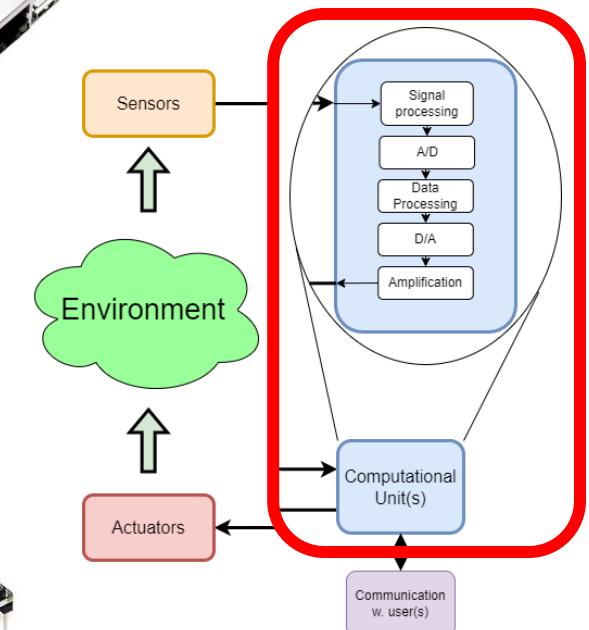
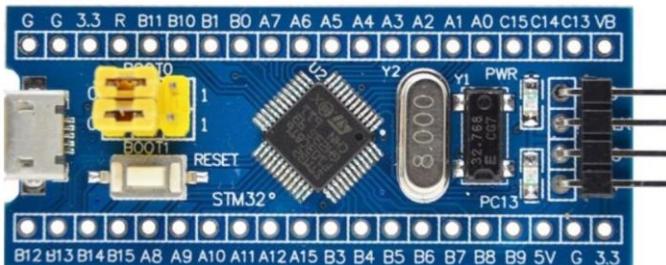
Fast forward to L04 - Actuators

- Actuators are elements (usually some kinds of motors) of embedded systems, whose purpose is to interact with the environment based on the Computational unit's commands.
- Human actuators:
 - Muscles



Teaser from the L05 – Controlling units

- The main computational unit of the system, where the signal processing, decision making, intervening signal generation and communication is done.
- „Human brain”



Mechatronics - Definition

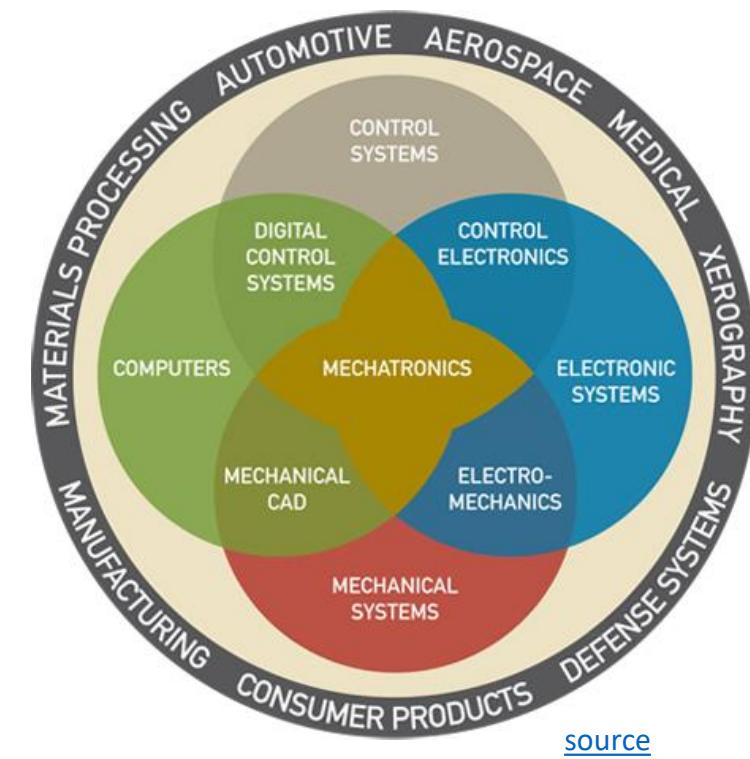
- Most definitions grasps some essential parts of the concept, but can't grasp the whole term.
- Next essential step in the natural evolution of engineering.
- Yaskawa Electric Company:
Mechanics + Electronics =
Mechatronics



Mechatronics – Definition (cont.)

- Most cited definition by Harashima, Tomizuka and Fukuda [9]

„Mechatronics is the synergic integration of mechanical engineering with electronic and intelligent computer control, in the design and manufacturing of industrial products and processes.”



[source](#)



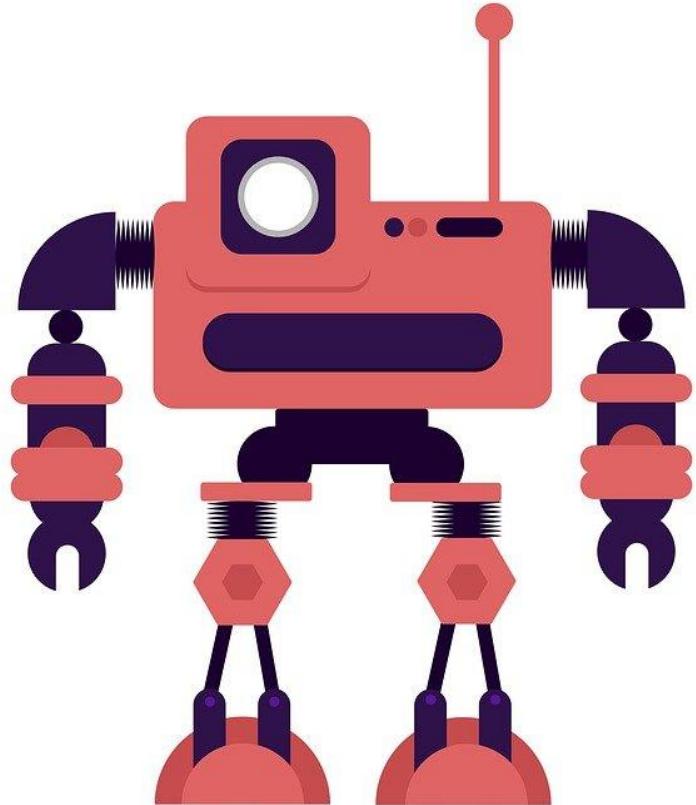
Robots

Definitions



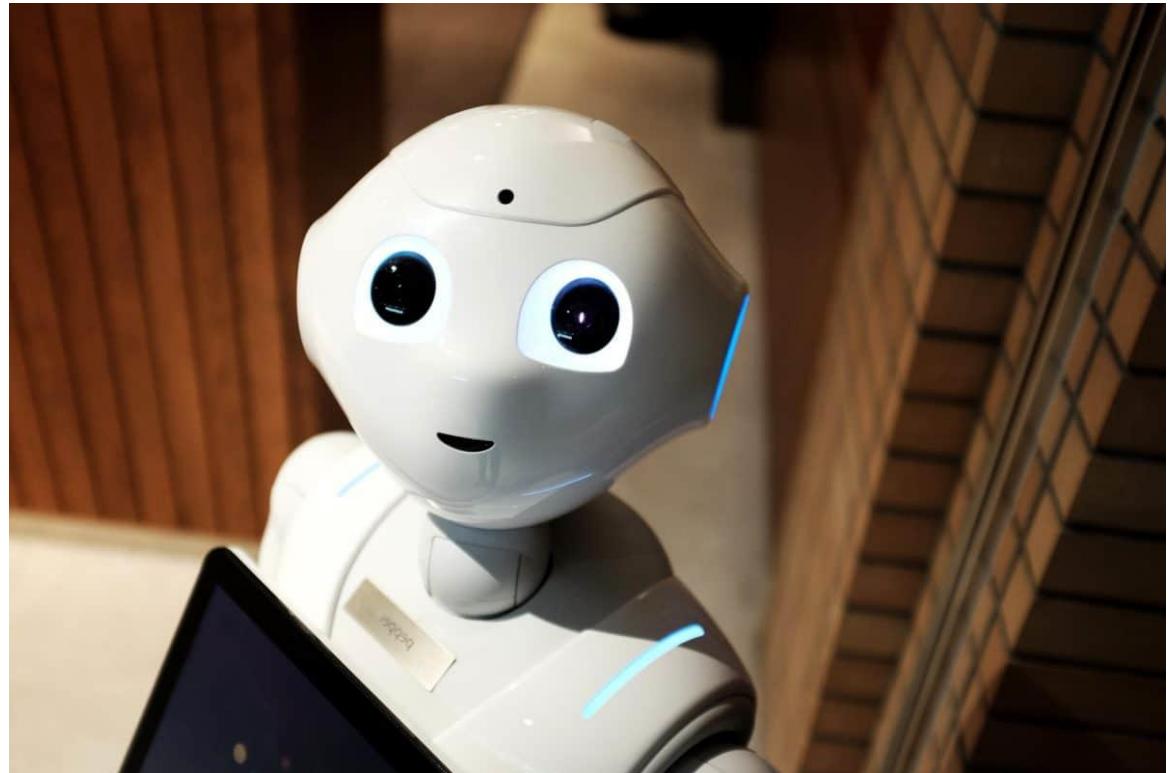
What is a robot? – I

- Let's think of our first thoughts on the question "What is a robot?", let's make our own definition!



What is a robot? – II

- A robot is : "a machine controlled by a computer that is used to perform jobs automatically" – (*cambridge dictionary*)^[2]



What is a robot? – III [1]

- **Industrial robot** is an „automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications”
- **Manipulator** is a „machine in which the mechanism usually consists of a series of segments, jointed or sliding relative to one another, for the purpose of grasping and/or moving objects (pieces or tools) usually in several degrees of freedom”



Source: <https://www.universal-robots.com/products/>

What is a robot? – IV [1], [8]

- **Industrial robot system** is a “system comprising:
 - industrial robot;
 - end-effector(s);
 - any machinery, equipment, devices, external auxiliary axes or sensors supporting the robot performing its task”



Source: [9]

Definitions – Somehow resembling to each other

***Do You remember what we said about
embedded systems and mechatronics?***

- ***Hopefully now You don't have any doubt, that this course will be essential to You, if You are interested in robotics. ;)***



Other types of robots good to know of



Source: [4]

- Companion robot
- Domestic robot
- Autonomous robot
- Mobile robot

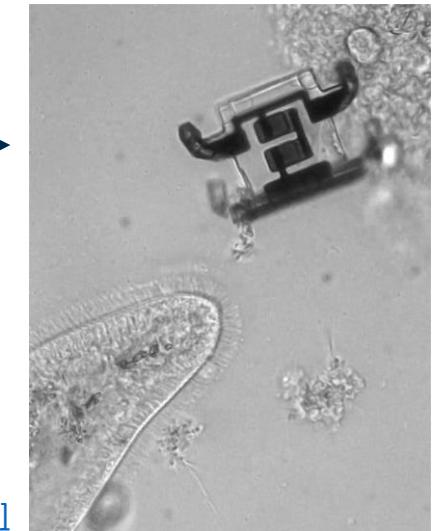


Source: [6]



Source: [5]

- Humanoid (anthropomorphic) robot
- Microbotics
- (and there are more and more categories ...)



Source: [7]



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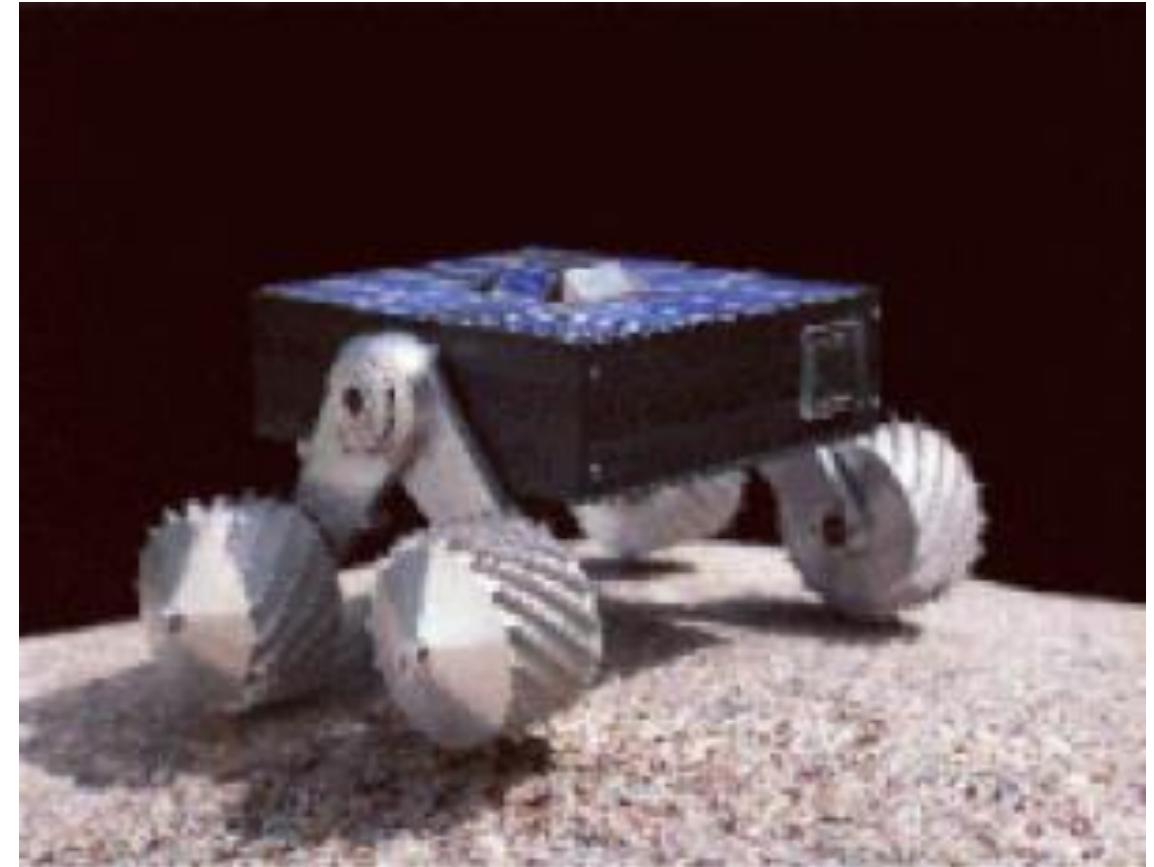
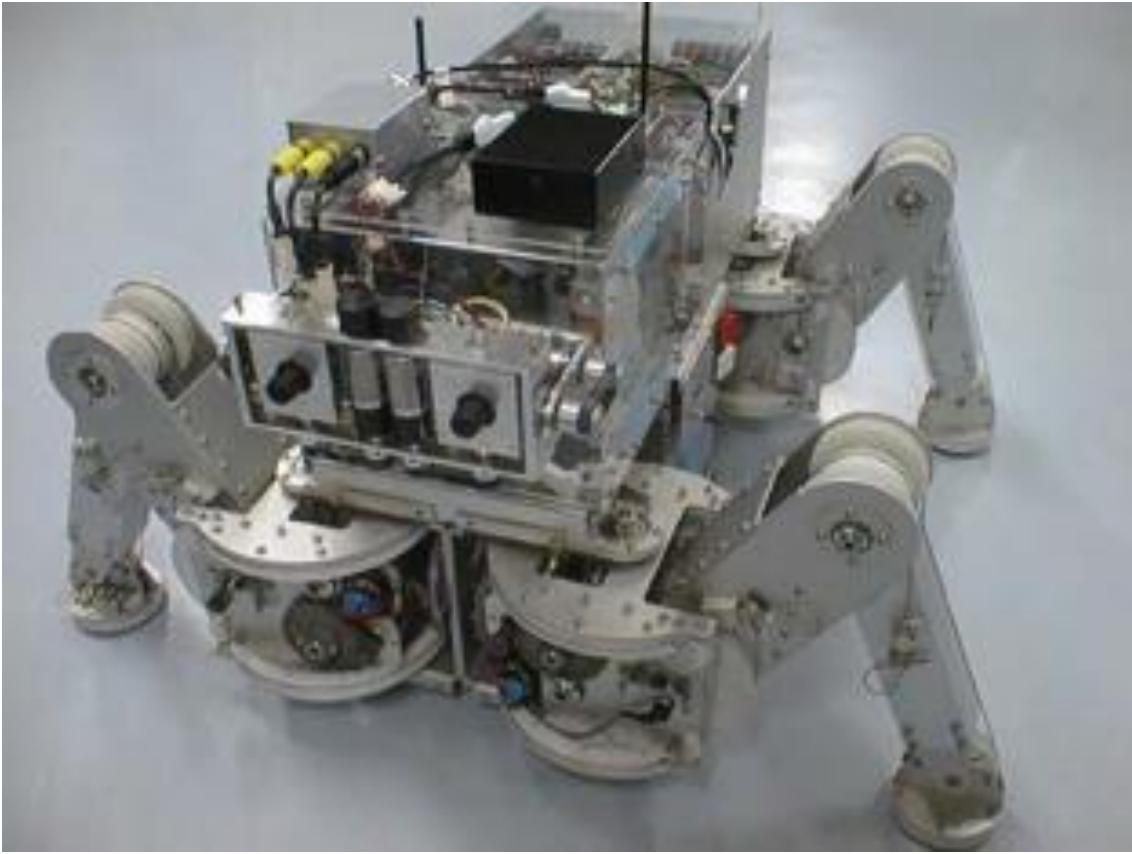
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Manipulator



Legged robot, wheeled robot



Autonomous Underwater Vehicle, Unmanned Aerial Vehicle



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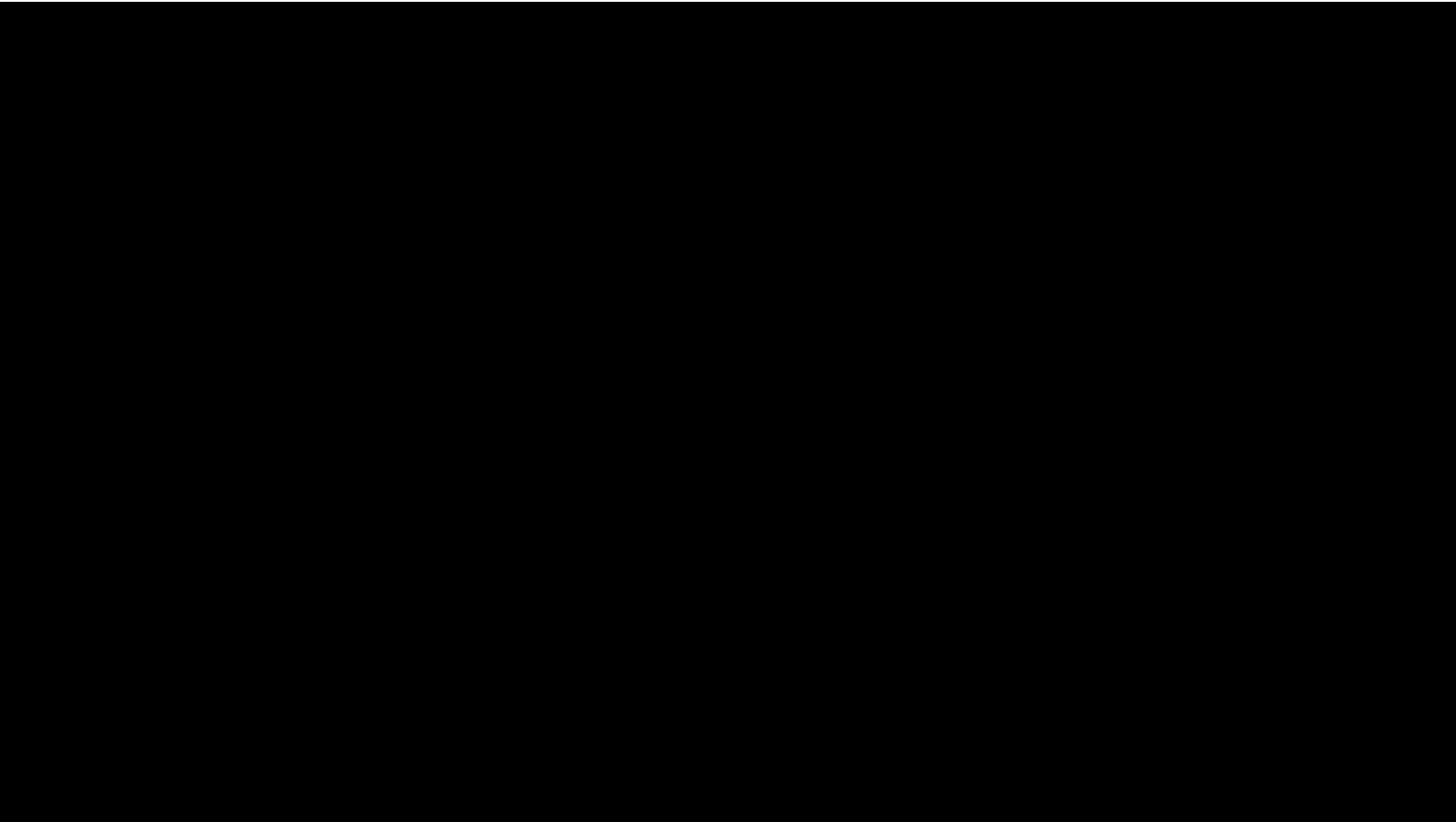
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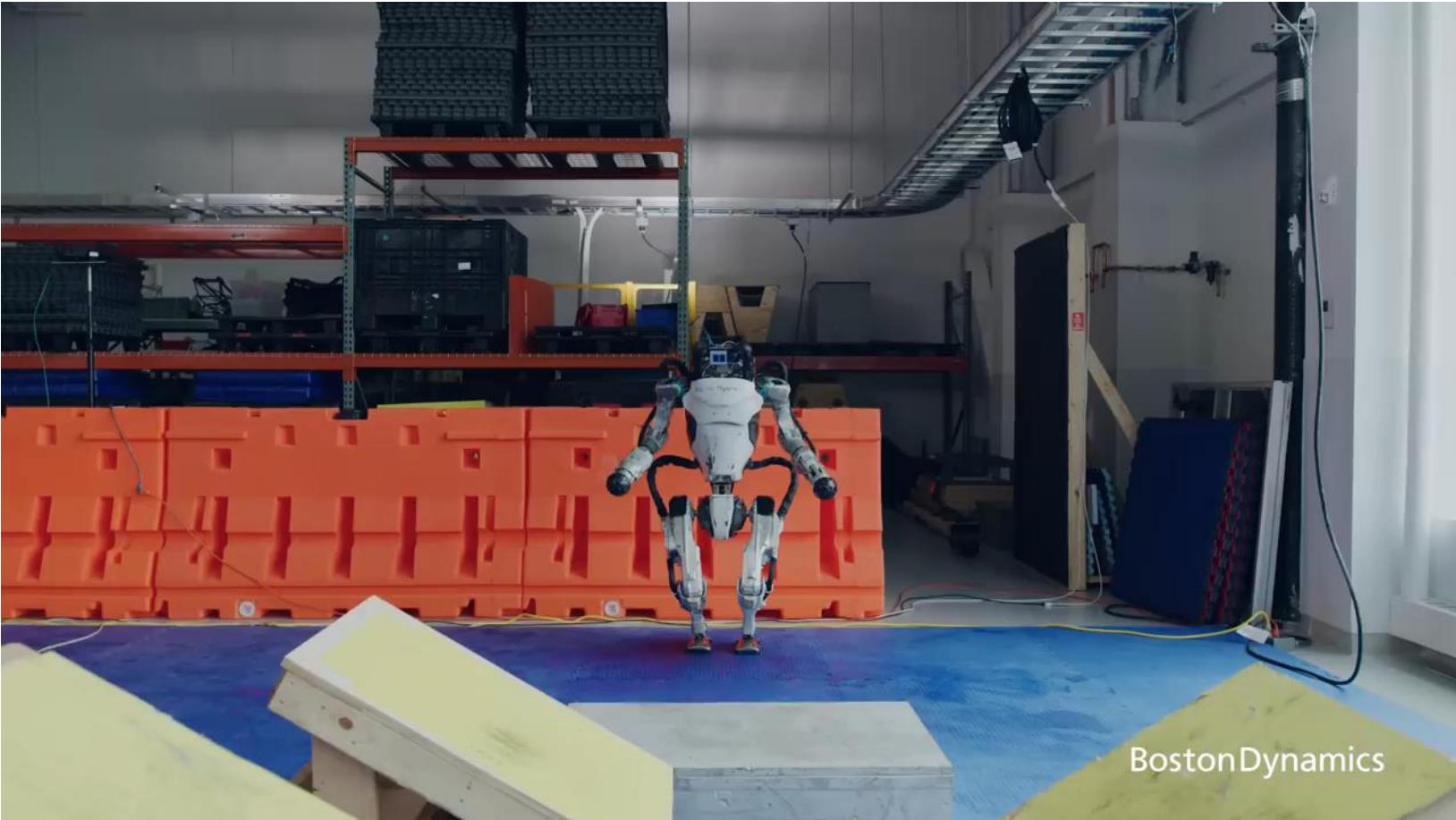
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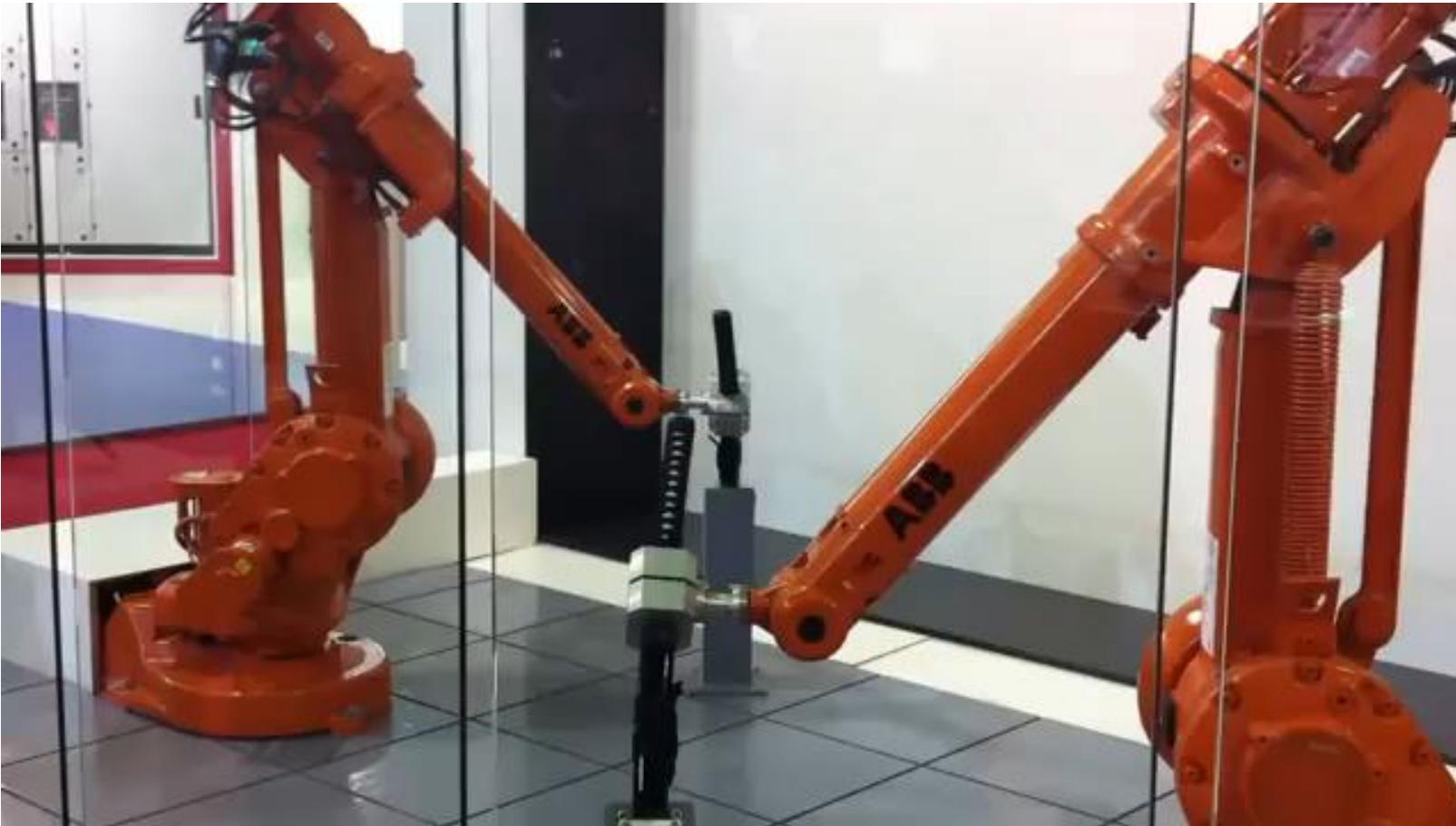
Anki Vector



Boston Dynamics



Sword fighting ABB robots



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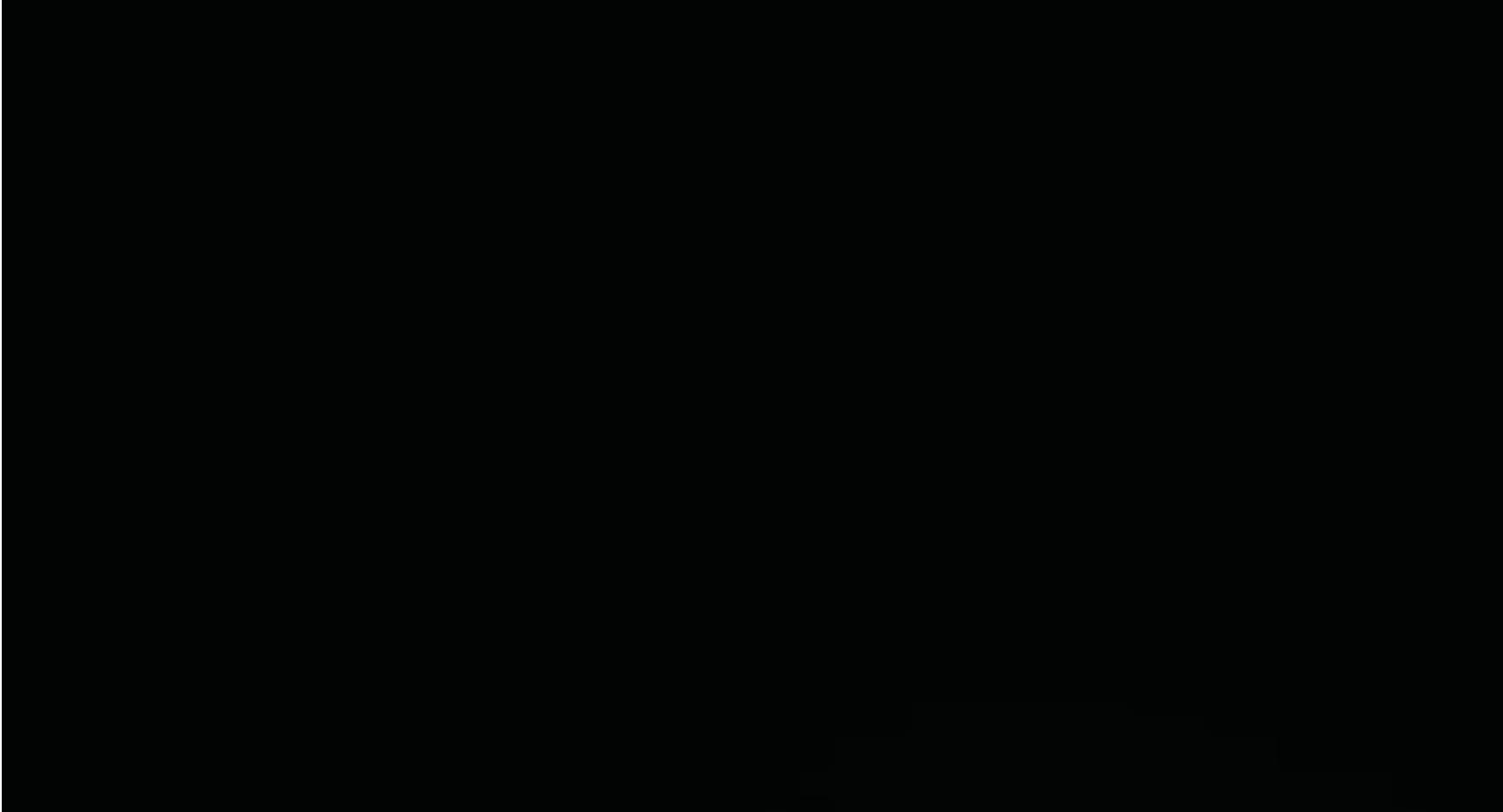
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Katana skills: Robot vs Iaijyutsu master



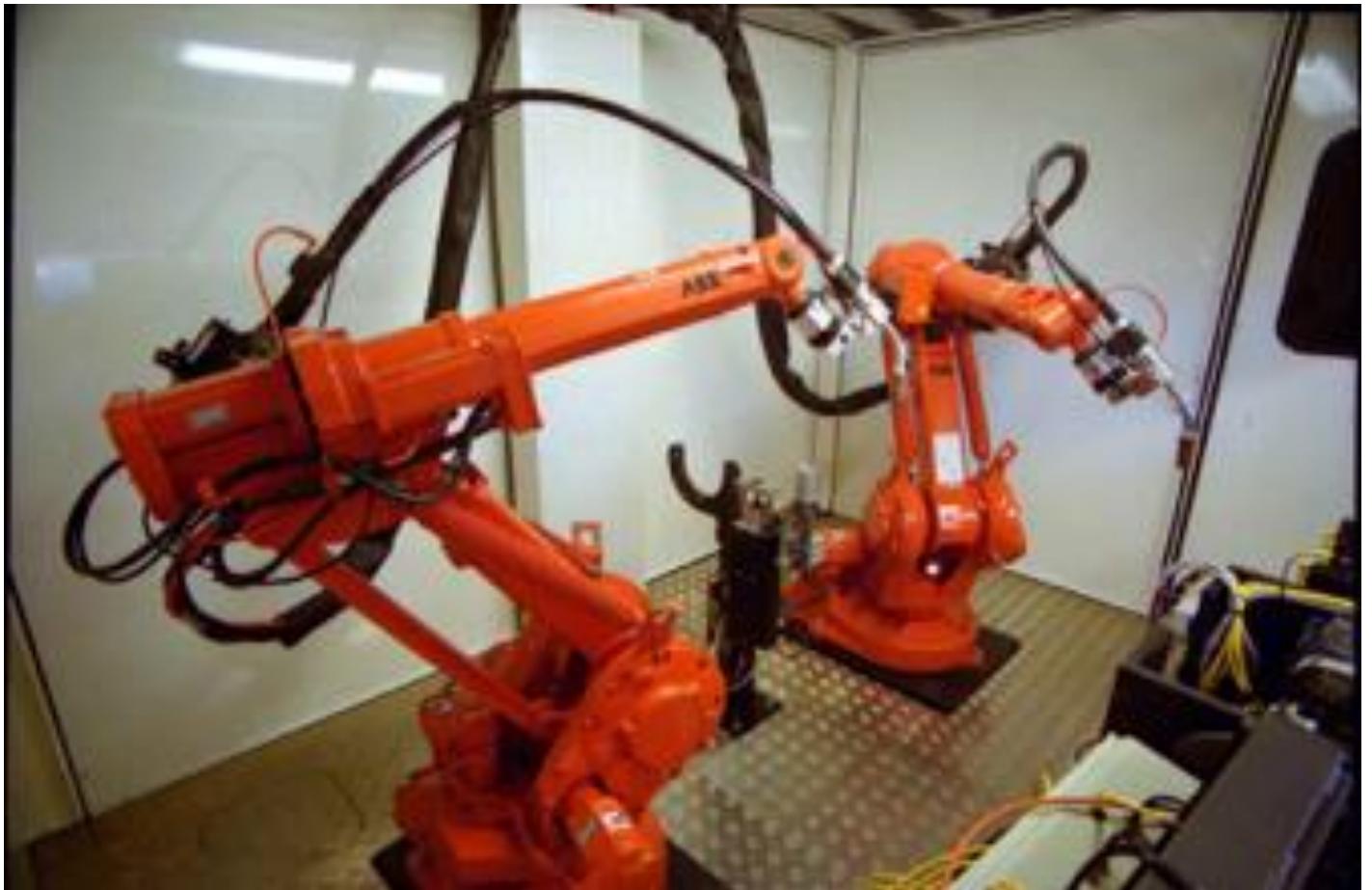
What can robots do?

- Jobs that are dangerous for humans
- E.g. decontaminating robot: cleaning the main circulating pump housing in the nuclear power plant



What can robots do?

- Repetitive jobs that are boring, stressful, or labor-intensive for humans
- E.g. welding robot

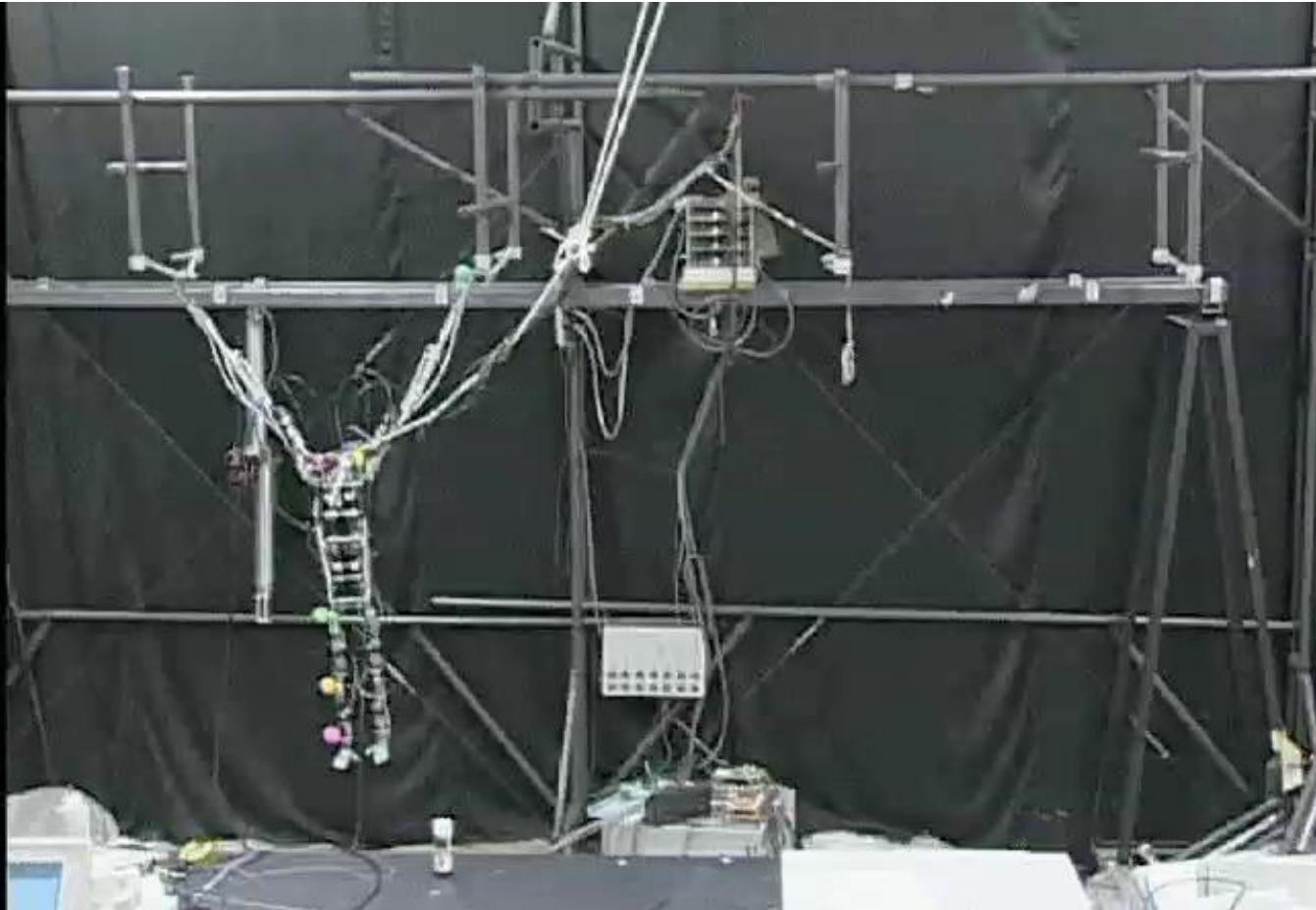


What can robots do?

- Menial tasks that human don't want to do
- E.g. the scrubmate robot



Brachiation

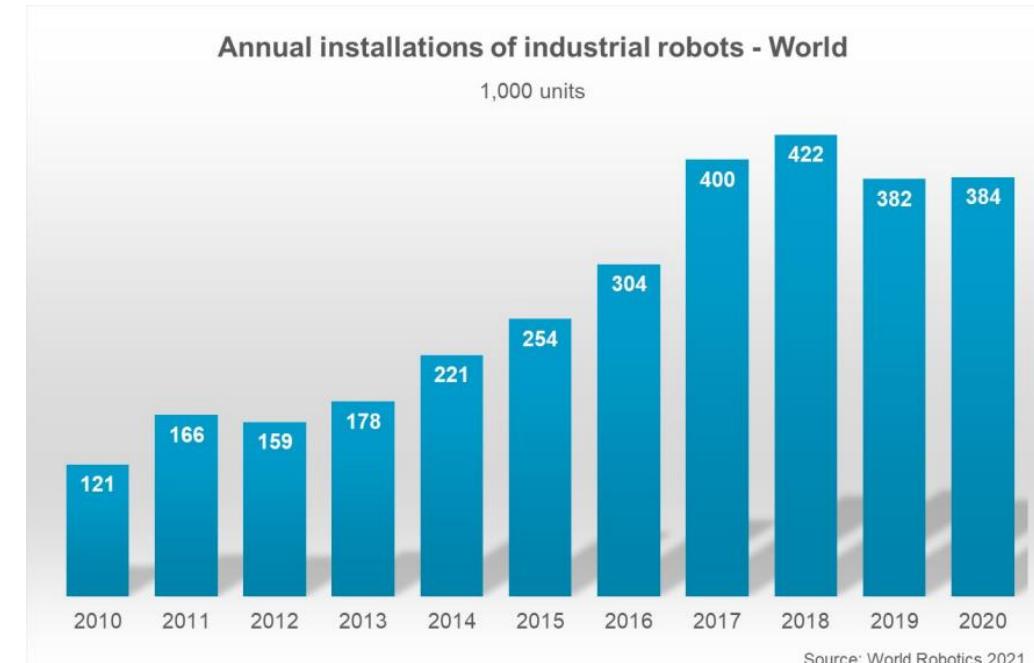
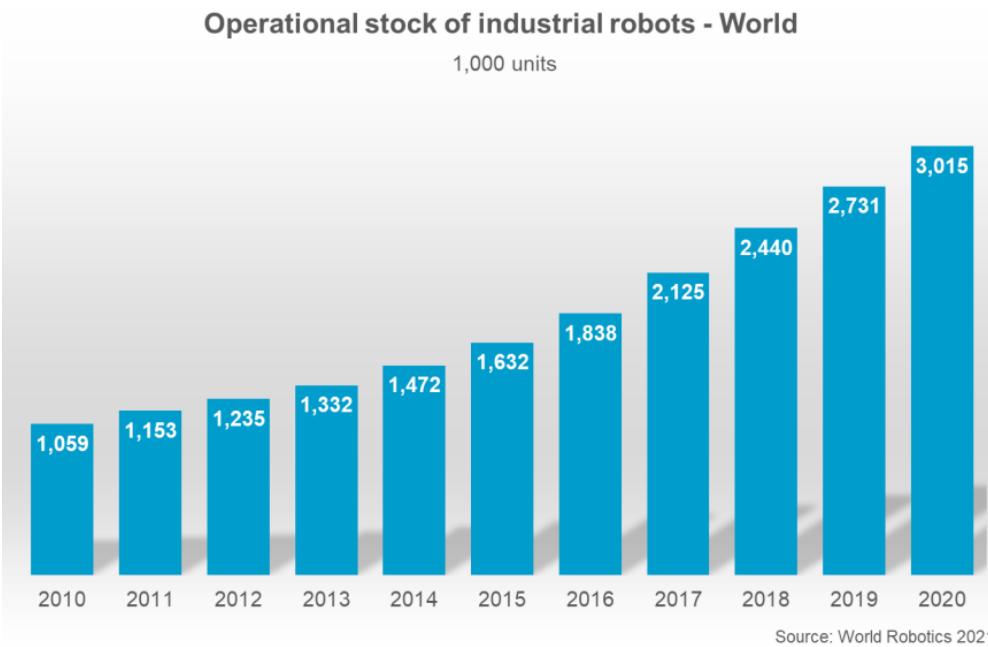


Robots in numbers [8]

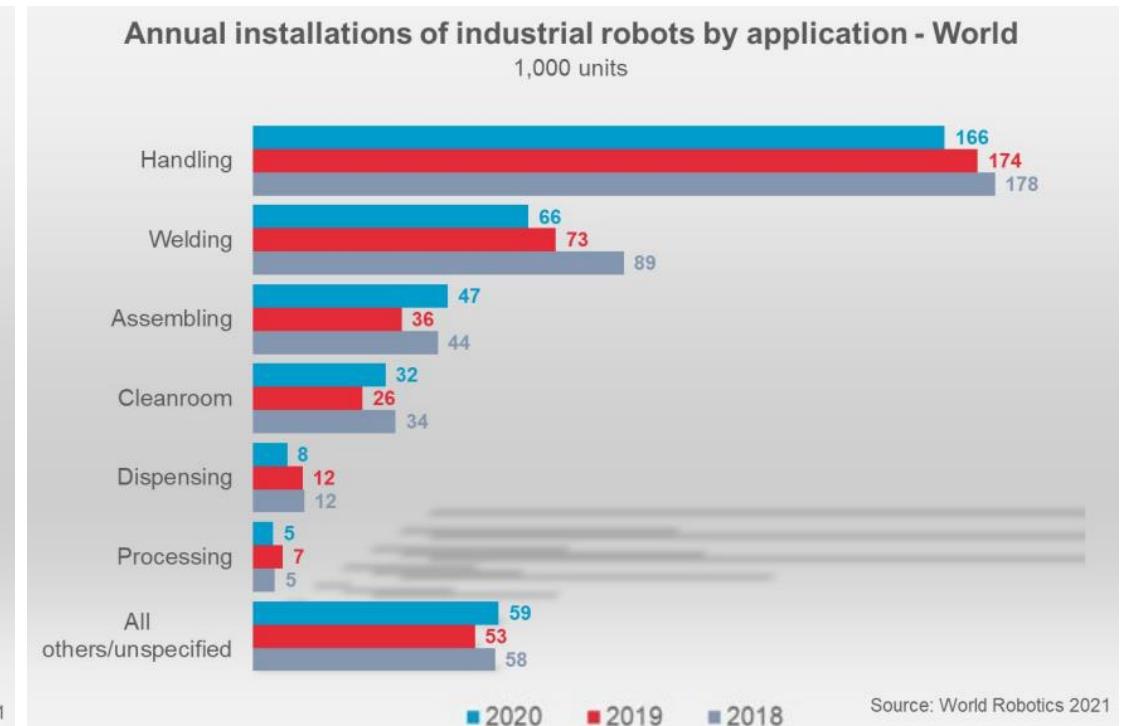
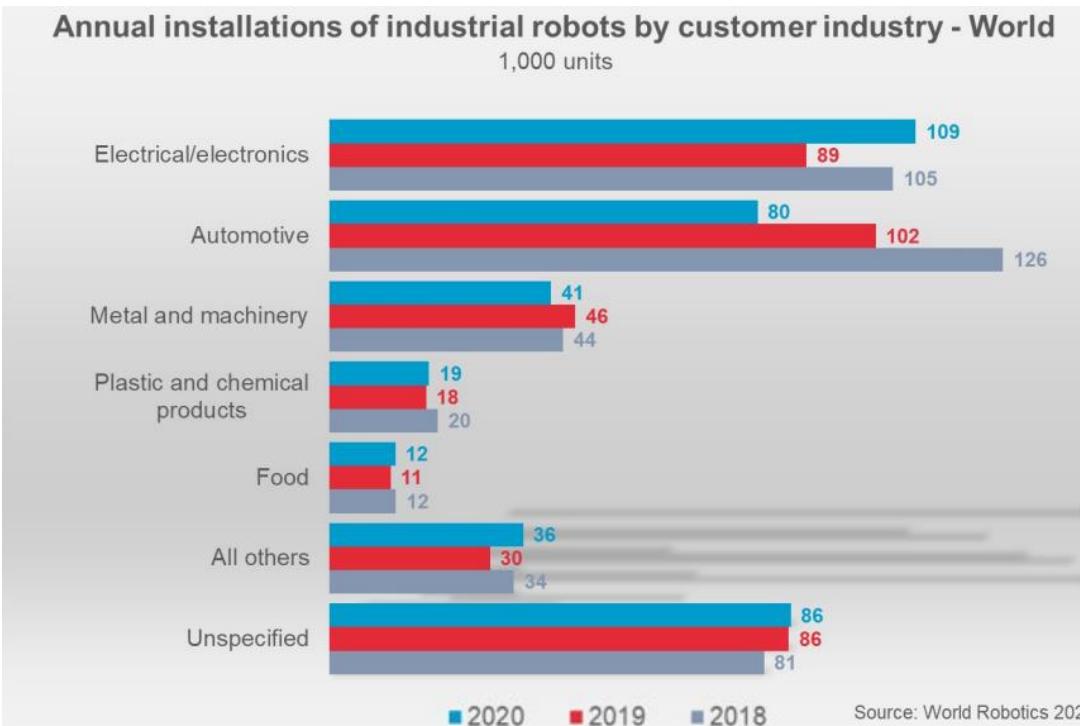
Statistical data from the International Federation of Robotics (2021)



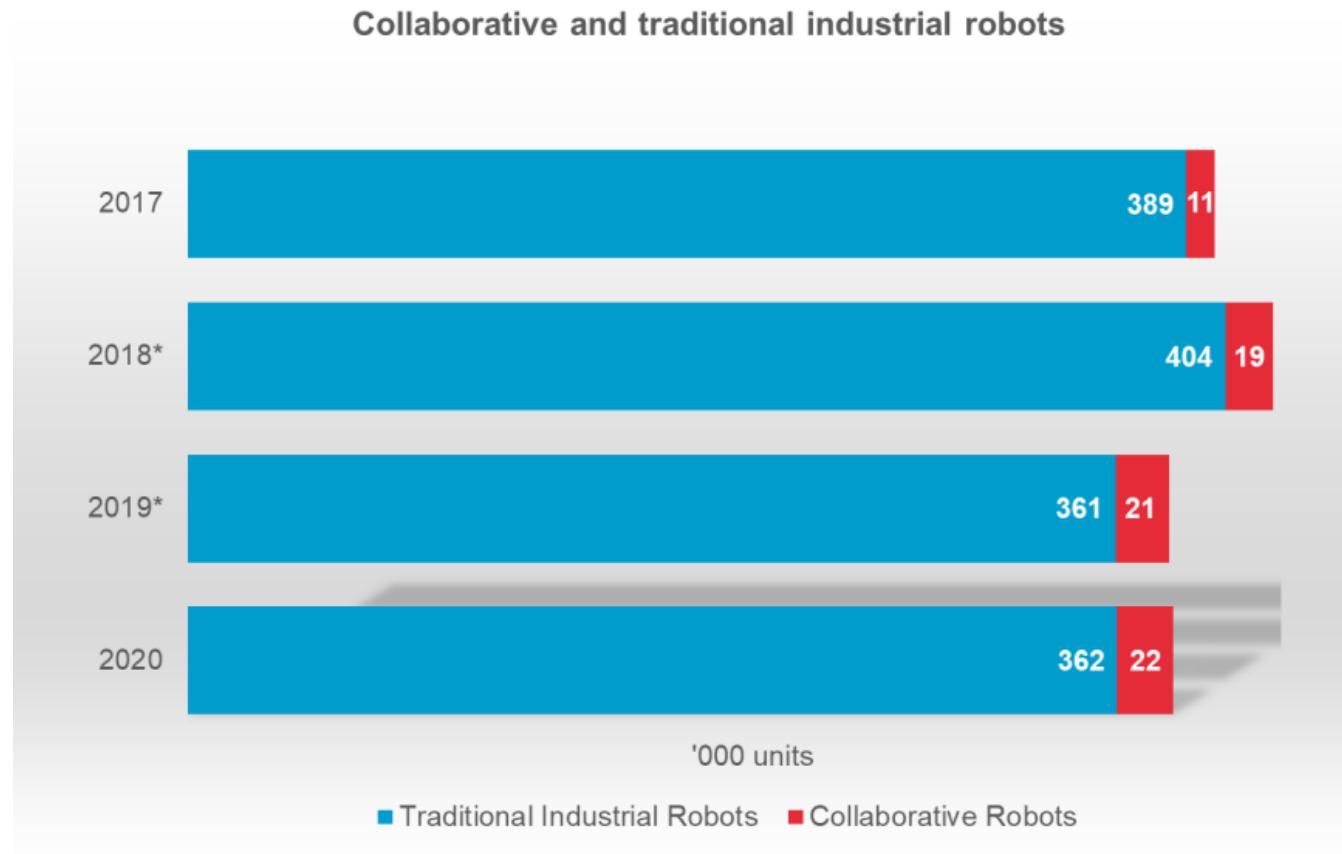
Number of robots used in industry is increasing



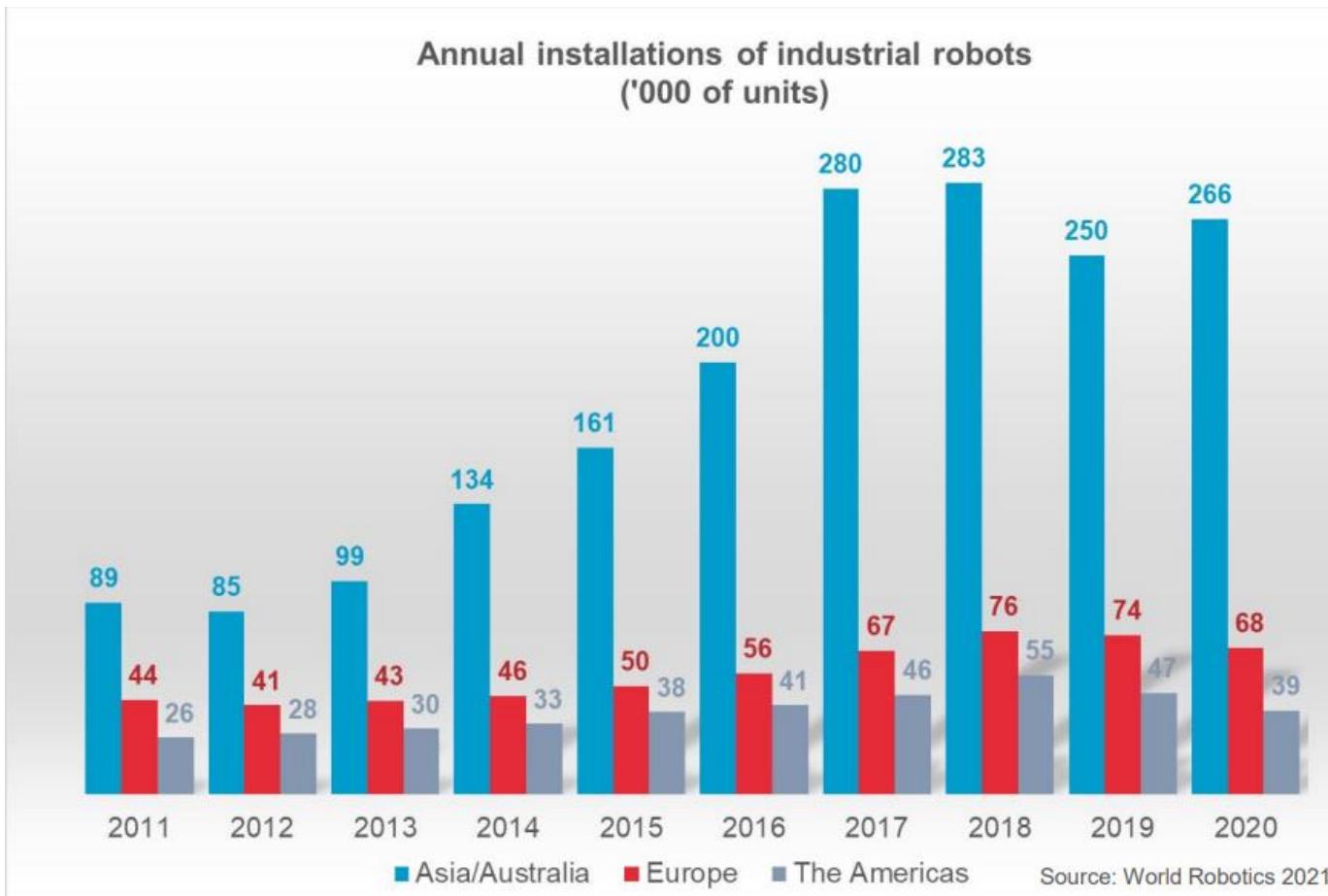
Electronics industry takes the most robots... The main application is handling



Rise of collaborative robotics

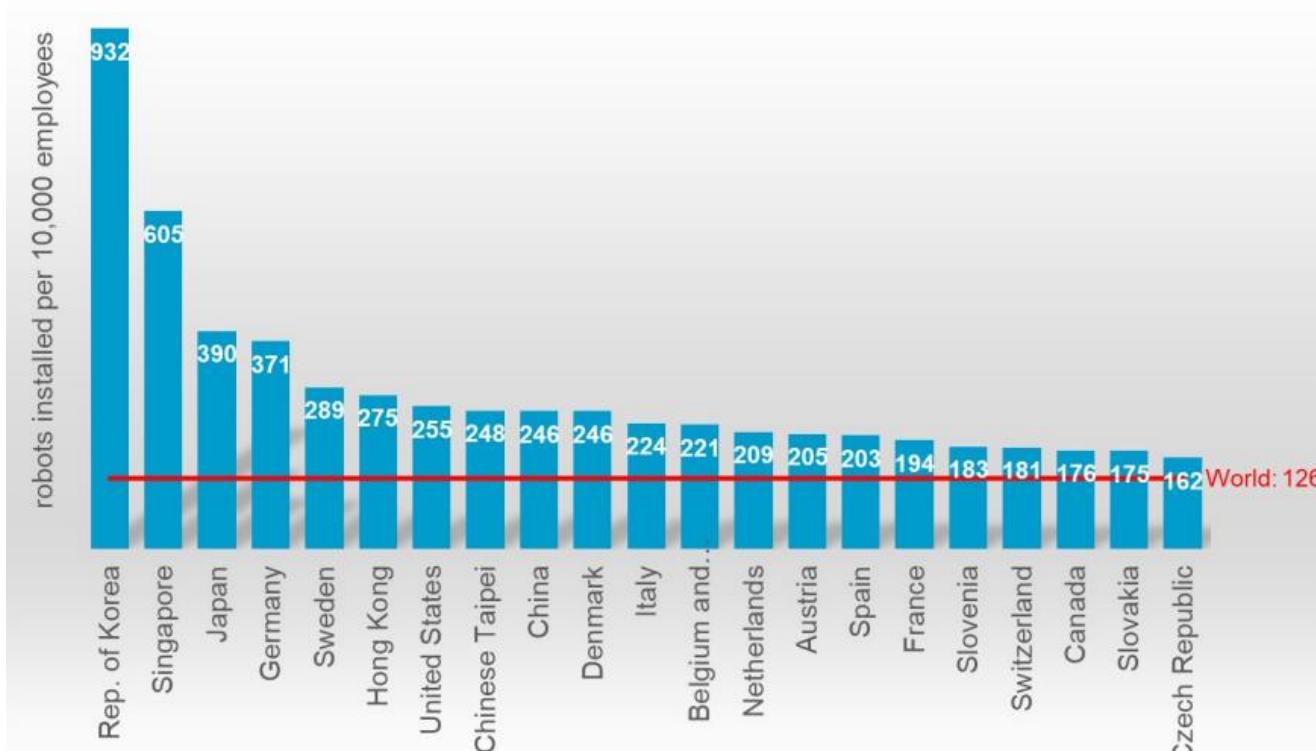


Robots around the world



Highest robot density is in Korea

Robot density in the manufacturing industry 2020



Source: World Robotics 2021



Brief history of robotics and automation

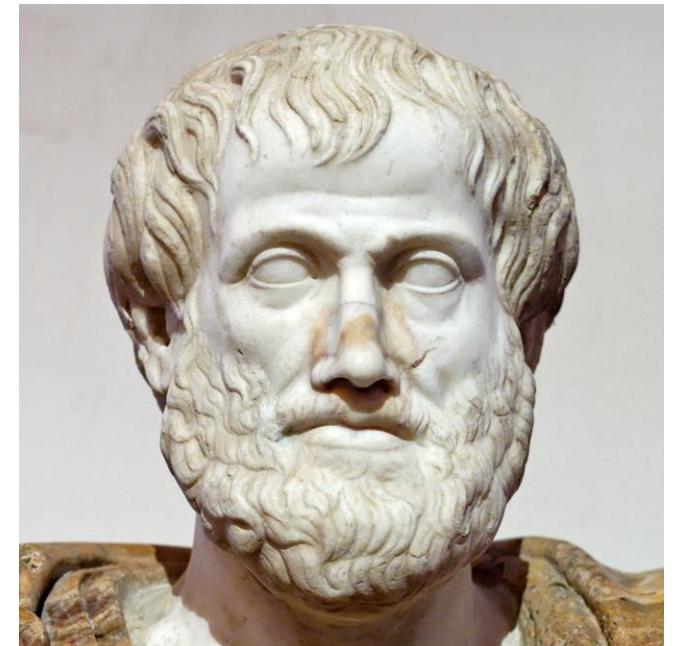
How the whole journey started?



Aristotle: Politics

„If every instrument could accomplish its own work, obeying or anticipating the will of others, like the statues of Daedalus, or the tripods of Hephaestus, which, says the poet, “of their own accord entered the assembly of the Gods;” if, in like manner, the shuttle would weave and the plectrum touch the lyre without a hand to guide them, chief workmen would not want servants, nor masters slaves.”

Machines should do the work that we don't want to do



In medieval times

- 13th -15th century: inventors were busy developing real automatons that mimicked human mannerisms. This first generation of robots were clock controlled ornaments with self-moving parts.
- E.g. automated rooster in Strasbourg in 1350 (flap wings and crow at noon)



Now is part of the collections of the Strasbourg Museum for Decorative Arts and is considered the oldest preserved automaton worldwide

Leonardo's robot

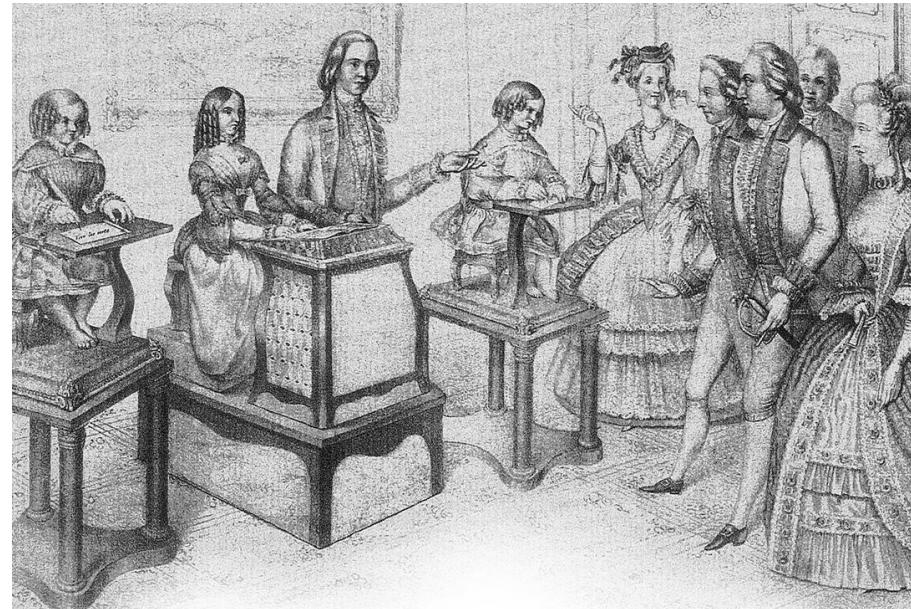
or Leonardo's mechanical knight

- Designed and probably constructed around 1495.
- Found in a sketchbook in 1950
- Displayed at a celebration hosted by Ludovico Sforza at the court of Milan
- Could: Stand, Sit, independently manouver its arms stc.
- Rebuilt since based on the notes AND IT IS WORKING!!!



Automatic scribe

- Pierre and Henri Louis Jacquet-Droz in 1774
- Any messages up to 40 character
- Pianist „robot”



Edison's Phonograph Doll

- Invented in 1877
- 22-inch doll with miniature removable phonograph with nursery rhymes
- Sales disaster (few weeks of marketing only)
- On [Wikipedia](#) You can find the track that were originally used.



First robots

- 1940: Westinghouse Electric Corp. creates two of the first robots
- Electric motors for entire body motion.
- Elektro could dance, count to ten, and smoke
- His dog companion Sparko, could walk, stand on its hind legs, and bark.

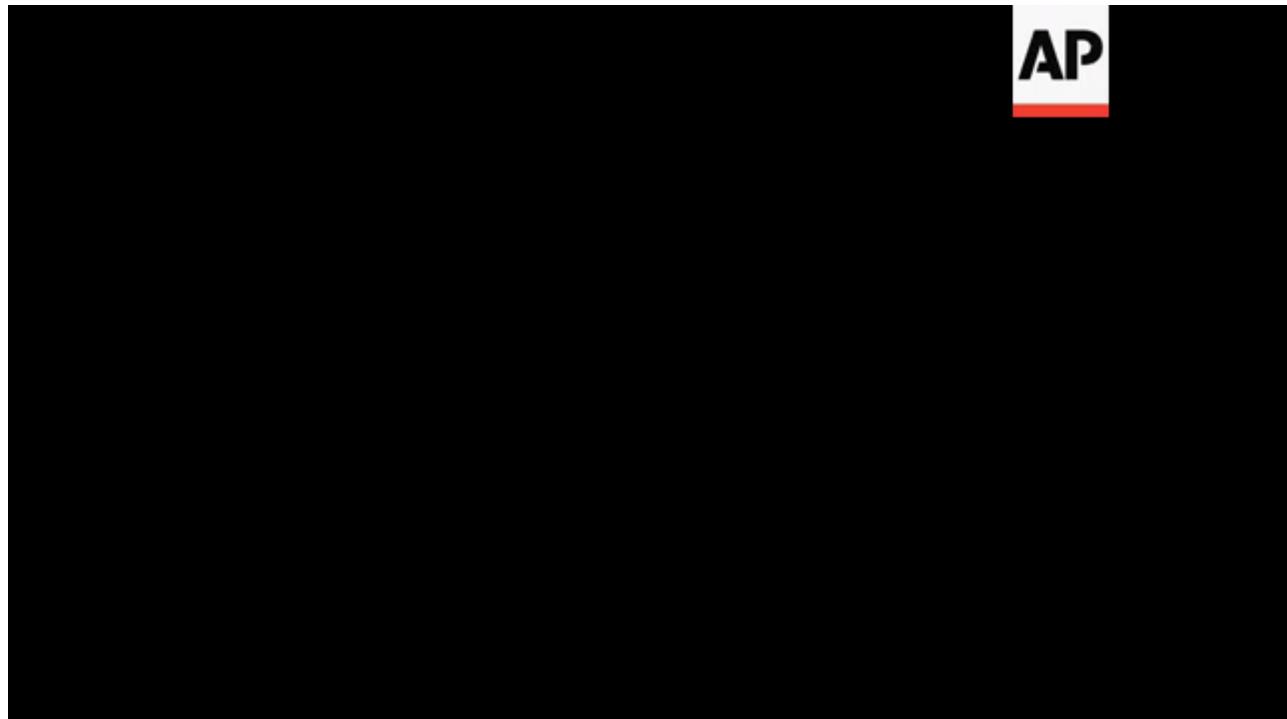


Elektro



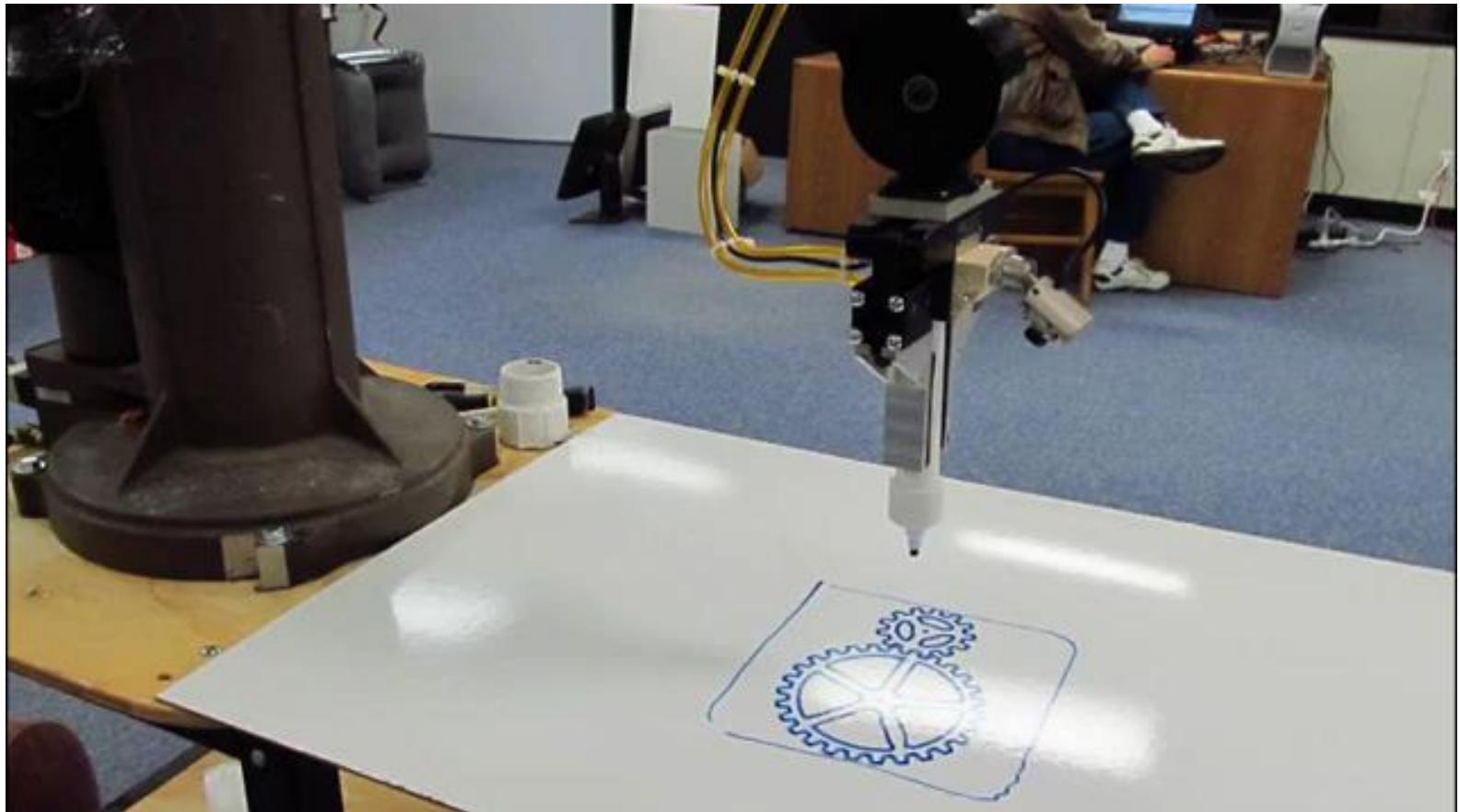
UNIMATE - First industrial robot

- 1954: The first reprogrammable robot is designed by George Devol and his team, who coins the term Universal Automation.
- He later shortens this to Unimation, which becomes the name of the first robot company (1962).
- Initially hardships in selling the product
- UNIMATE originally automated the manufacturing of TV picture tubes



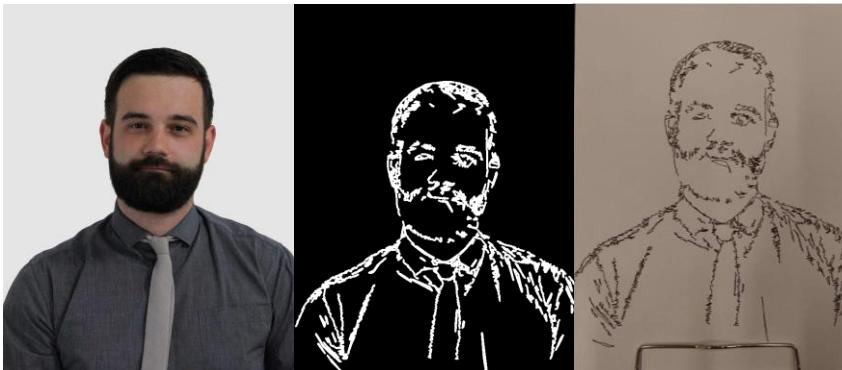
Puma - 1978

- Programmable Universal Machine for Assembly
- Developed by Unimation with a General Motors design support



We have drawing robot as well

- Former project from our Computational Intelligence course
- Custom endeffector



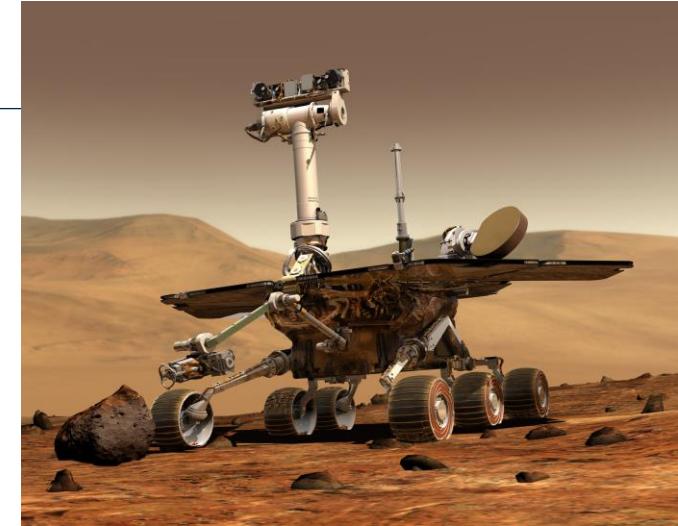
Ages of heroes in robotics – 1980s

- The robot industry enters a phase of rapid growth.
- Many institutions introduce programs and courses in robotics. Robotics courses are spread across mechanical engineering, electrical engineering, and computer science departments.



Close past – emerging applications

- 1995-present: Emerging applications in small robotics and mobile robots drive a second growth of start-up companies and research
- 2003: NASA's Mars Exploration Rovers will launch toward Mars in search of answers about the history of water on Mars
- DARPA Grand Challenge (2007)
- ... and many more !!!



Robots in culture

From Karel Čapek and Asimov to the Terminator



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Golem of Prague (legend)

- Judah Loew ben Bezalel, the late 16th-century rabbi of Prague, also known as the Maharal, who reportedly "created a golem out of clay from the banks of the Vltava River and brought it to life through rituals and Hebrew incantations to defend the Prague ghetto from antisemitic attacks and pogroms"



The term „Robot”

- The term of ‘robot’ was first introduced in 1921 in Karel Čapek’s - R.U.R. (Rossum’s Universal Robots).
- Word „robot” → ‘roboťa’ (czech) = *forced labor* or simply *work*



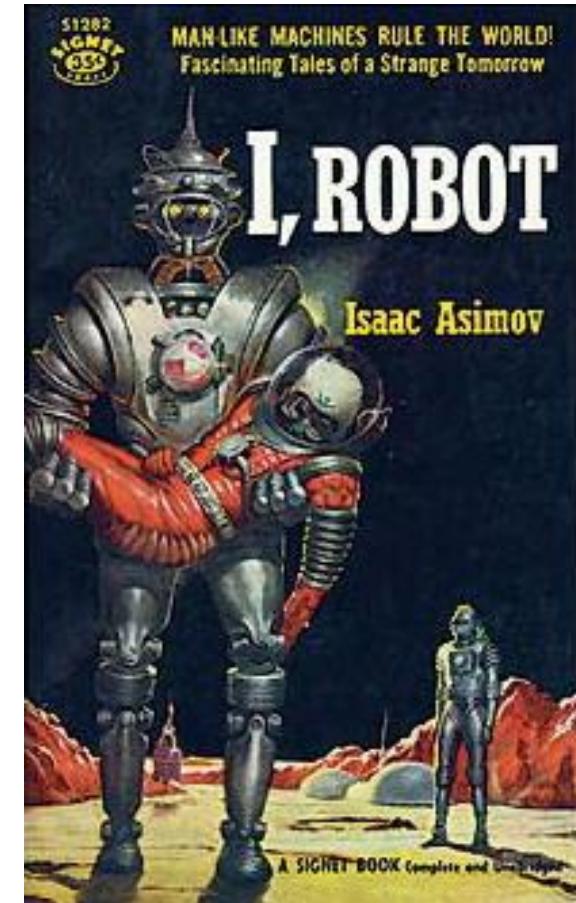
R.U.R. plot

- Robots are artificial creatures
- Created for doing laborious work
- They resemble to human (flesh and blood body, only they have no reproduction organs)
- Once the robot „population” uprises to the human „enslavers”
- They practically wipe out the human race → The engineers who were able to repair them are also killed
- At the end two robots somehow figure out how to reproduce → Adam and Eve of the new robot race



Asimow uses first time the term of „robotics” in 1941

- **First Law**
 - A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- **Second Law**
 - A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- **Third Law**
 - A robot must protect its own existence as long as such protection does not conflict with the First or Second Law
- **Zeroth Law**
 - A robot may not harm humanity, or, by inaction, allow humanity to come to harm.



Tons of films in the topic

Terminator



Star Wars



Wall-E



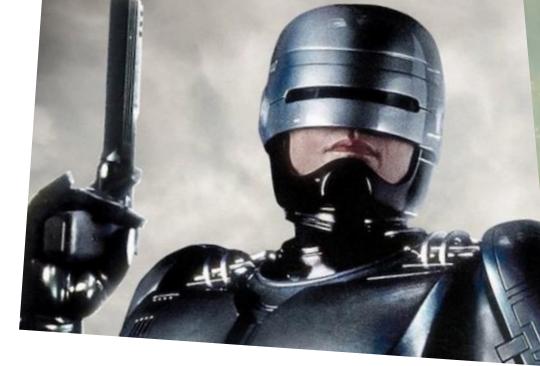
Chappy



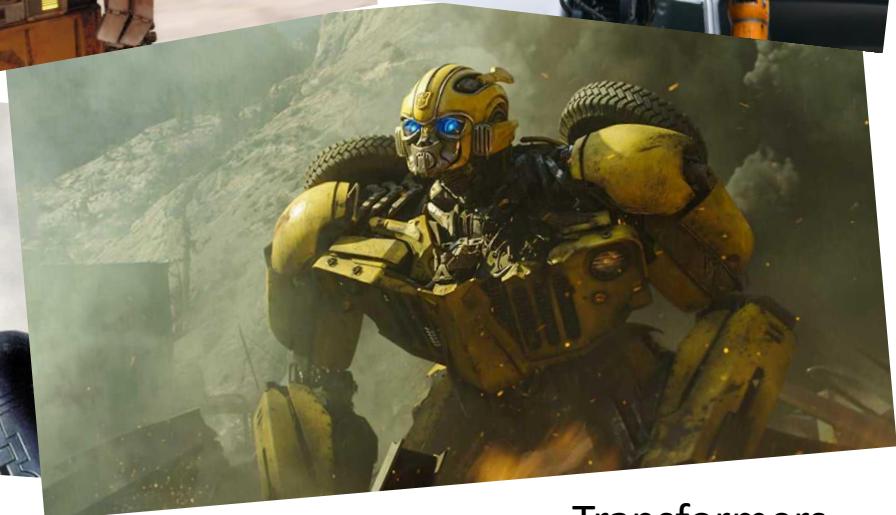
Bicentennial Man



Short Circuit



Robocop



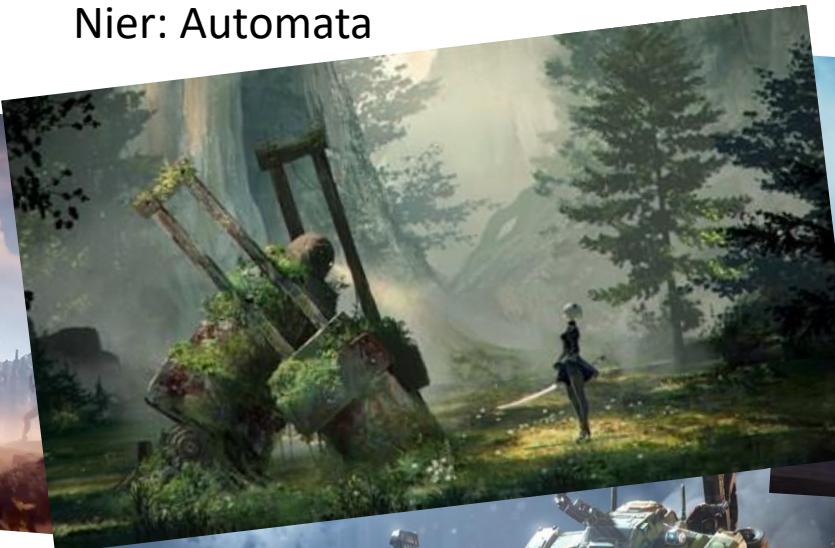
Transformers

Video Games

Horizon Zero Dawn



Nier: Automata



Ratchet and Clank

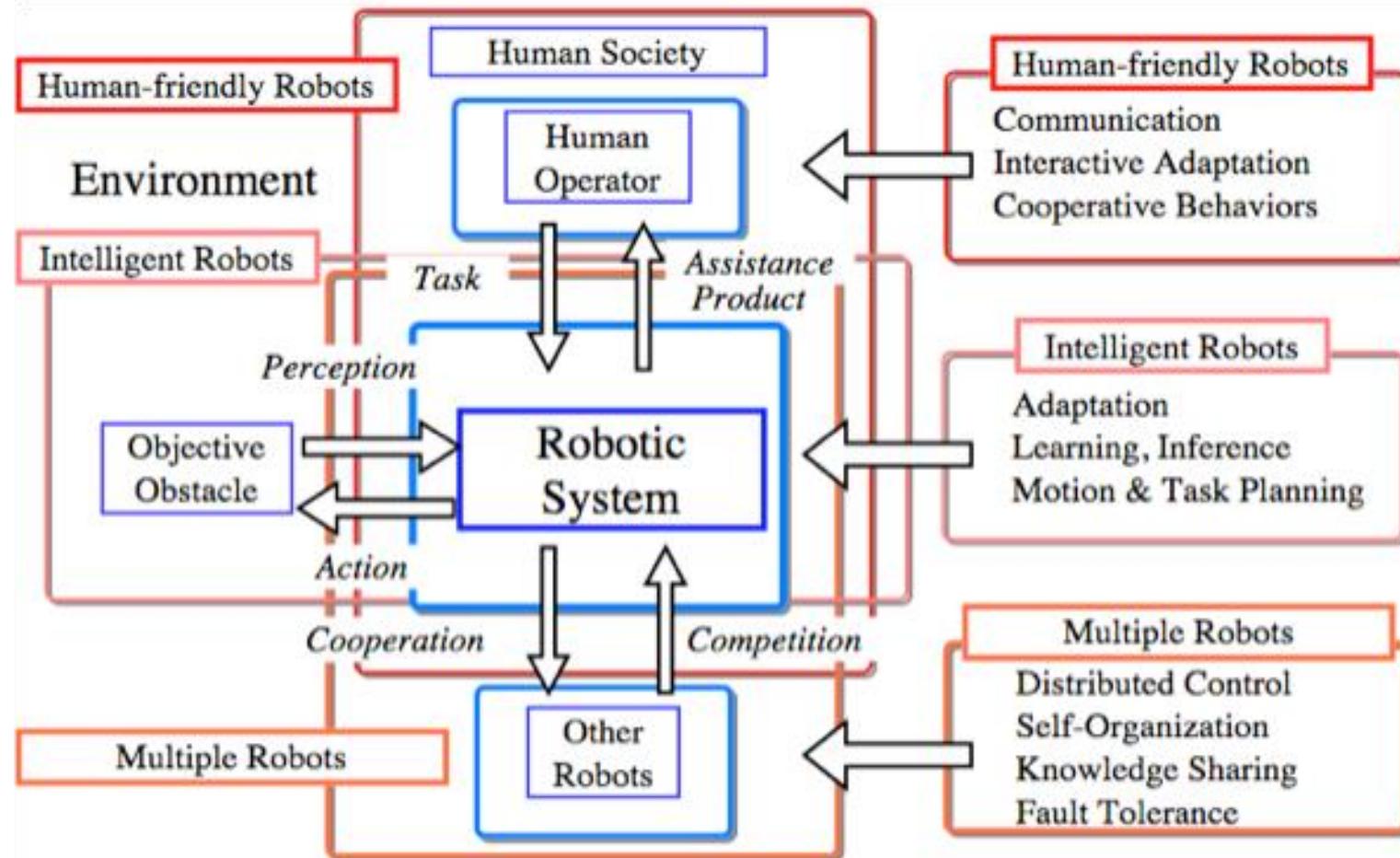


Titanfall

Can't help myself – artistic installation



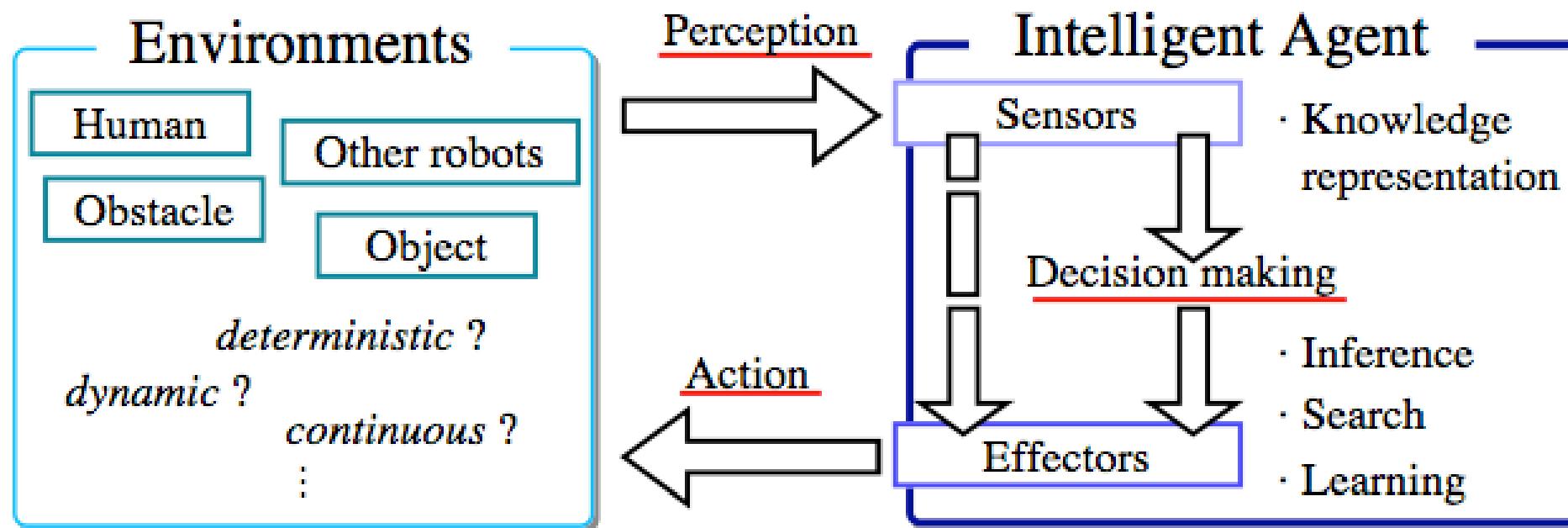
Research streams of robotics



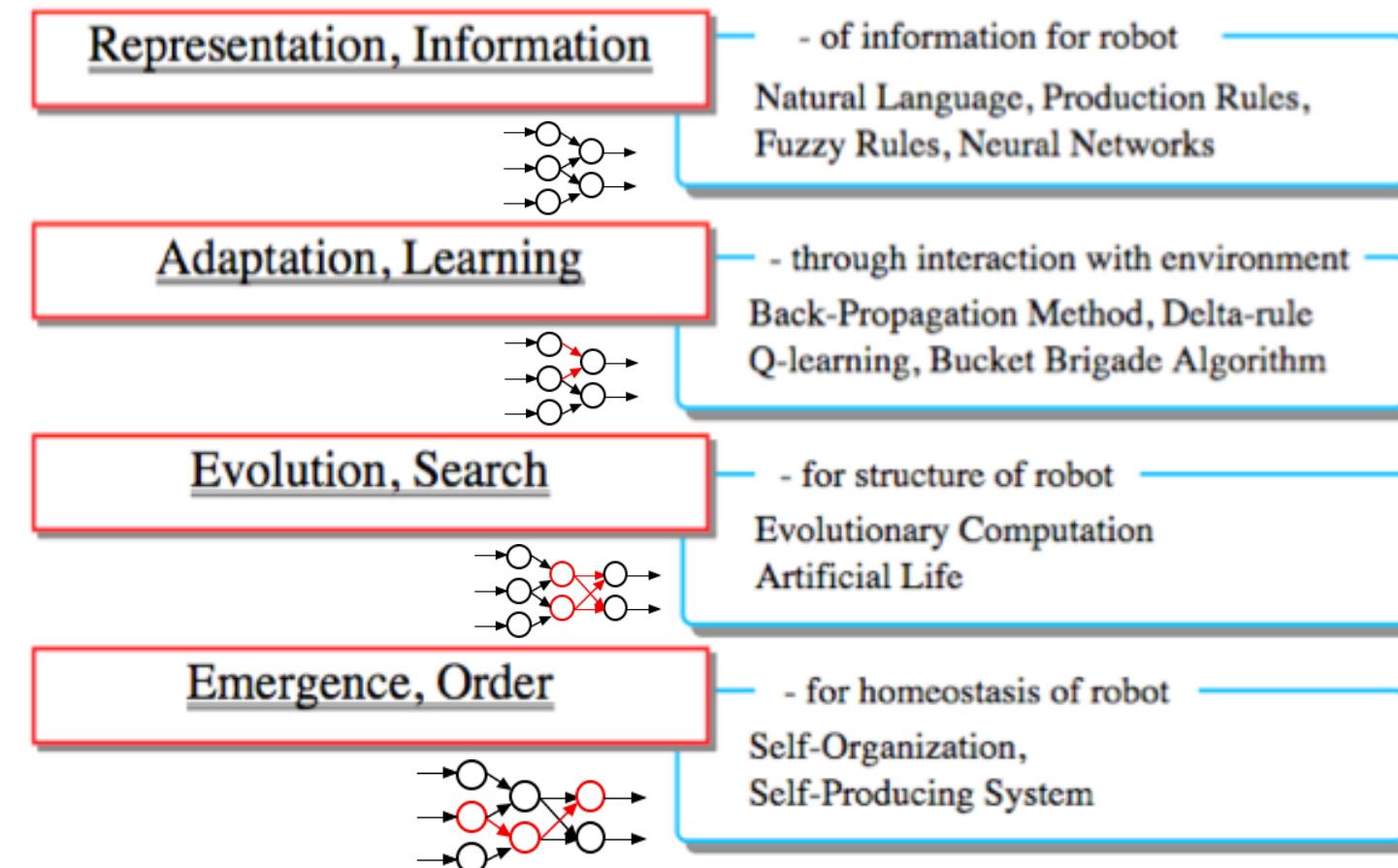
Traditional intelligent robotics

Robotics as the intelligent connection of perception to action

[M.Brady,1987]



Technologies for intelligent robotics



Links of the lecture

- [1] - <https://committee.iso.org/home/tc299>
- [2] - <https://dictionary.cambridge.org/dictionary/english/robot>
- [3] - <https://www.magyar-elektronika.hu/10005-tartalom/2209-belso-szallitasi-feladatok-megoldasa-kollaborativ-robotokkal>
- [4] - https://www.detska-risa.sk/38413-thickbox_default/vector-robot-by-anki.jpg
- [5] - <https://hu.wikipedia.org/wiki/ASIMO>
- [6] - <https://xiaomiplanet.sk/xiaomi-mijia-robot-vacuum-mop-pro-predstavenie-8/>
- [7] - <https://www.nytimes.com/2019/04/30/science/microbots-robots-silicon-wafer.html>
- [8] - https://ifr.org/downloads/press2018/2021_10_28_WR_PK_Presentation_long_version.pdf
- [9] - <https://ieeexplore.ieee.org/document/7827930/>

