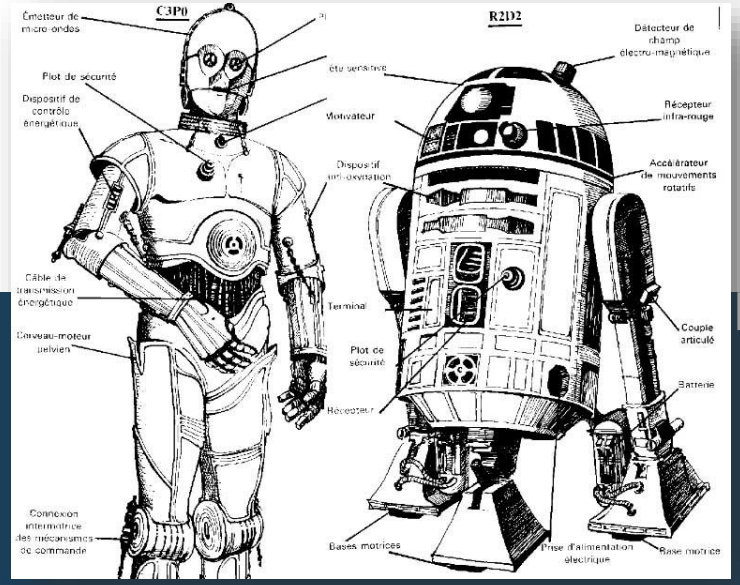
POLITECNICO
MILANO 1863



Robotics

Introduction

Matteo Matteucci
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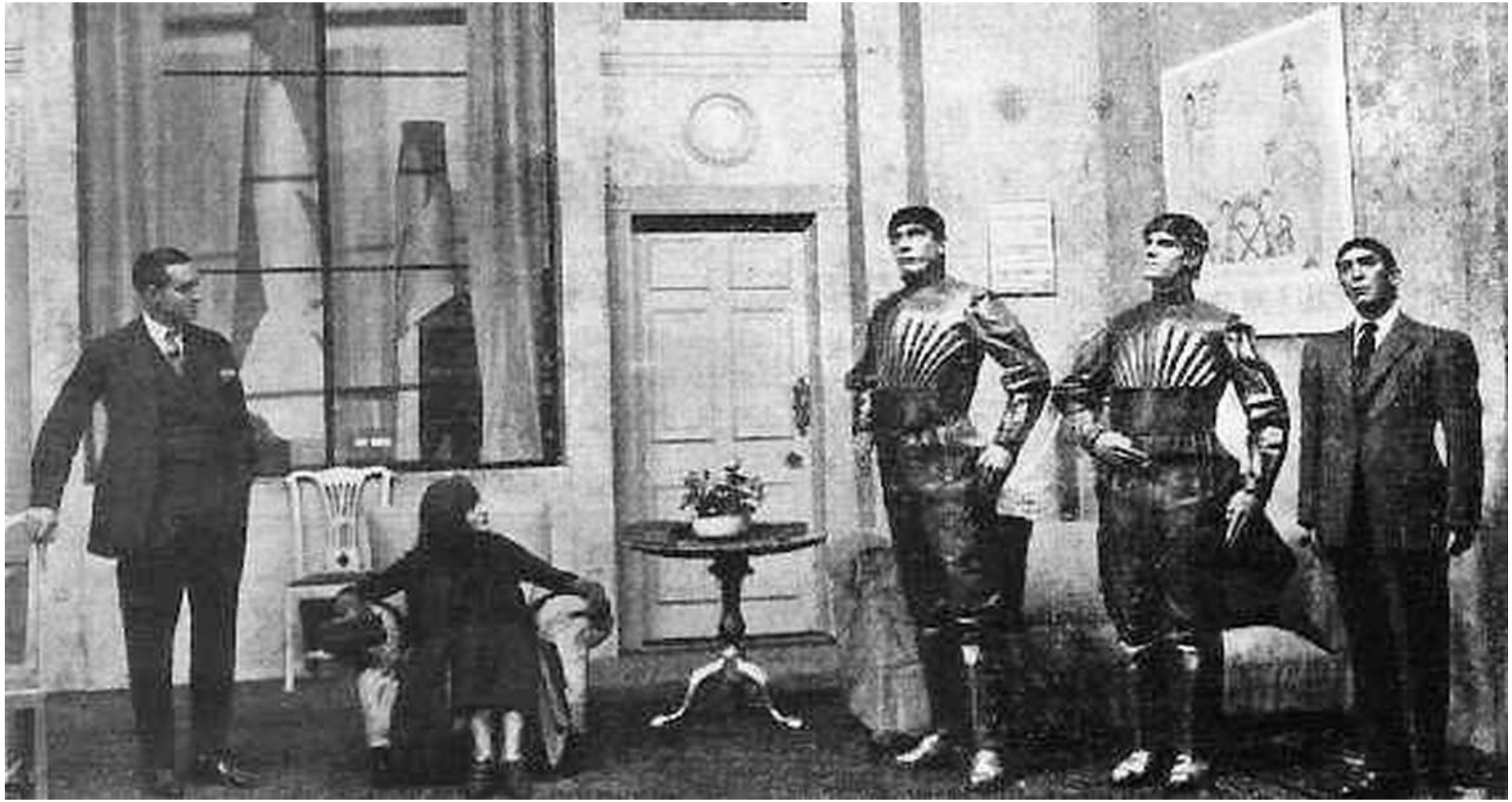
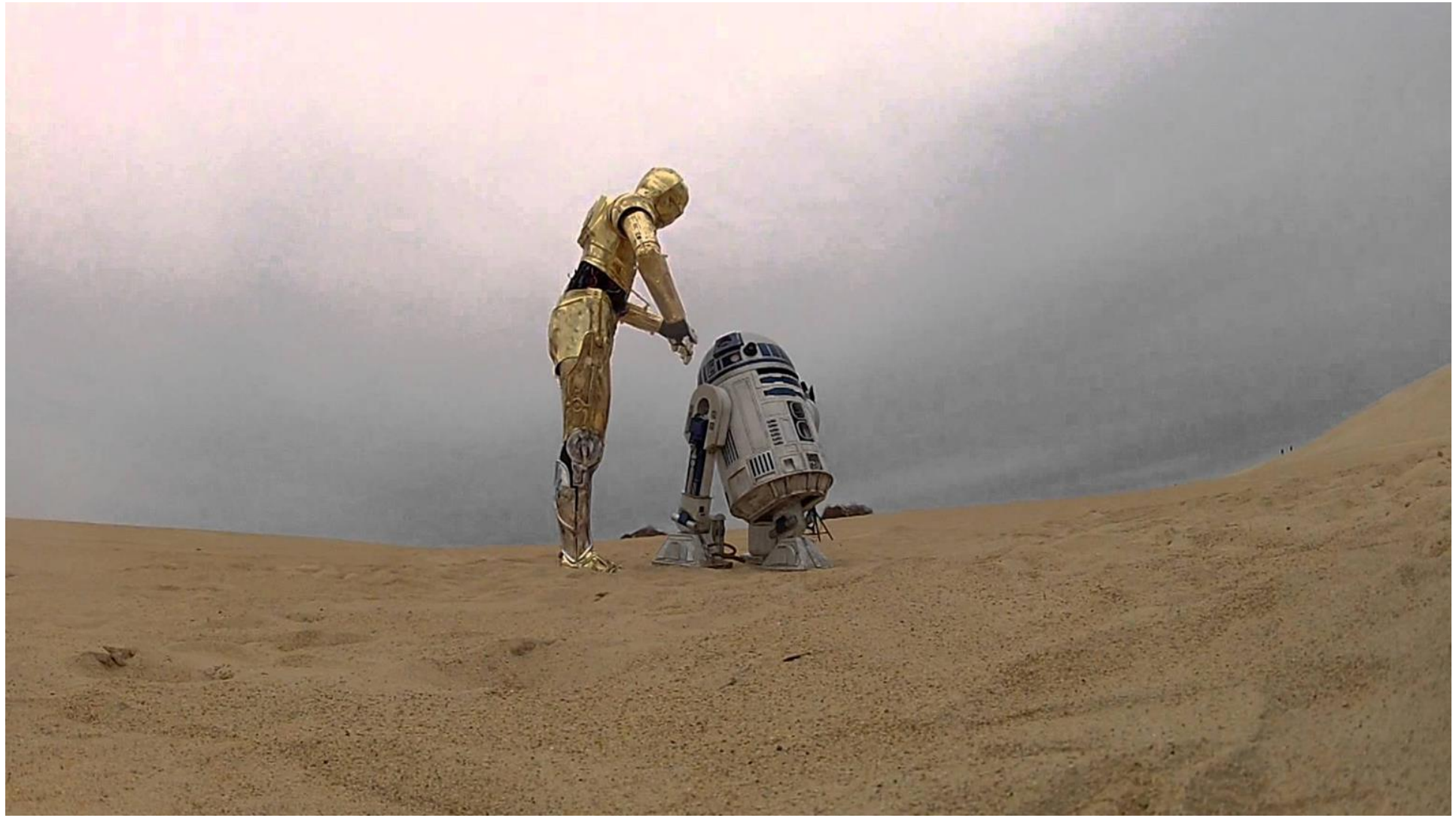
Artificial Intelligence and Robotics Lab - Politecnico di Milano

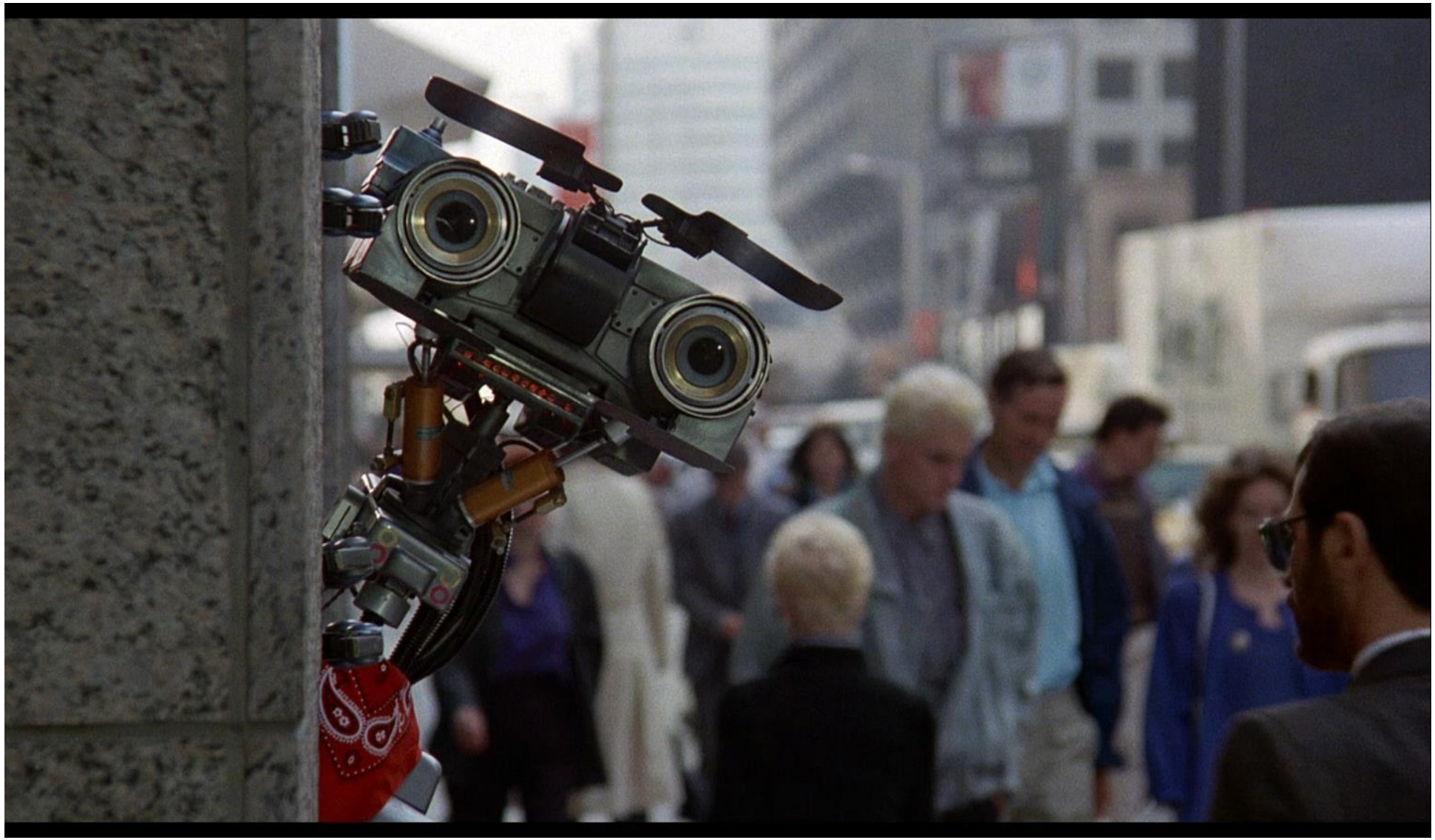
Rossum Universal Robots (1920)



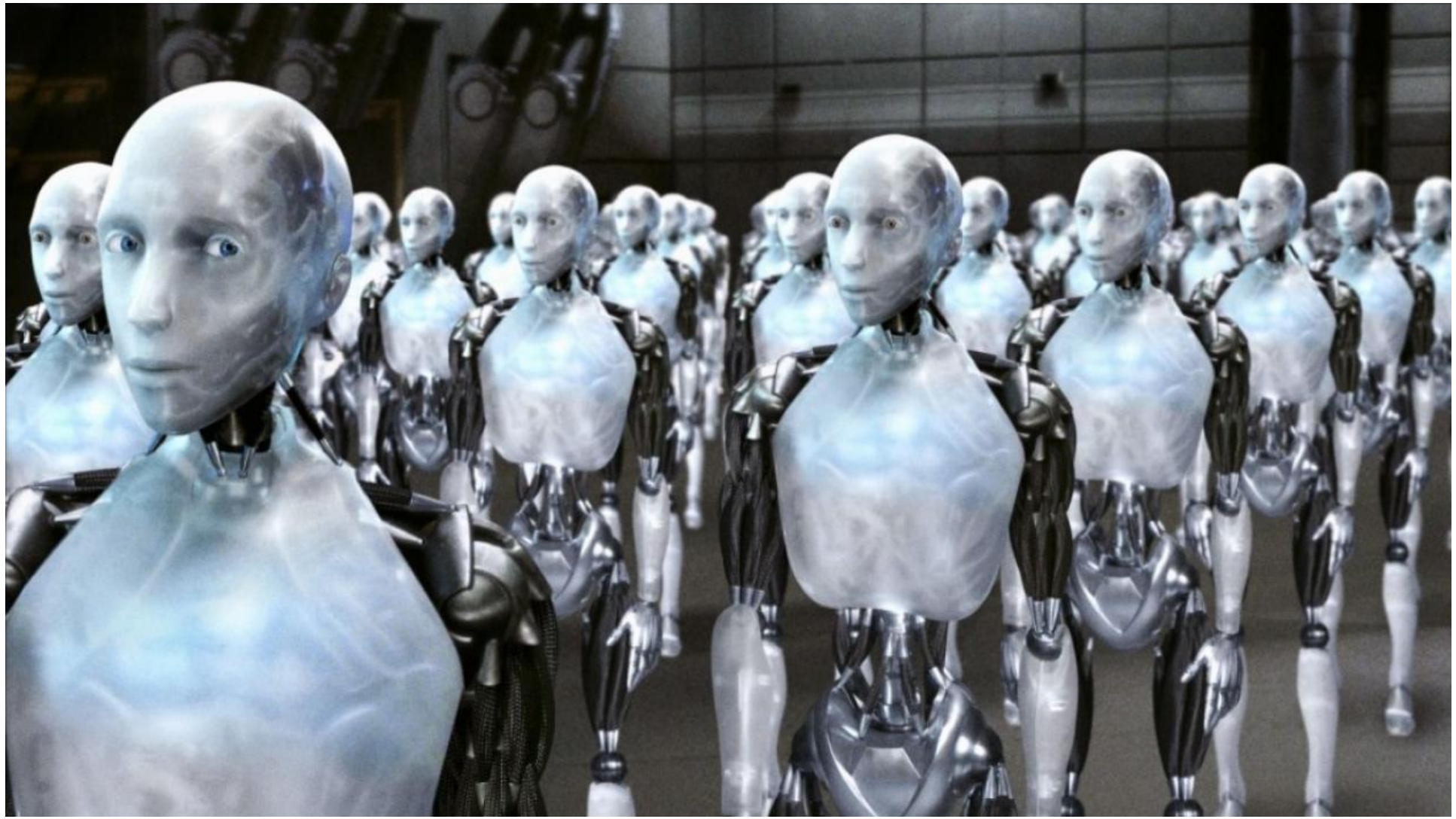
Star Wars (1977)



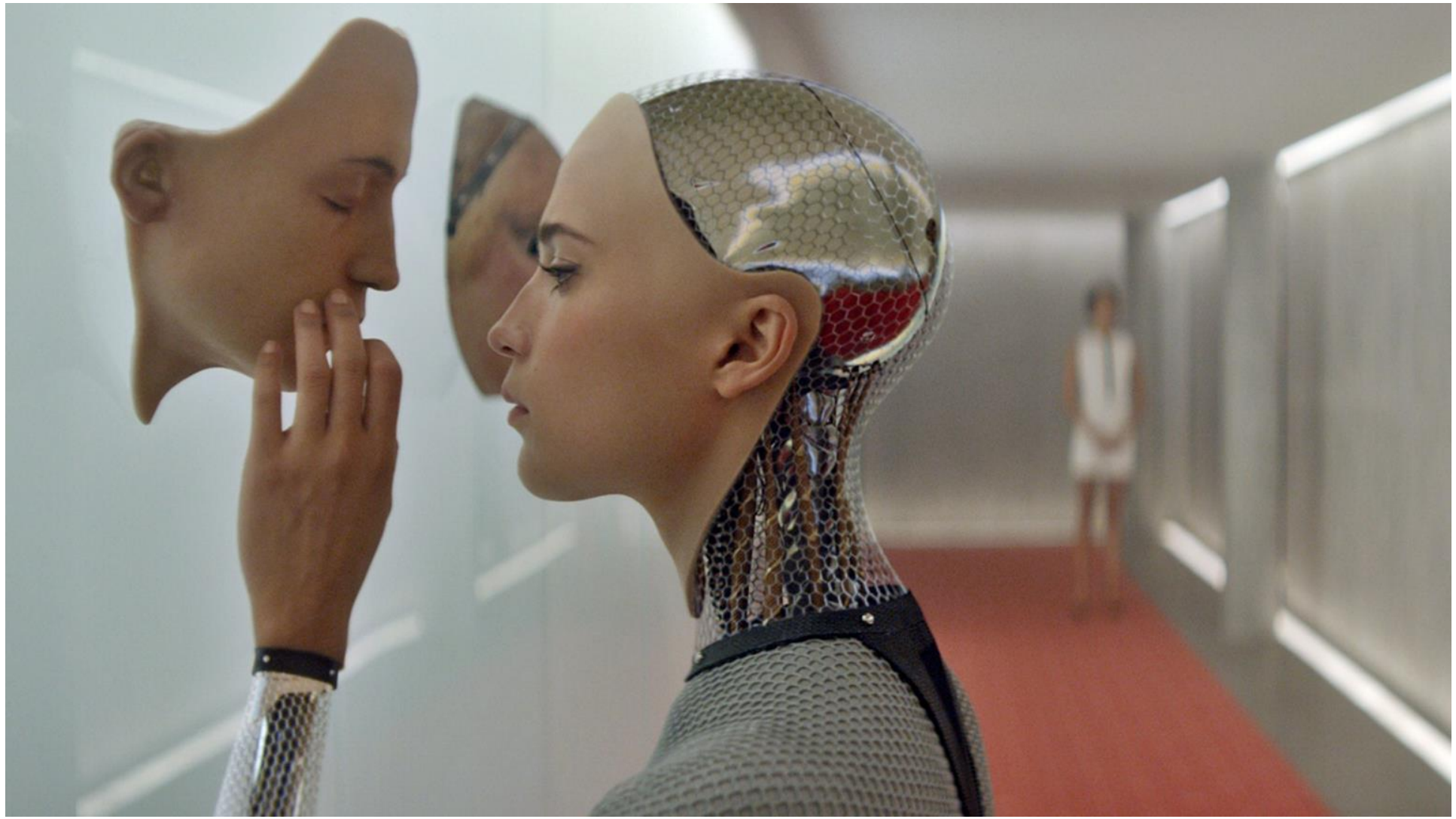
Short Circuit (1986)



I Robot (2001)

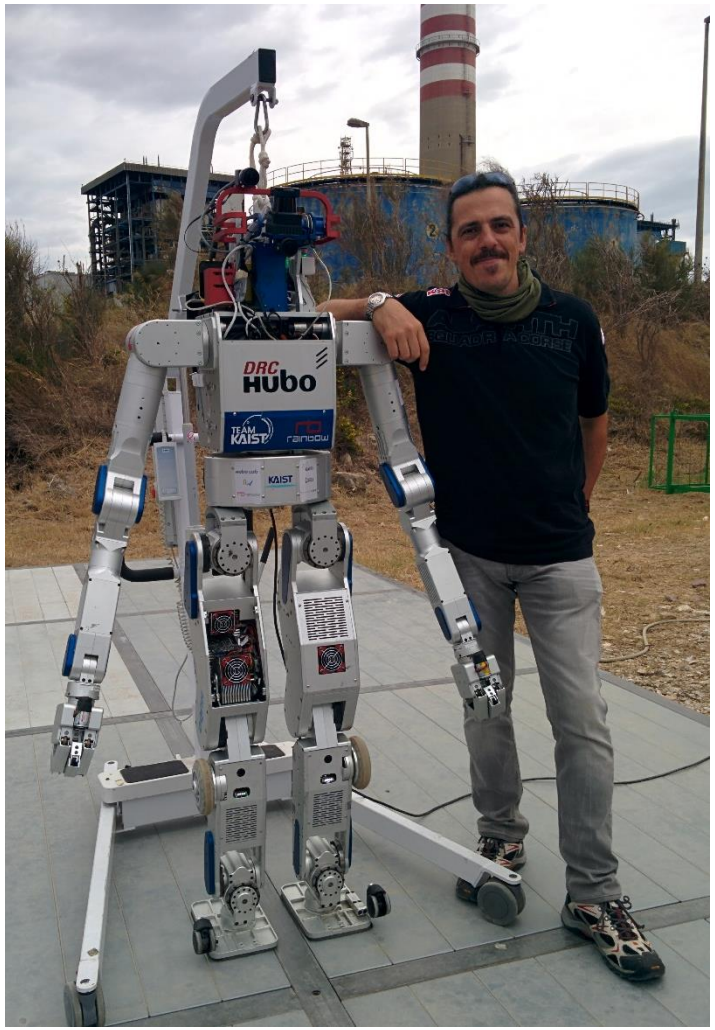


Ex Machina (2015)



Sometimes reality is different...

... and the winner is ...



... and check! Sometimes dreams come true (ATLAS 2016) ...

... and every year it gets better ☺

... and better ☺

Steps in robot history

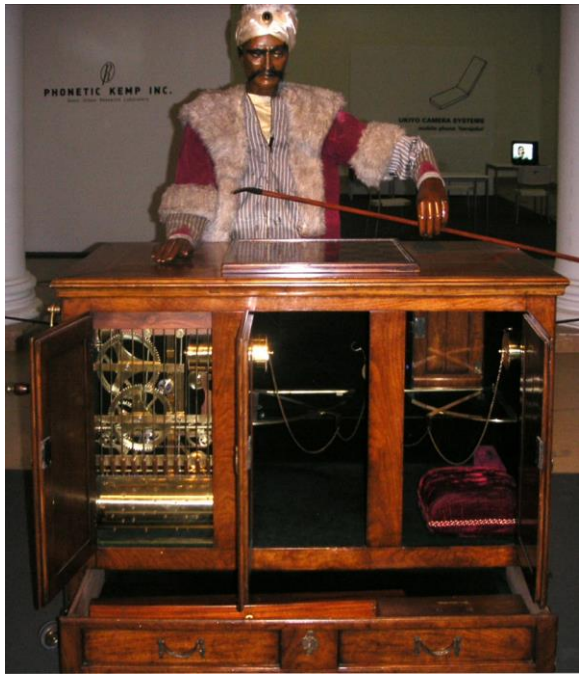
Mechanical era (1700):

- automata
- karakuri-ningyo

Automata: the robot ancestors

Karakuri-ningyo
Edo Period
(1603 – 1868)

The Writer
Pierre Jaquet-Droz
(1721-1790)



The Turk
Wolfgang von Kempelen
(1734 – 1804)

Steps in robot history

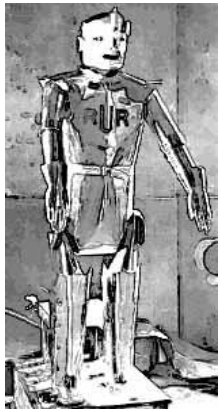
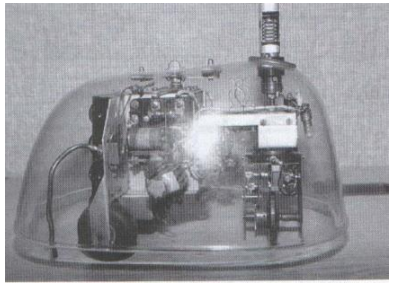
Mechanical era (1700):
- automata
- karakuri-ningyo

Fiction era (’20s):
- *Rossum Universal Robot*

Cybernetics era (‘40s):
- Turtle and telerobot

Automation era (from the ‘60s):
- Industrial robots




First robots

1961 - UNIMATE, the first industrial robot, began work at General Motors. Obeying step-by-step commands stored on a magnetic drum, the 4,000-pound arm sequenced and stacked hot pieces of die-cast metal.

1968 - Marvin Minsky developed the Tentacle Arm, which moved like an octopus. It had twelve joints designed to reach around obstacles. A PDP-6 computer controlled the arm, powered by hydraulic fluids. Mounted on a wall, it could lift the weight of a person.

What is a Robot?

A reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks.

(Robot Institute of America, 1980)

An what about these???

We need a different defintion of robot!

3DRobotics

jibo

STARSHIP

Steps in robot history

Mechanical era (1700):
- automata
- karakuri-ningyo

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- *Rossum Universal Robot*

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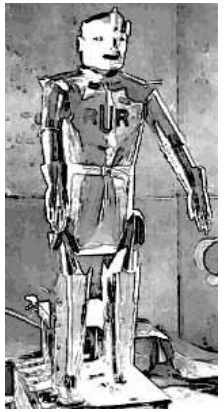
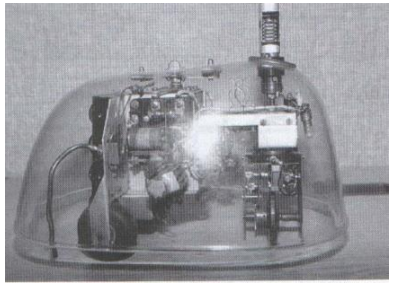
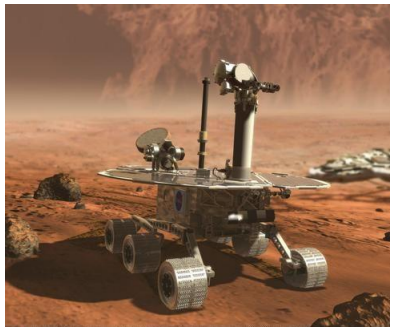
Automation era (from the ‘60s):
- Industrial robots

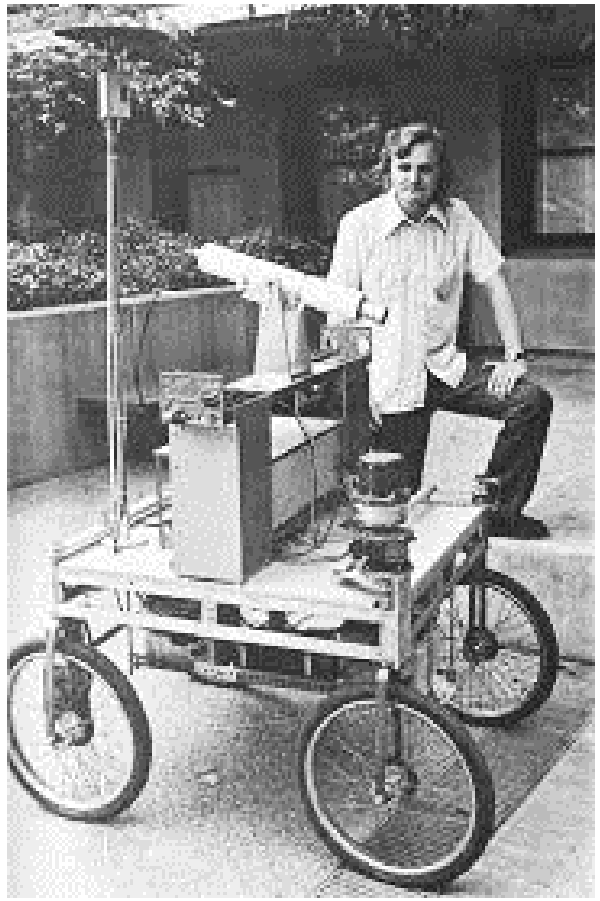
Information era (from the ‘90s):
- Intelligence
- Autonomy
- Cooperation






Shakey (1972) and the Stanford Cart (1970)

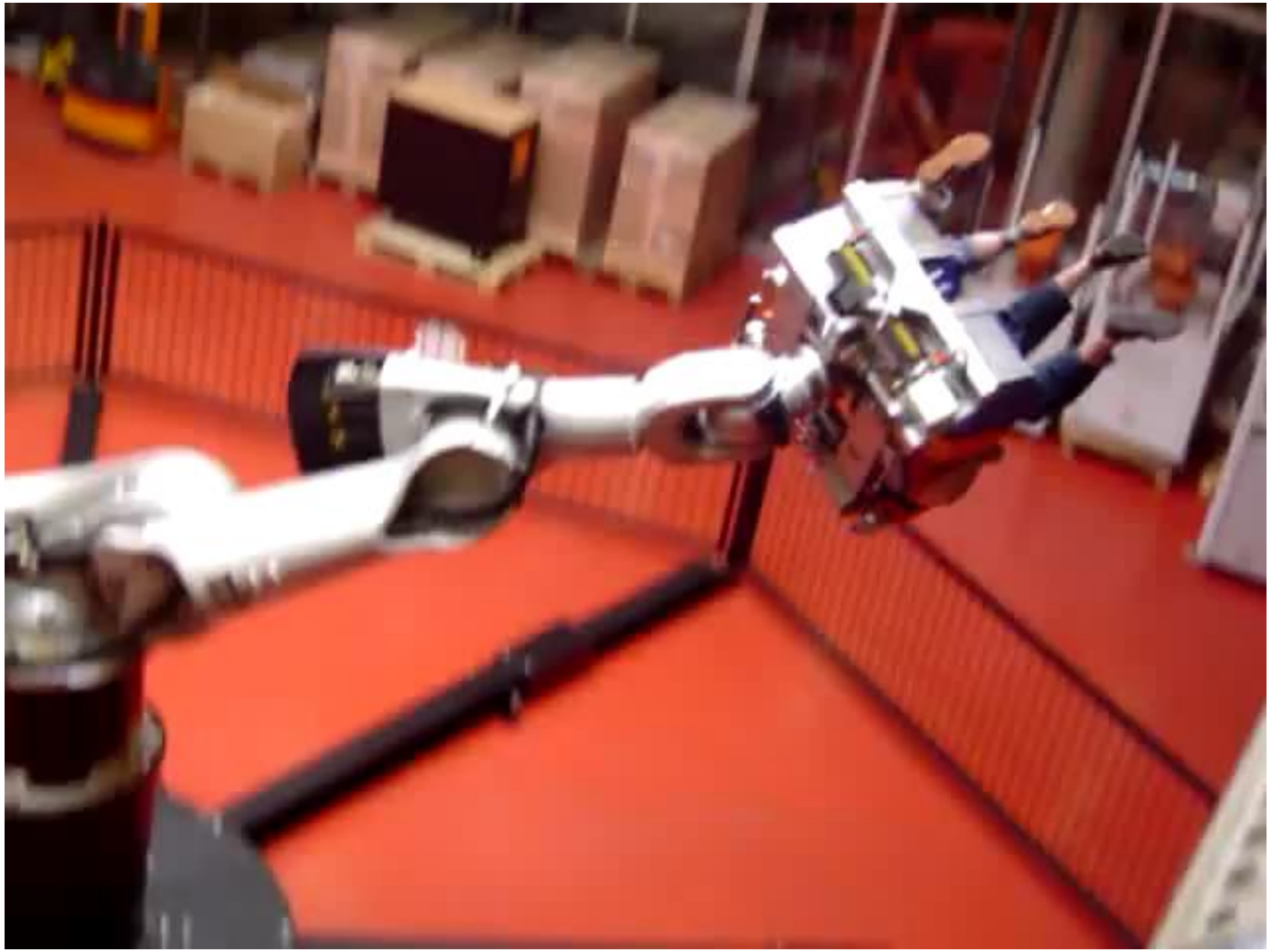


ISO 8373:2012 - Robots and robotic devices

International Organization for Standardization

- ✓A robot is an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks. Autonomy in this context means the ability to perform intended tasks based on current state and sensing, without human intervention.
- ✓A service robot is a robot that performs useful tasks for humans or equipment excluding industrial automation application.

Industrial vs Service Robotics



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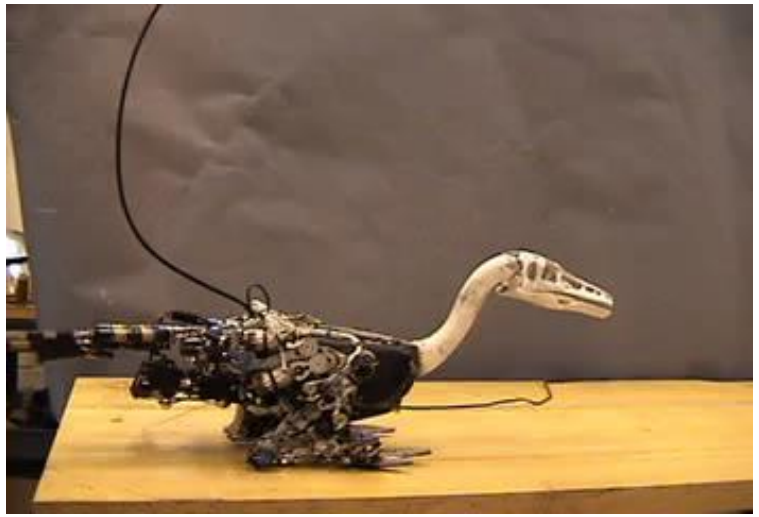
- ✓ A personal service robot or a service robot for personal use is a service robot used for a non-commercial task, usually by lay persons. E.g., domestic servant robot, automated wheelchair, personal mobility assist robot, and pet exercising robot.

Autonomous service robot





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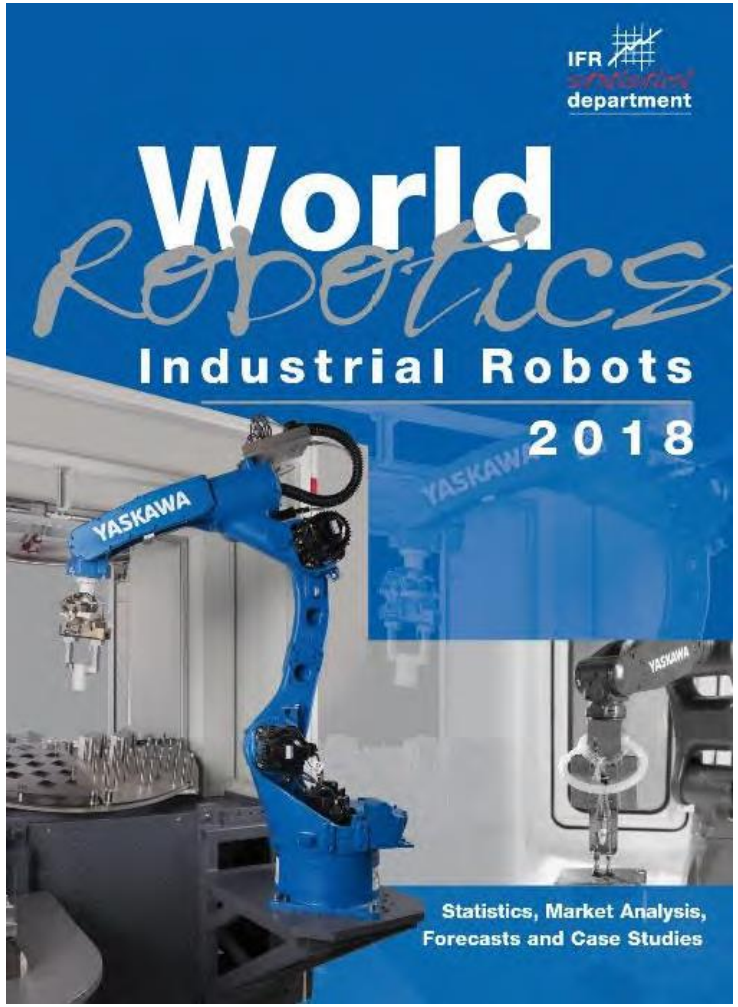
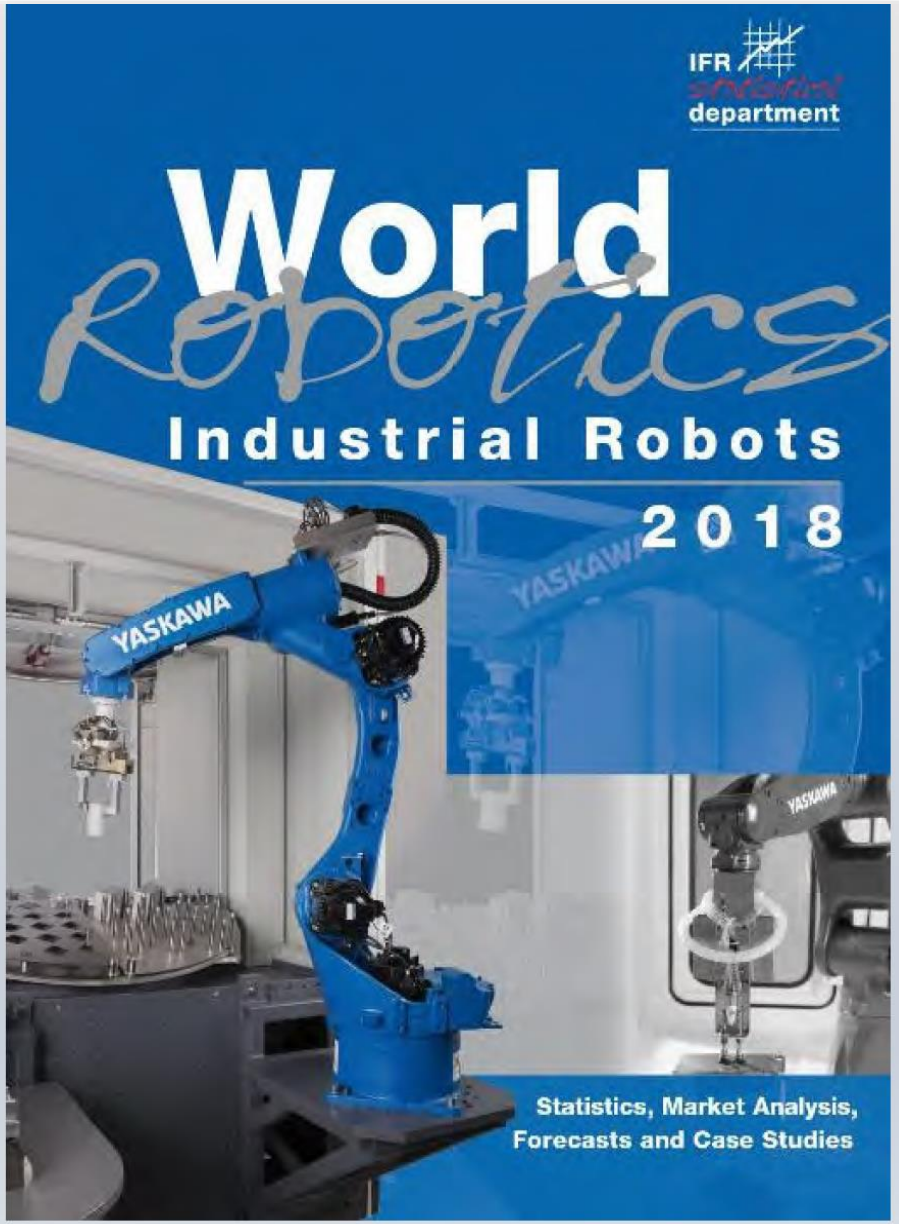
- ✓ A professional service robot or a service robot for professional use is a service robot used for a commercial task, usually operated by a properly trained operator. E.g., cleaning robot for public places, delivery robot in offices or hospitals, fire-fighting robot, rehabilitation robot and surgery robot in hospitals. In this context an operator is a person designated to start, monitor and stop the intended operation of a robot or a robot system.

Industrial and Service Robots Market (https://ifr.org/free-downloads)





Records, records

IFR International Federation of Robotics

2017: 381,300 units, +30%

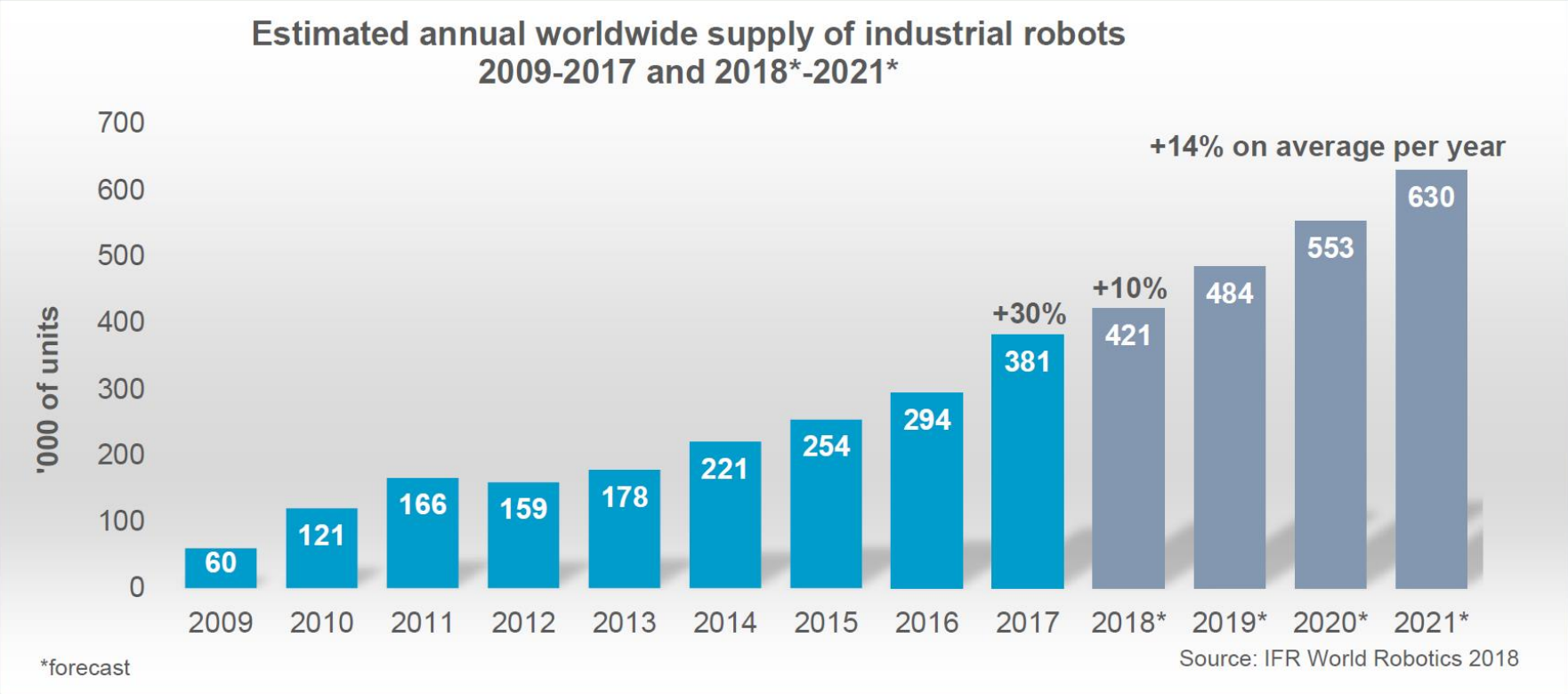
2018: 421,000 units, +10%

2021: 630,000 units,

+14% on average per year

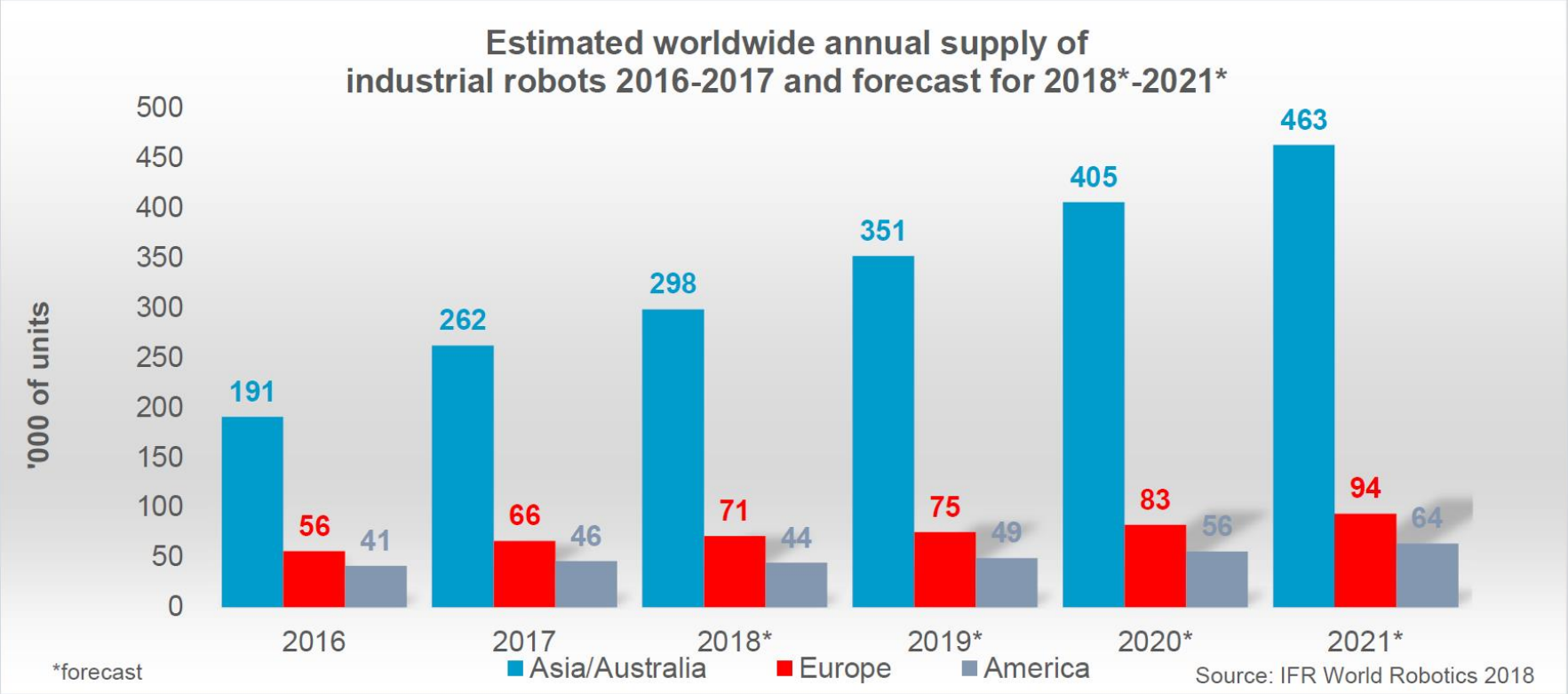
Continued record sales since 2013

IFR International Federation of Robotics



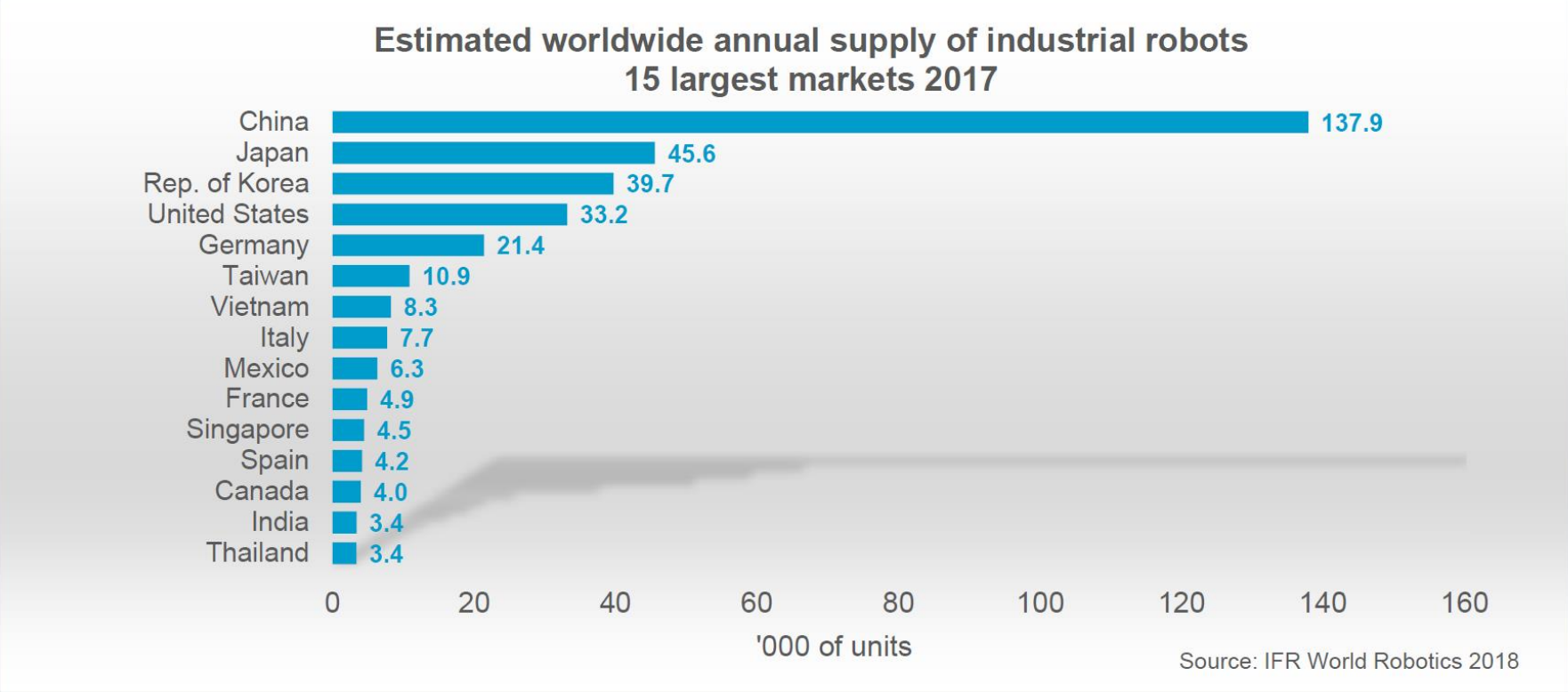
Emerging region Asia

IFR International Federation of Robotics

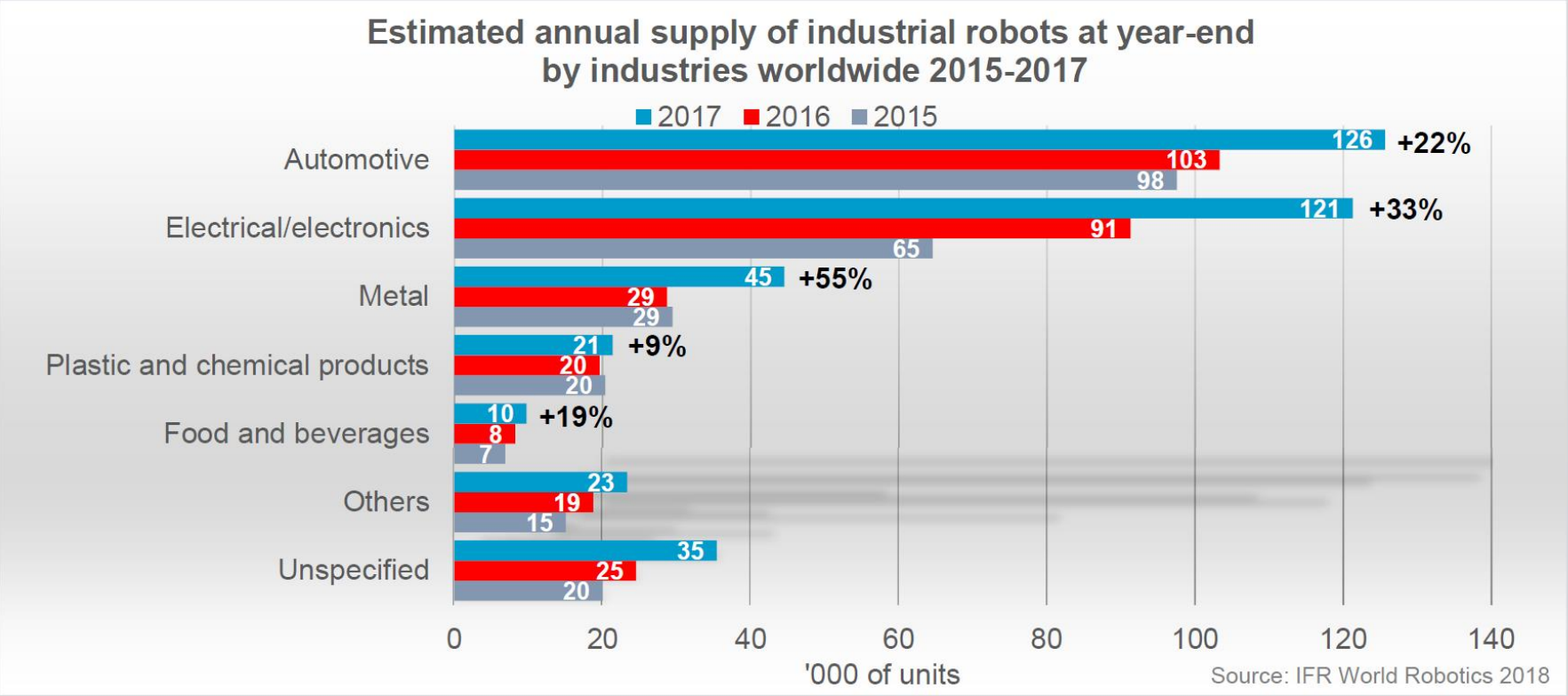


China has significantly expanded its leading position

IFR International Federation of Robotics



Main drivers of the growth 2017: automotive, electronics, metal



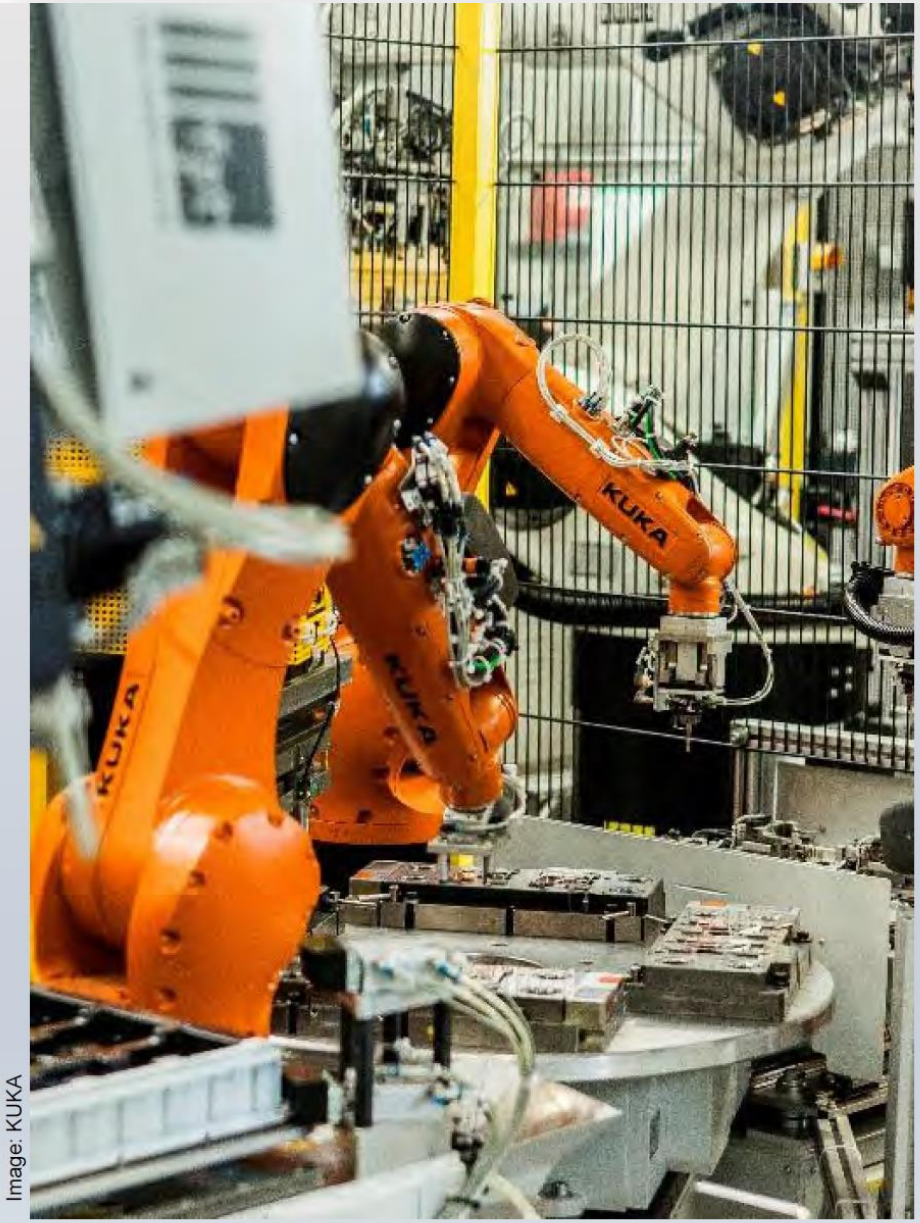


Image: KUKA

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Key Drivers for Automation more relevant than ever

- Shift to high mix/low volume production
- Global competitiveness
- Digitalization of manufacturing – Industry 4.0
- Growing consumer markets
- Energy efficiency-driven technology shifts
- Regionalized production

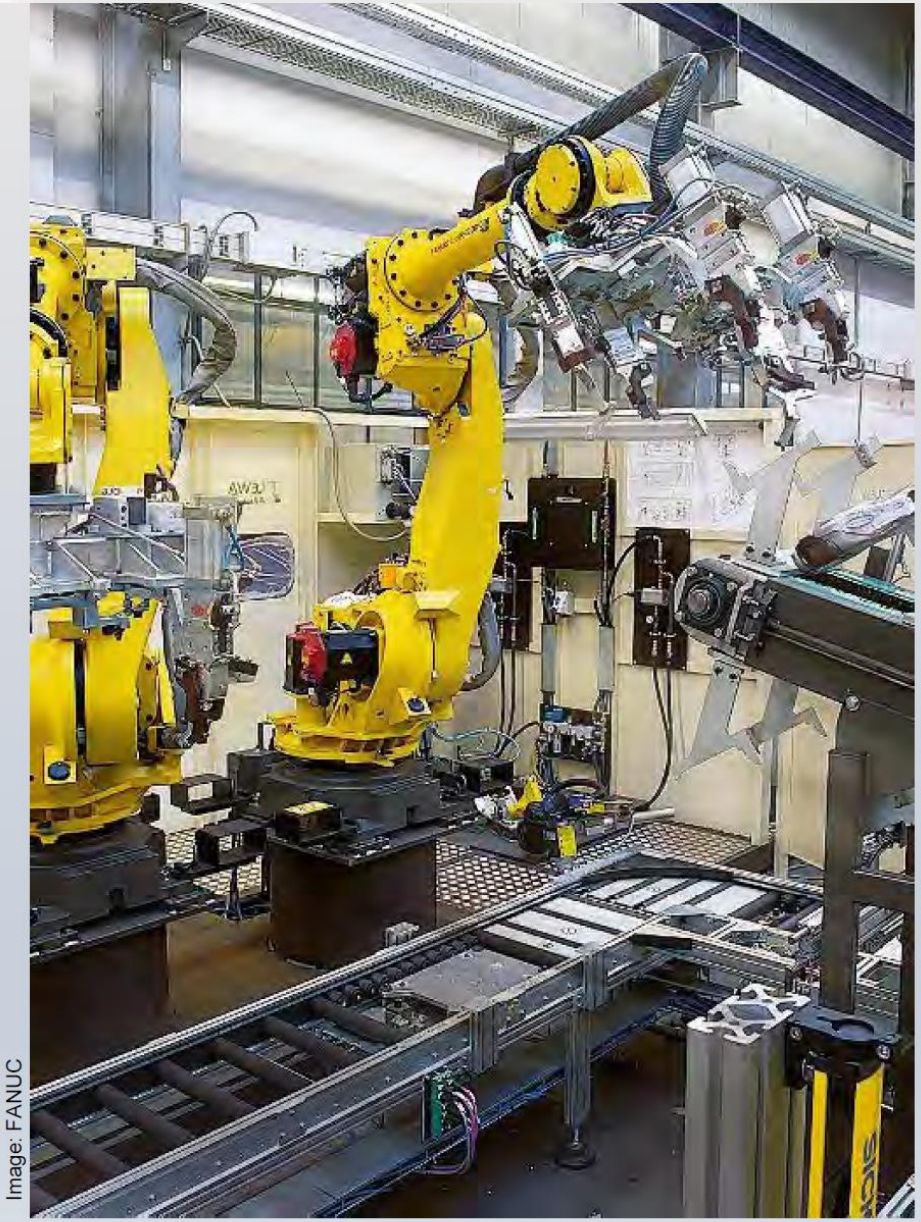

Image: FANUC

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Main customer: automotive industry

Transition from Internal Combustion Engines (ICE) to electric vehicles/hybrids

Increased complexity

Customization – increasing mix requires more flexible production

Automation of final assembly

Automotive parts suppliers – more SME's will use robots

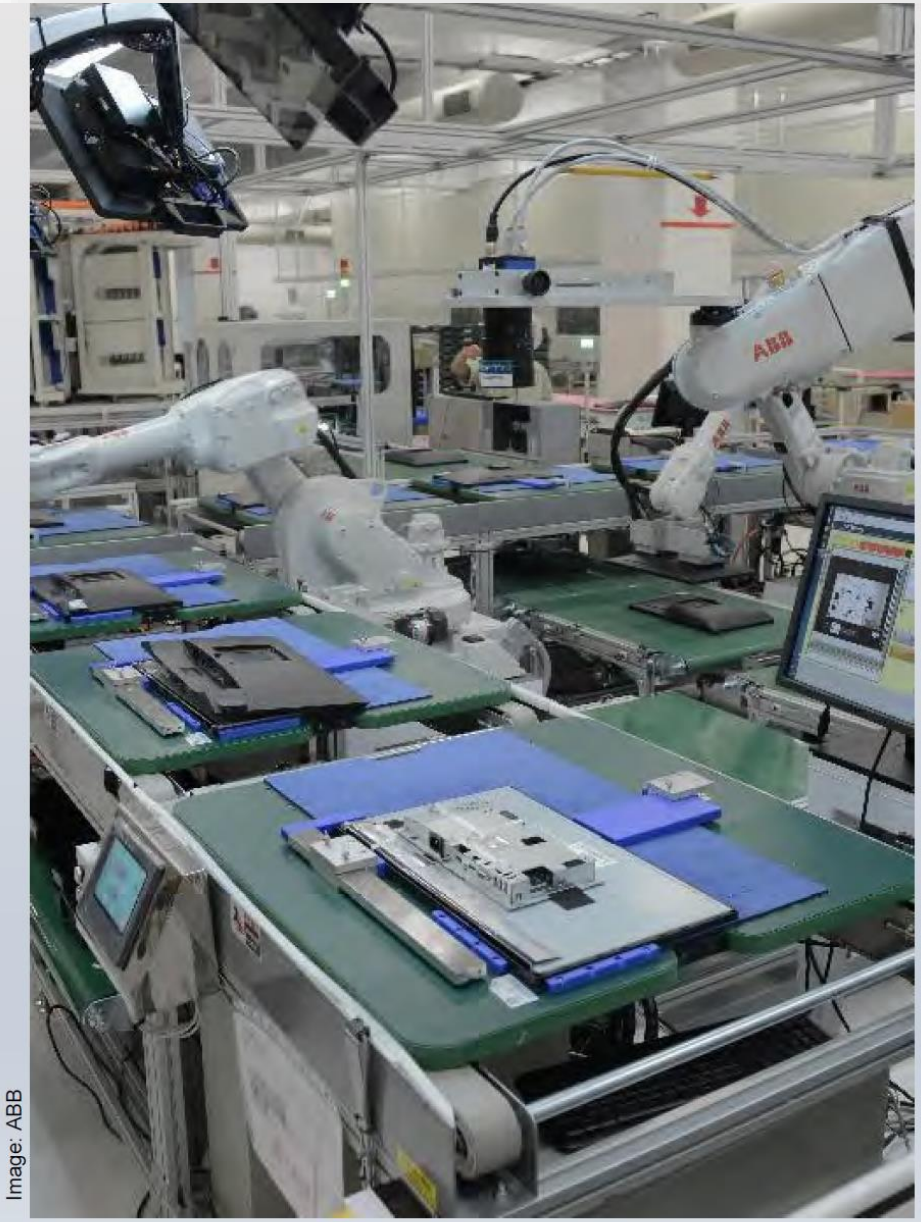

Image: ABB

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Main customer: electrical/electronics industry

- Continuously increasing demand for batteries, chips and displays
- Short life cycles of electronic products
- High turnover of people with associated labor shortages
- Increasing degree of robot adoption
- Higher quality demands on manufacturing process

Image: Yaskawa

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Robot sales will in increase in all other industries

Metal industries – more flexibility and cost efficiency

Rubber and plastics industry – more integrated manufacturing concepts

Food and beverage industry – shift to even shorter production runs

Pharmaceutical industry - improving productivity without sacrificing quality

Technological Developments expanding Robot Adoption

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Today

- **More intelligent components, e.g. Smart Grippers**
- **Greater connectivity, e.g. "Plug & Play" interfaces and Cloud Computing**
- **Easier to Use, e.g. "Programming by Demonstration"**

Tomorrow

"Machine learning" enables robots ….

- to learn by trial-and-error or by video demonstration.
- to self-optimize.
- to communicate with other machines to improve entire processes.

New business models, e.g. Robotics as a Service (RaaS)

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Professional Service Robots have entered our daily lives

Value of sales

2017: US$ 6.6 bn, +39%

2018: US$ 8.7 bn, +33%

2019-2021: US$ 37 bn, +19% (CAGR)

Unit sales:

2017: 109,500 units, +85%

2018: 165,300 units, +32%

2019-2021: 736,600 units, +21% (CAGR)

Professional Service robots: Main drivers of the value growth are logistic systems

IFR International Federation of Robotics

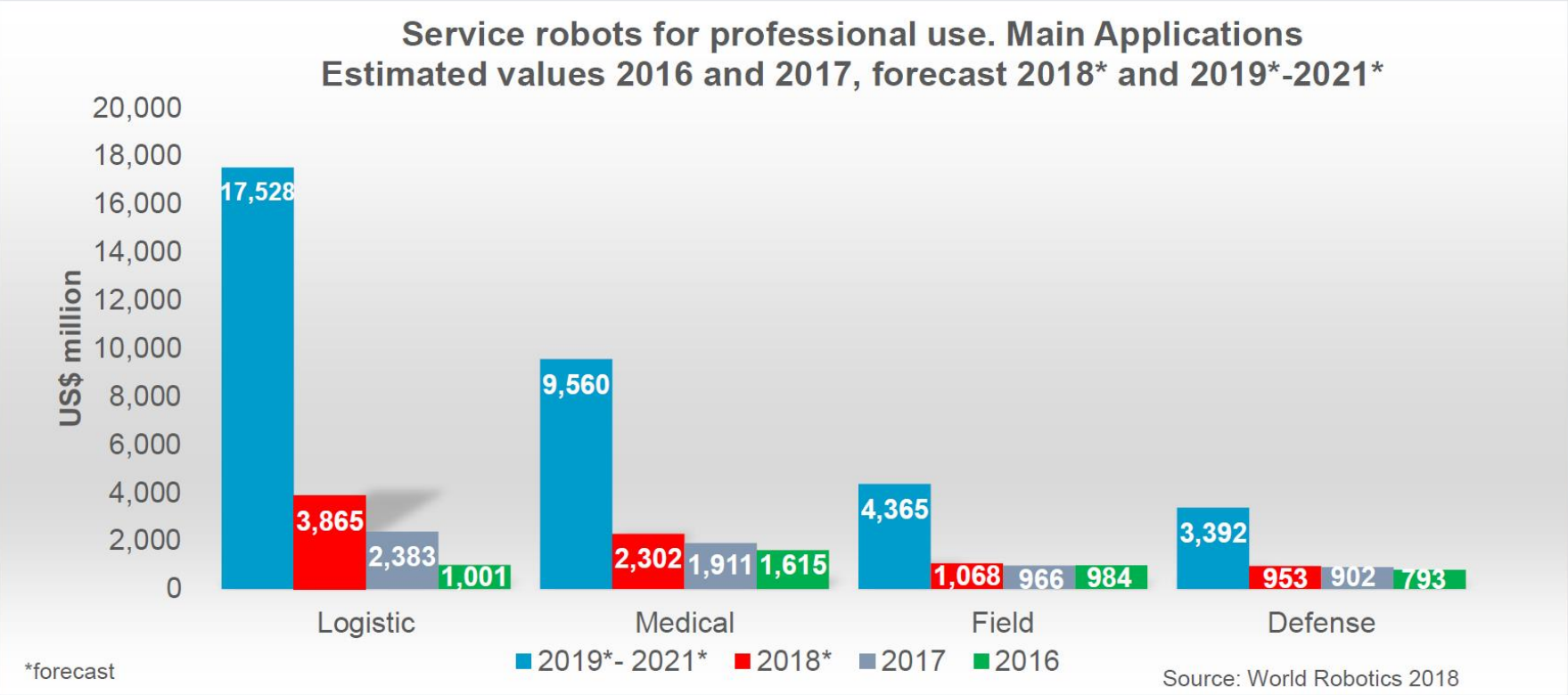

Image: Omron

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AGVs in factories, warehouses, logistic centers, hospitals…

69,000 units installed in 2017, 162% more than in 2016

- 6,700 units in manufacturing
- 62,200 units in warehouses, logistic centers, hospitals …

2018:

115,000 units, 66% higher than in 2017

2019-2021:

485,000 units, +18% on average per year

Image: AOT Carlo

Image: Naio

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Medical robots – most valuable service robots: US$ 1.9 billion in 2017

- 2017: 2,900 units, +75%
- 2018: 4,400 units, +49%
- 2019-2021: 22,100 units, +27% (CAGR)

Field robots – mostly milking robots

- 5,400 milking robots in 2017, slight increase
- Still low number but high increase: agricultural robots – 520 units in 2017 up from 190 units
- 2018: 7,200 field robots, +17%
- 2019-2021: 32,700, +22% (CAGR)

Logistic systems are also the drivers of the growth in units

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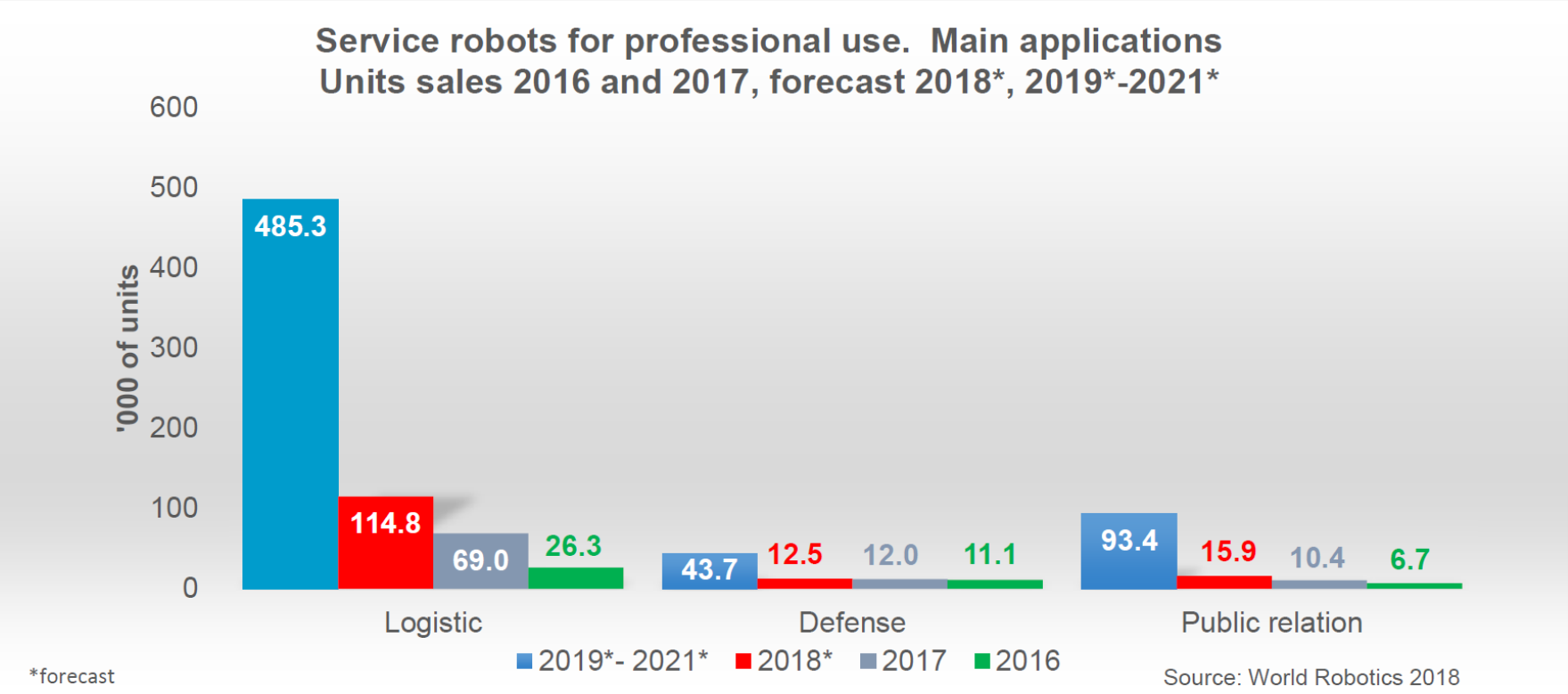

High potential for exoskeletons

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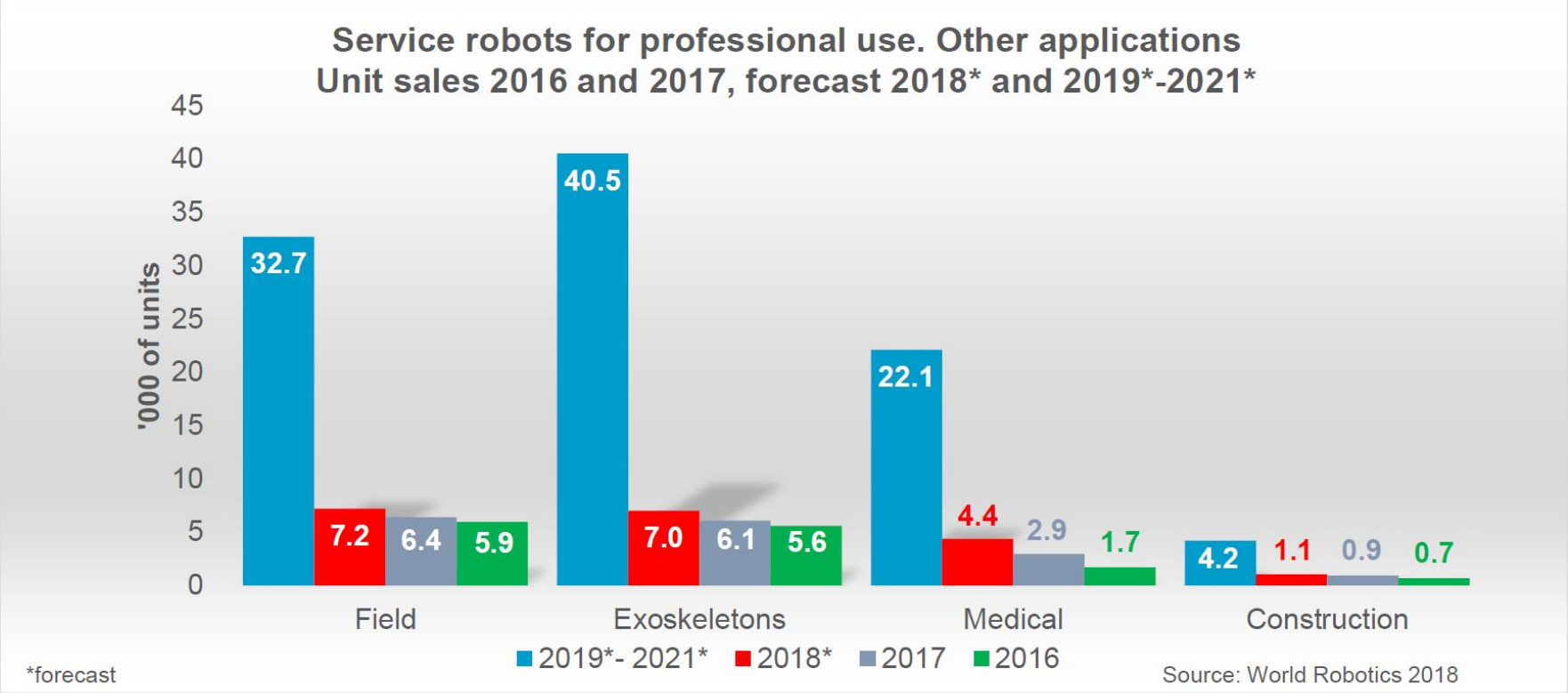

Vacuuming and floor cleaning robots are most established personal/domestic service robots / revised graph 5 Dec. 2018

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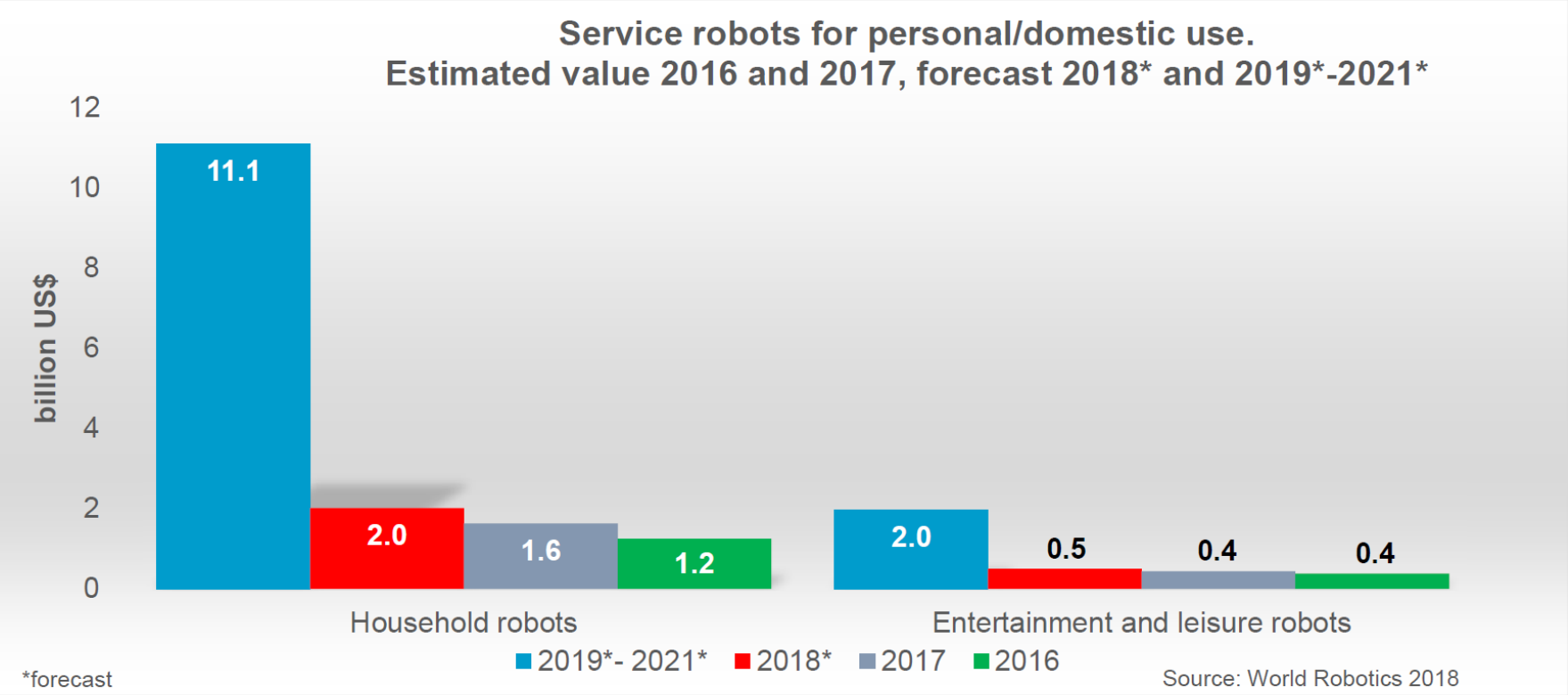

2017: 8.5 million units, +25% - considerable increase expected

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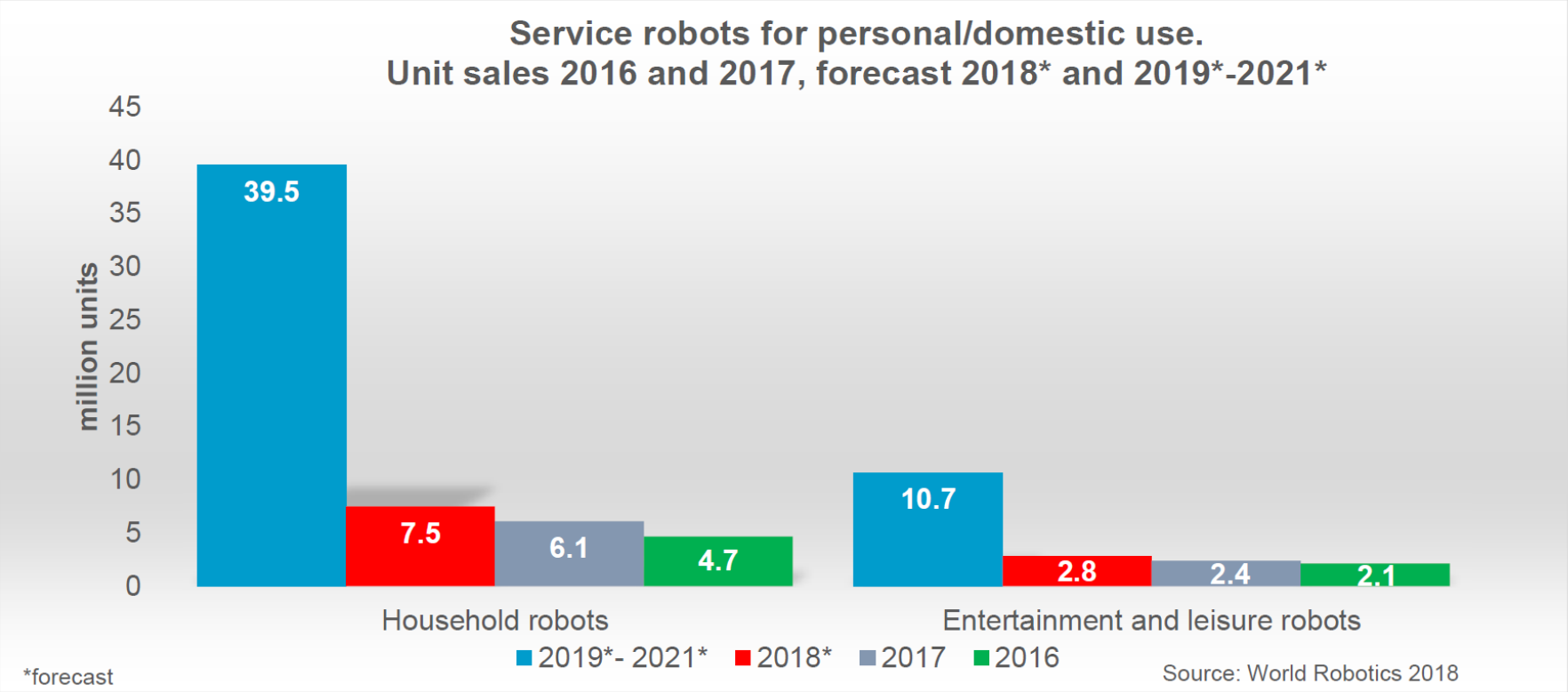
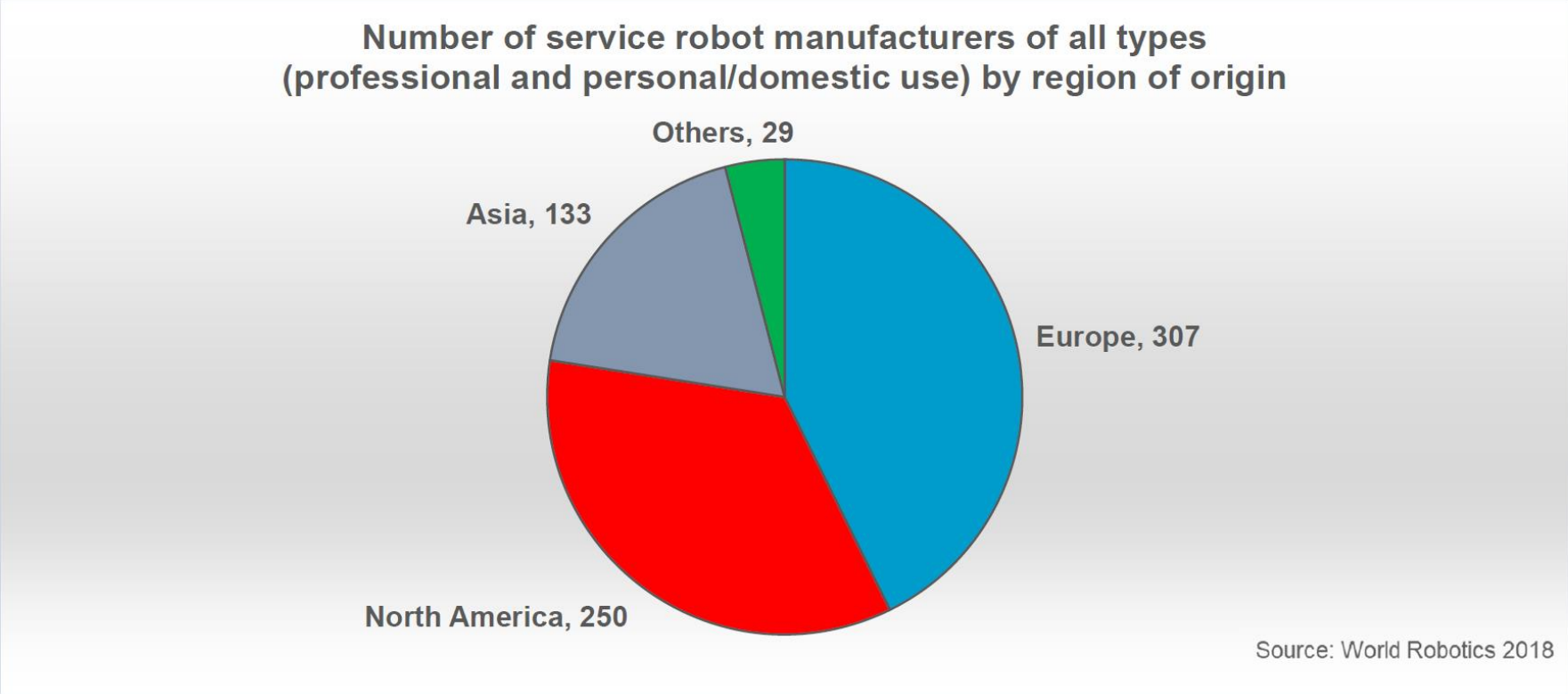


More than 700 service robot companies identified

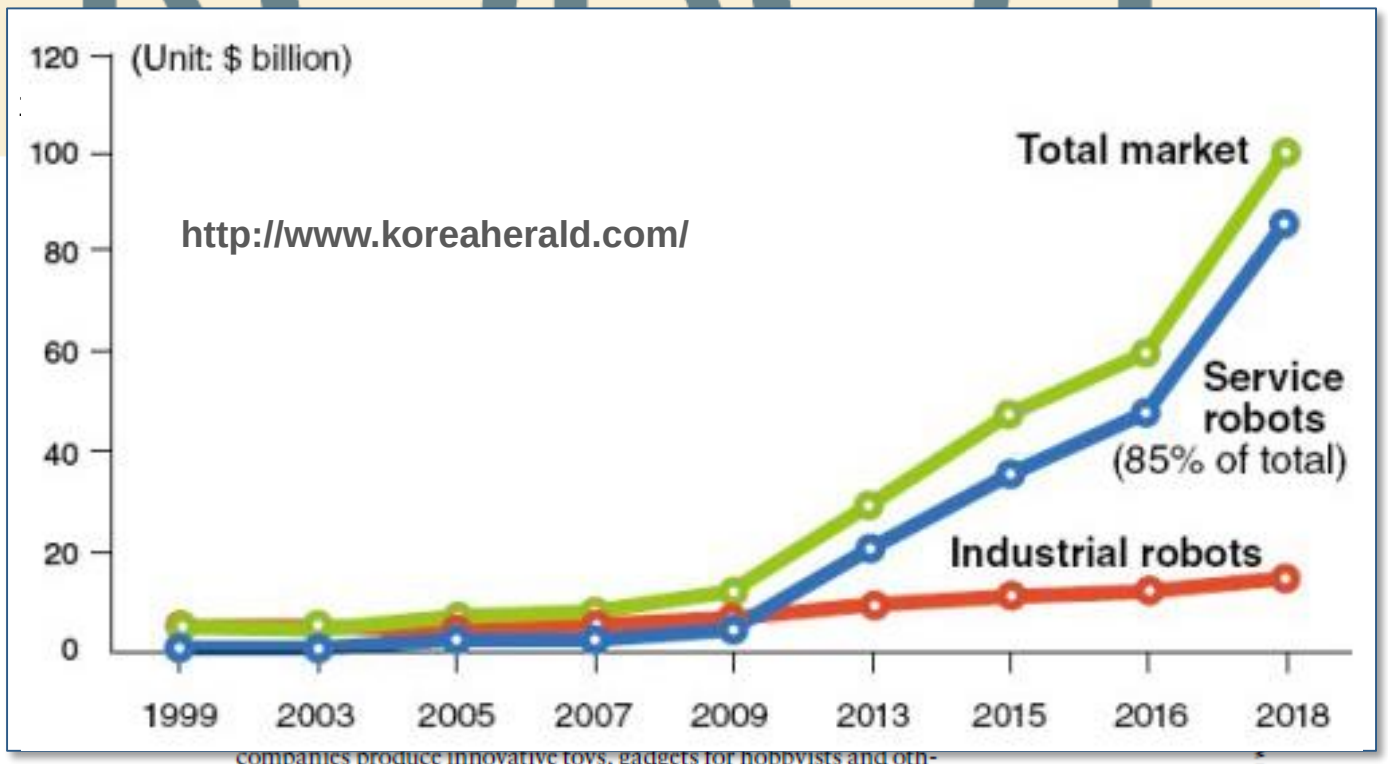
IFR International Federation of Robotics



The Bill Gates "Prophecy" …

A

ROBOT



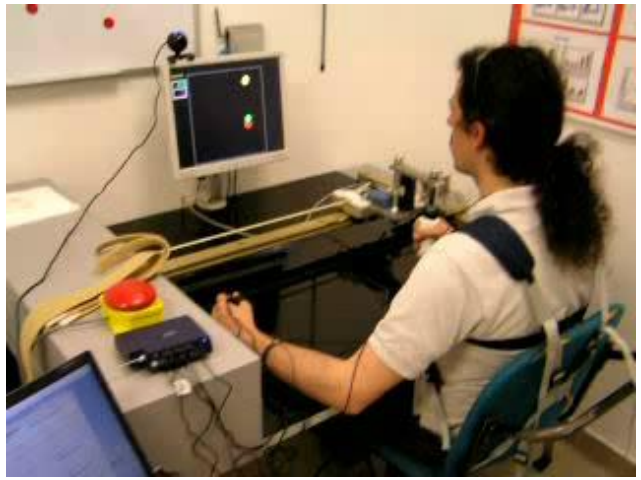
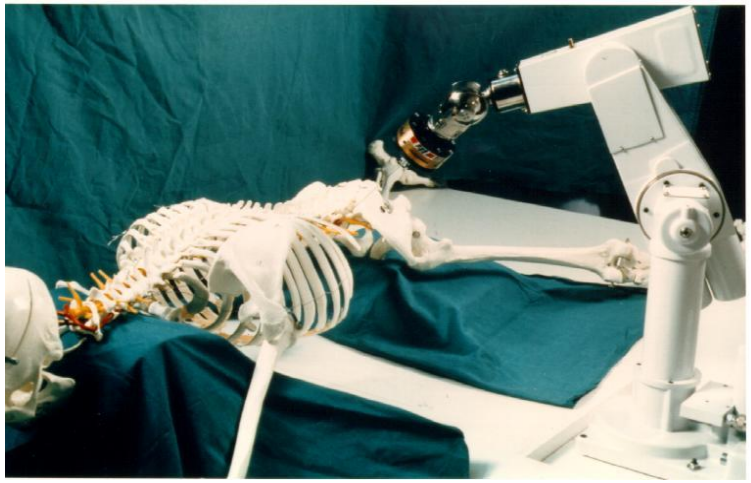
http://www.koreaherald.com/

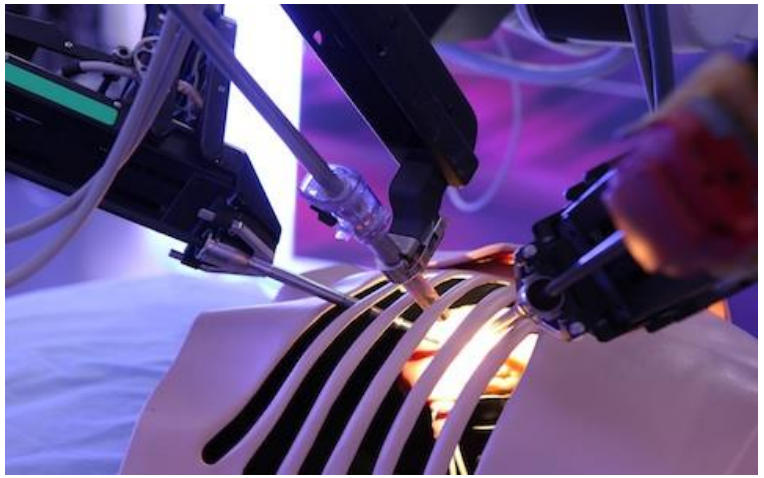
companies produce innovative toys, gadgets for hobbyists and other interesting niche products. But it is also a highly fragmented industry with few common standards or platforms. Projects are complex, progress is slow, and practical applications are relatively rare. In fact, for all the excitement and promise, no one can say with any certainty when—or even if—this industry will achieve

Some notes about the ISO definitions

- ✓ A robot system is a system comprising robot(s), end-effector(s) and any machinery, equipment, or sensors supporting the robot performing its task.
- ✓ According to the definition, "a degree of autonomy" is required for service robots ranging from partial autonomy (including human robot interaction) to full autonomy (without active human robot intervention). In this context human robot-interaction means information and action exchanges between human and robot to perform a task by means of a user interface.

Medical robots



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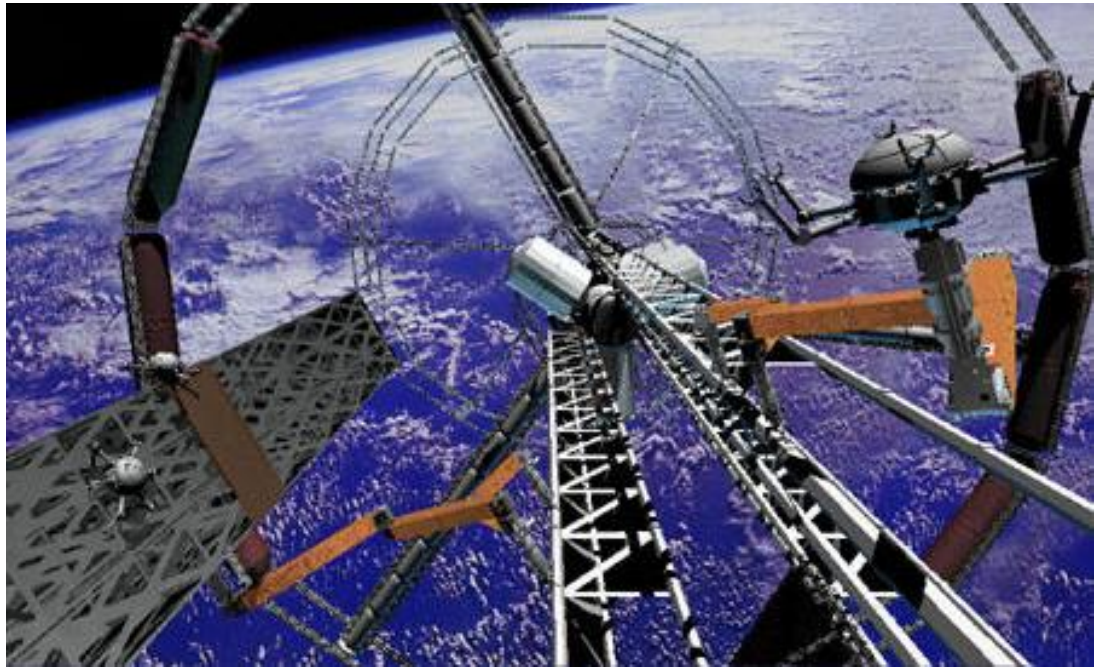
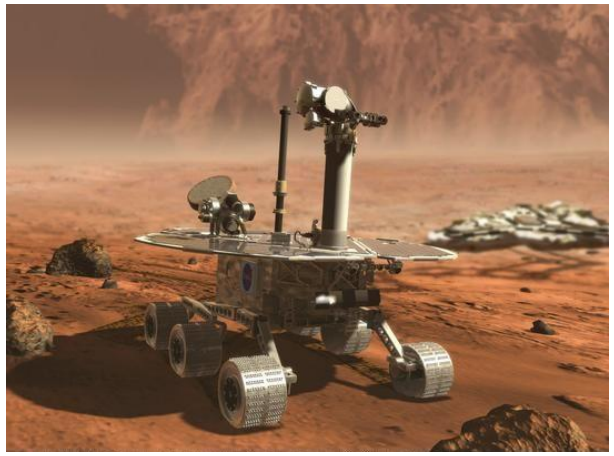
- ✓ Manipulating industrial robots (which can be either fixed in place or mobile) could also be regarded as service robots, provided they are installed in non-manufacturing operations. Service robots may or may not be equipped with an arm structure as is case with some industrial robots. Often, but not always, service robots are mobile.

Space robots





Autonomous vehicles

The Race to Market

Traffic Ahead

Many carmakers are developing prototype vehicles that are capable of driving autonomously in certain situations. The technology is likely to hit the road around 2020.





	BMW	Mercedes-Benz	Nissan	Google	General Motors
VEHICLE	5 Series (modified)	S 500 Intelligent Drive Research Vehicle	Leaf EV (modified)	Prius and Lexus (modified)	Cadillac SRX (modified)
KEY TECHNOLOGIES	• Video camera tracks lane markings and reads road signs • Radar sensors detect objects ahead • Side laser scanners • Ultrasonic sensors • Differential GPS • Very accurate map	• Stereo camera sees objects ahead in 3-D • Additional cameras read road signs and detect traffic lights • Short- and long-range radar • Infrared camera • Ultrasonic sensors	• Front and side radar • Camera • Front, rear, and side laser scanners • Four wide-angle cameras show the driver the car's surroundings	• LIDAR on the roof detects objects around the car in 3-D • Camera helps detect objects • Front and side radar • Inertial measuring unit tracks position • Wheel encoder tracks movement • Very accurate map	• Several laser sensors • Radar • Differential GPS • Cameras • Very accurate map

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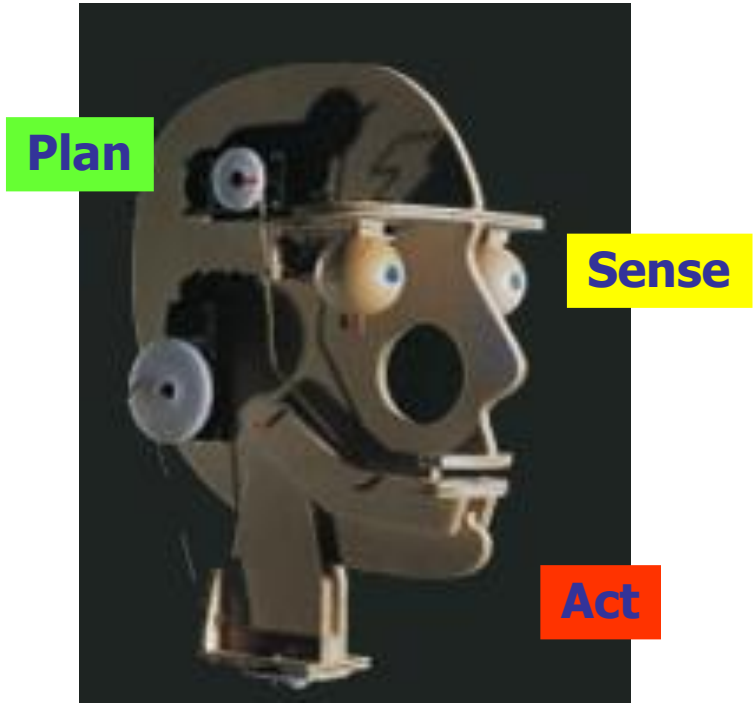
- ✓ In some cases, service robots consist of a mobile platform on which one or several arms are attached and controlled in the same mode as the arms of industrial robot. Furthermore, contrary to their industrial counterparts, service robots do not have to be fully automatic or autonomous. In many cases these machines may even assist a human user or be tele-operated.

Teleoperated and telepresence robots

What makes an autonomous robot?

A machine gets information from a set of sensors and upon these accomplish its task autonomously by moving its body parts …



Note: The Sense-Plan-Act model is just one possible cognitive architecture for autonomous robots (Cognitive Robotics)

What does it make a mobile robot?