POLITECNICO DI MILANO





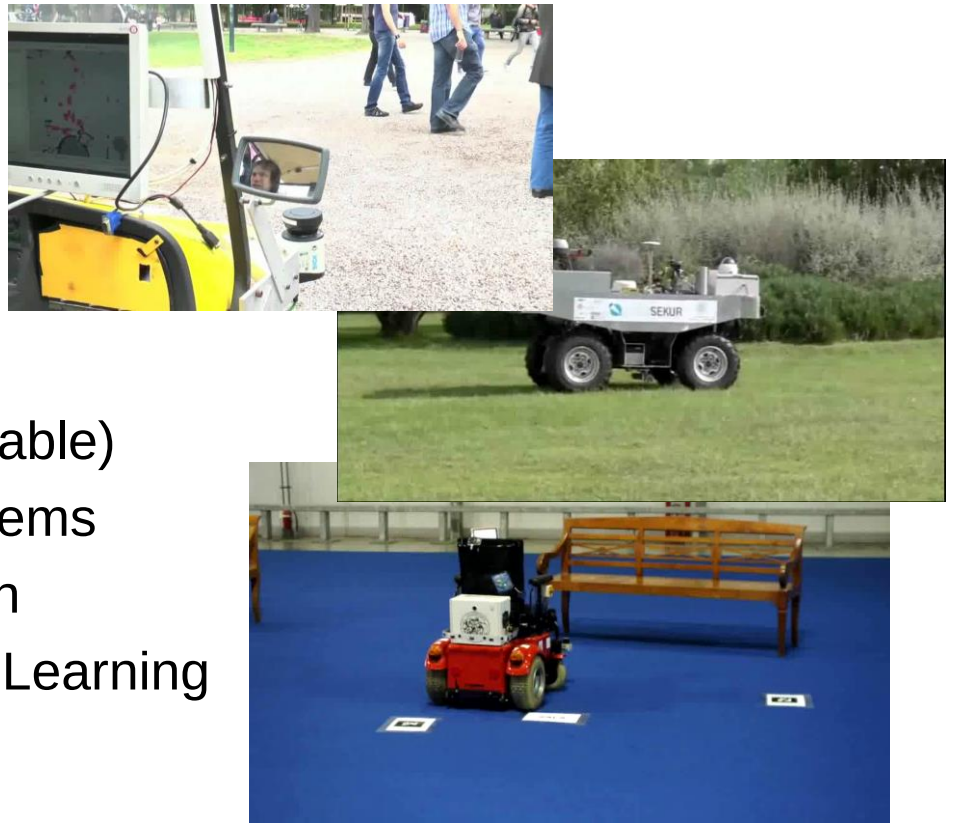
Robotics – Introduction

Matteo Matteucci – matteo.matteucci@polimi.it

About me and my lectures …

Lectures given by Matteo Matteucci

- +39 02 2399 3470
- matteo.matteucci@polimi.it
- http://www.deib.polimi.it/ …



Research Topics (several Thesis available)

- Robotics and Autonomous Systems
- Computer Vision and Perception
- Pattern Recognition & Machine Learning
- Benchmarking in Robotics

Aims of these lectures: learning how to design and implement the software which makes autonomous an autonomous mobile robot (e.g., symbolic planning, trajectory planning, localization, perception, mapping, etc.)

... what about you?

Where are coming from?

- Master in Computer Engineering
- ...
- ...

Why Robotics?

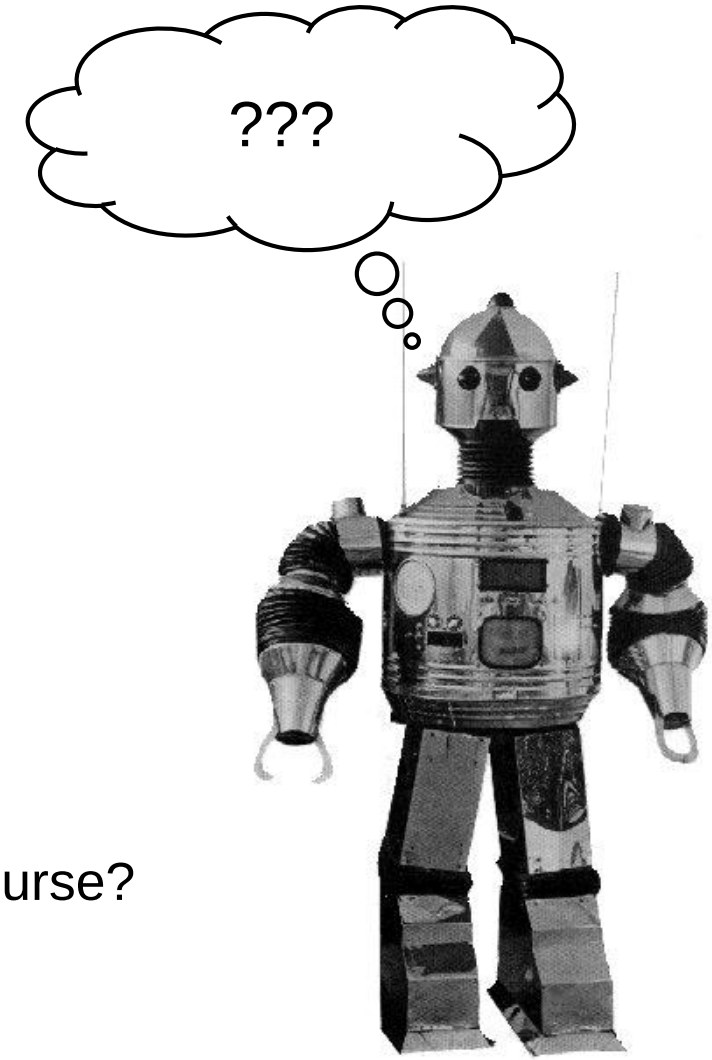
- ...

What do you expect from this course?

- ...

What does it worry you the most about this course?

- ...



... what about the course?

Novel course edition …

- Same name
- New teachers (more or less)
- New program / approach (more or less)
- New organization / rules (more or less)

All the infos on the course website

- http://chrome.ws.dei.polimi.it/index.php/Robotics

Lectures given by:

- Matteo Matteucci (Lecturer – 30h)
  http://www.deib.polimi.it/ … *then search* …
  matteo.matteucci@polimi.it
- Gianluca Bardaro (Teaching Assistant – 20h)
  http://www.deib.polimi.it/ … *then search* …
  gianluca.bardaro@polimi.it

Lectures outline / approach

Introduction to (mobile) robotics

Anatomy of a mobile robot
- Sensors and actuators
- Common Kinematics

Robot autonomous navigation
- Motion control and obstacle avoidance
- Trajectory following
- Trajectory planning (graph and sample based)

Localization and Mapping
- Localization vs Mapping
- Simultaneous Localization & Mapping (with lasers)

Symbolic Planning

«Theory»

Robot Simulation
- Gazebo simulation
- Description of a simple robot

Middleware in robotics
- Motivations and state of the art
- Robot Operating System (ROS)
- ROS tools (rviz, tf, map server)
- ROS actionlib

Navigation in ROS
- Trajectory planning / following
- ROS movebase

The PPDL Language

«Practice»

Course organization / rules

Classes (no distinction between lecture and exercise):

- Wednesday, 13:15 – 15:15, in EG3
- Thursday, 13:15 – 15:15, in D11

These overlap with ...

Detailed calendar online (updated weekly)

- http://chrome.ws.dei.polimi.it/index.php/Robotics

Grading policy:

In few (very exceptional) cases be replaced by a lab activity, but this has to be planned, discussed, and agreed with the teacher.

- Written examination covering the whole program up to 27/32
- Home project in simulation graded up to 05/32
- Final score will be the sum of the grades of the two … 32/32

In some (exceptional) cases the home project can be replaced by a lab project, possibly with a slightly higher grade, but this has to be motivated and discussed with the teacher in advance.

Course material

Material available on the course website

- Check ***http://chrome.ws.dei.polimi.it/index.php/Robotics***
- Slides from the teachers (not necessarily available in advance)
- Link to online sources, books and papers
- Link to other websites for tools and digital resources

Past exams and sample questions

- Expect 2 theoretical questions + 2 practical exercises (on average)
- No coding exercise since you have it in the home project
- Exam is new so no past exams available yet, we will provide examples of possible questions ongoing … check for hints ;-)

Do you need any further info?

- …

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Robotics – What about?

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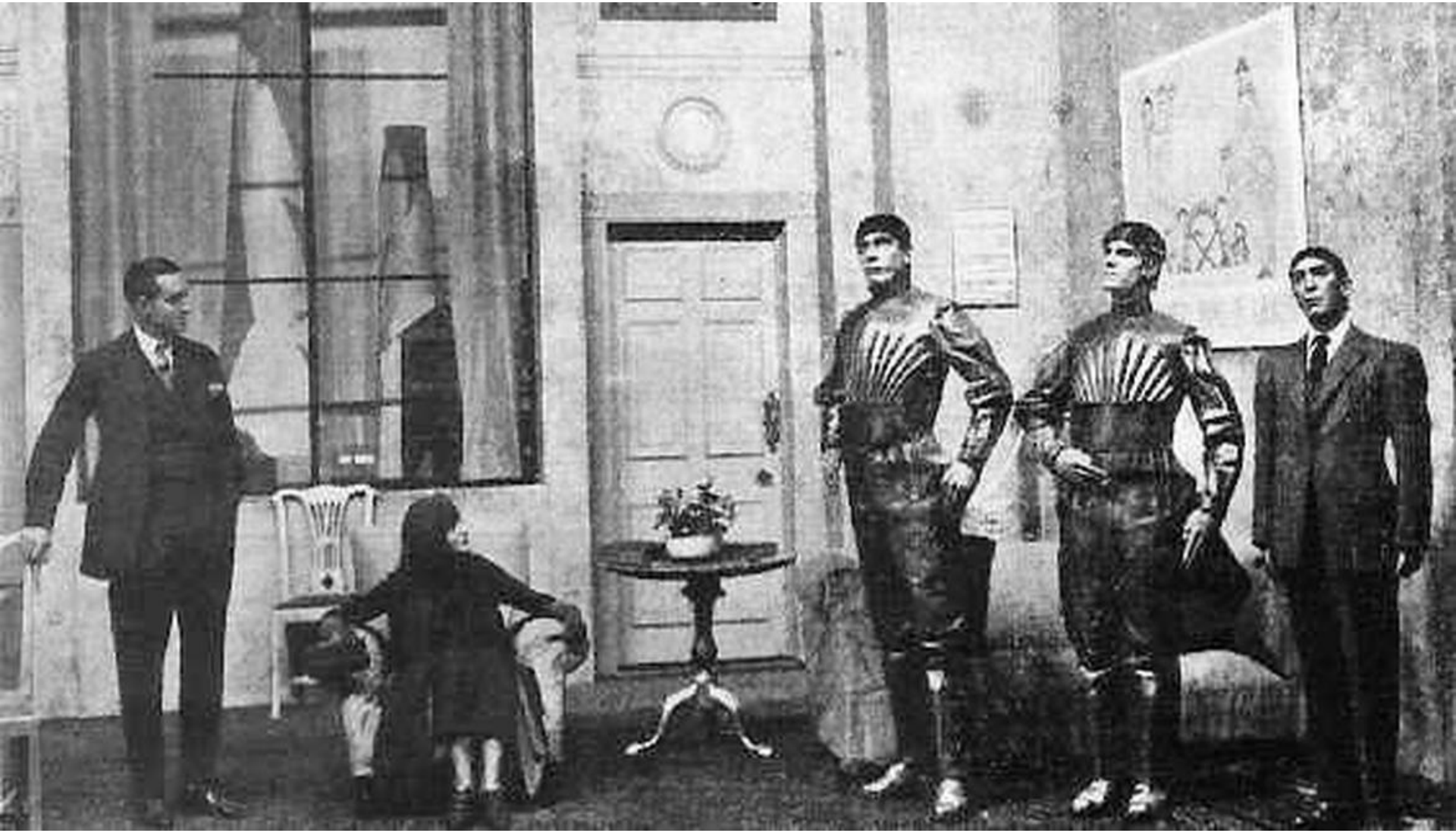
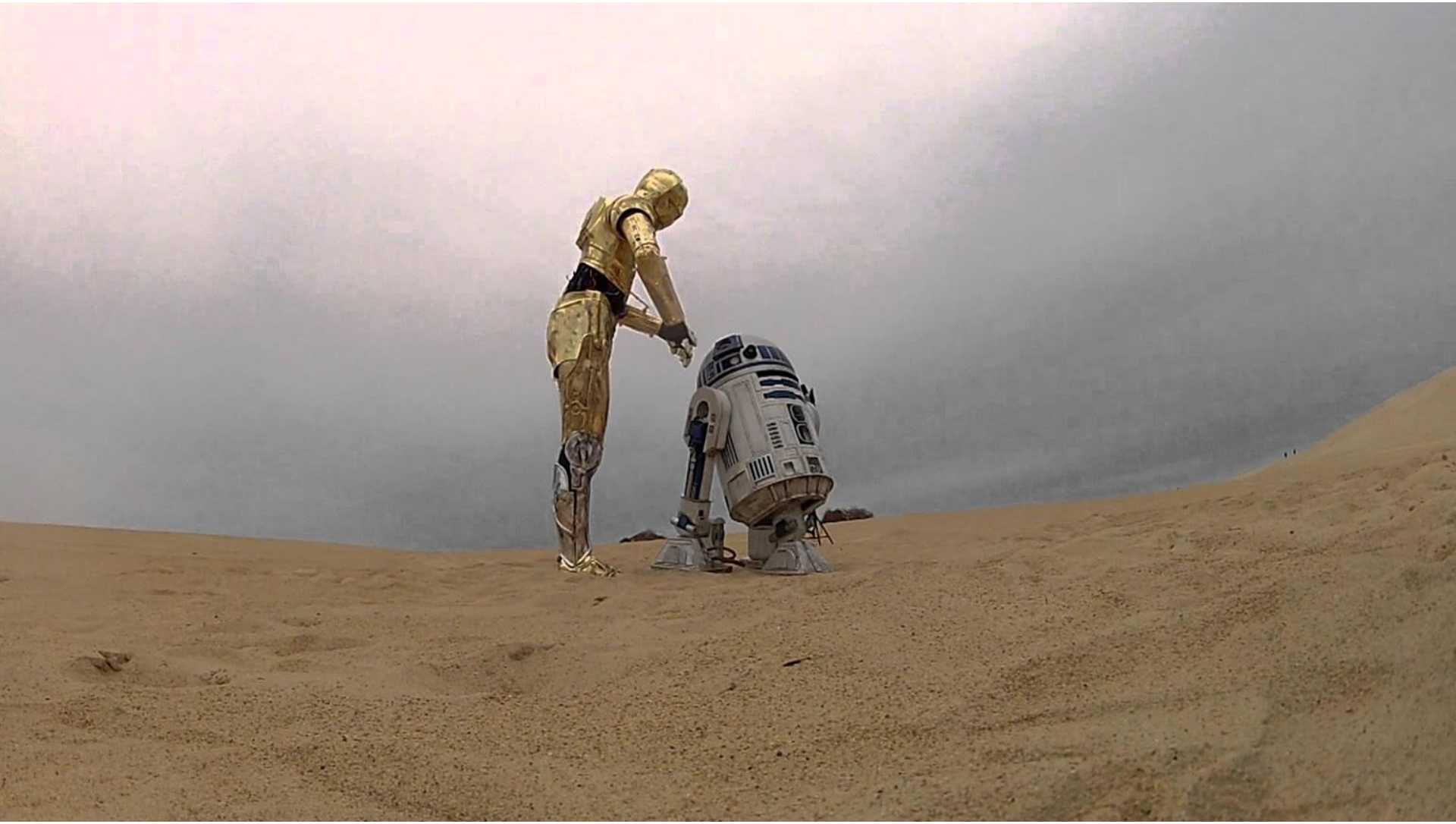
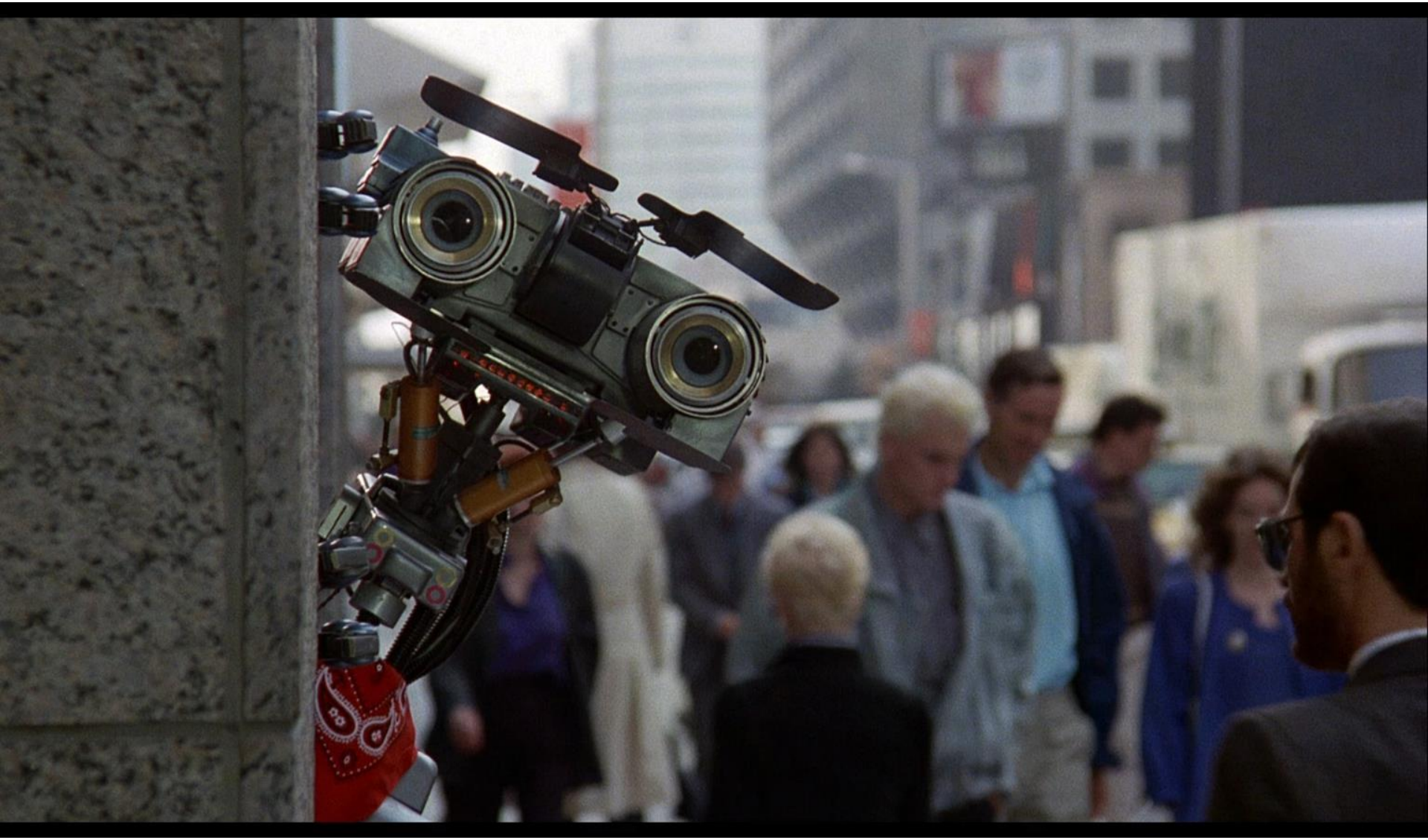
Rossum Universal Robots (1920)



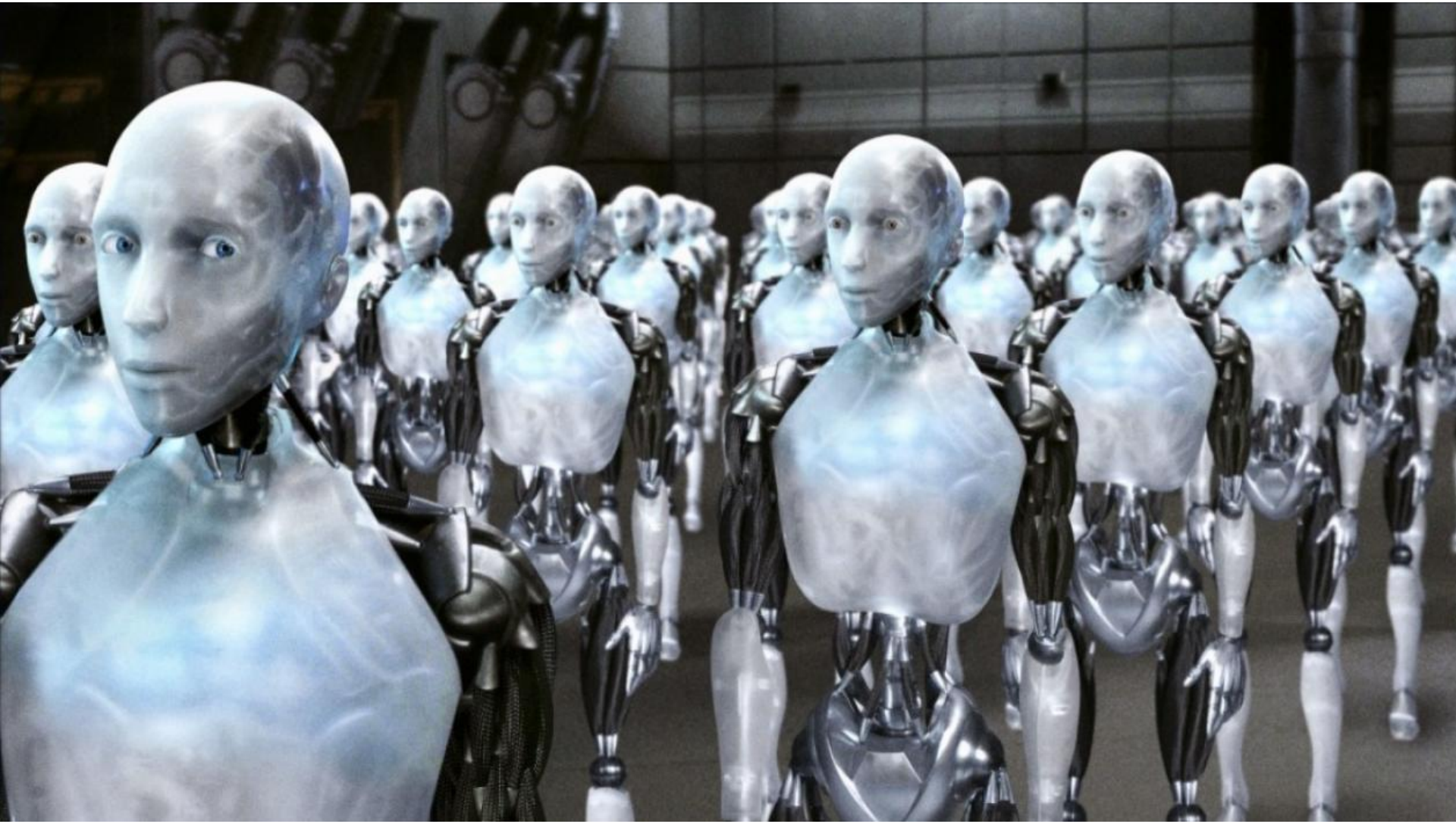
Star Wars (1977)



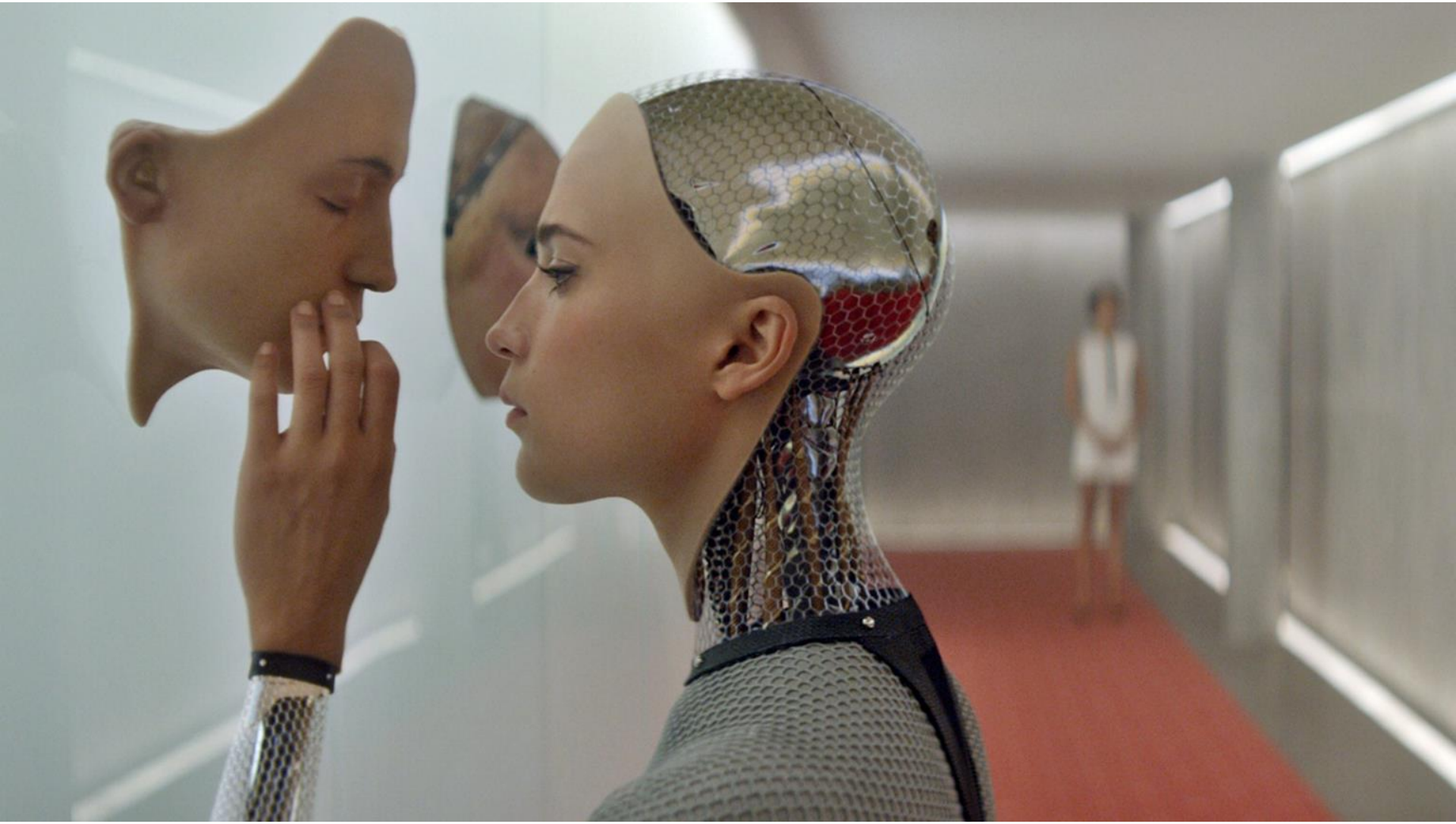
Short Circuit (1986)



I Robot (2001)

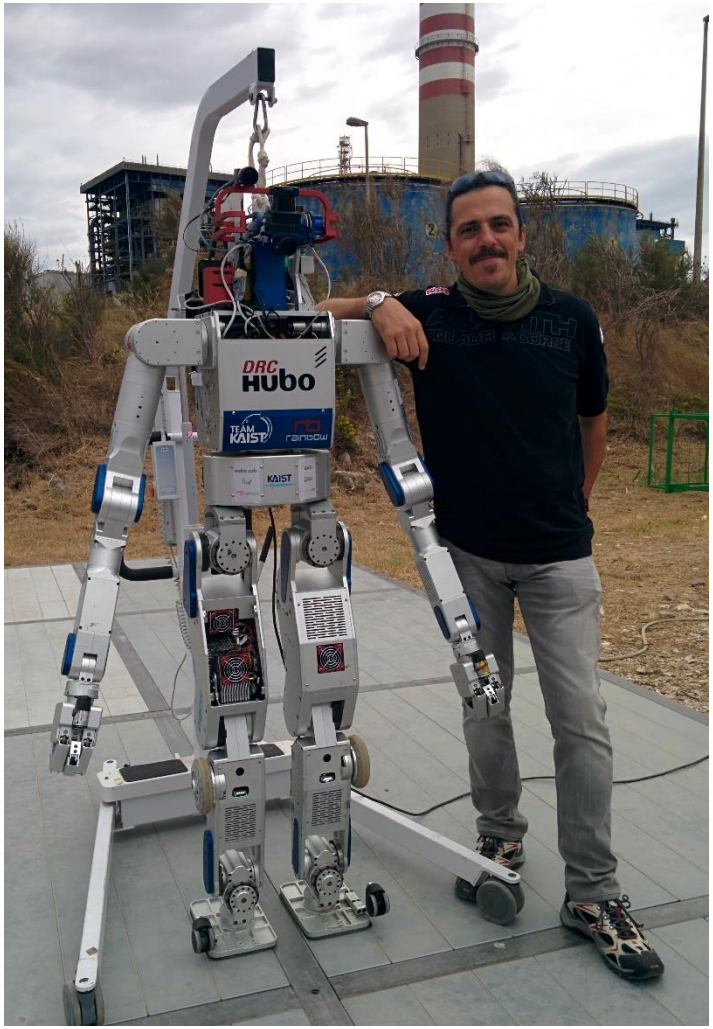


Ex Machina (2015)



Sometimes reality is different...

... and the winner is ...



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

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)

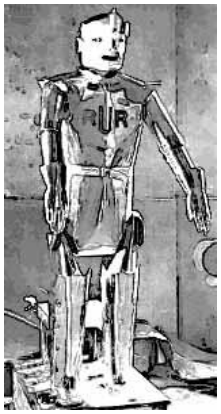
Steps in robot history

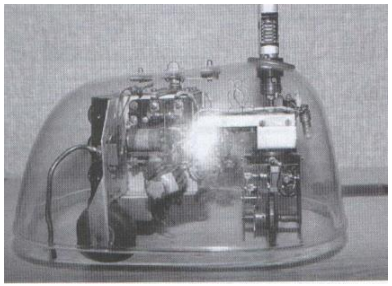
Mechanical era (1700):
- automata
- karakuri-ningyo

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!

Steps in robot history

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

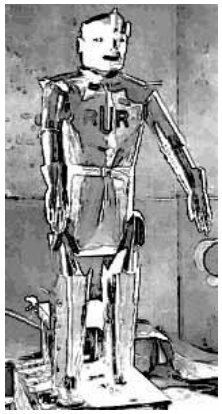
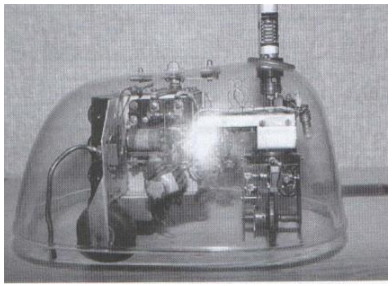
Fiction era (’20s):
- *Rossum Universal Robot*

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

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

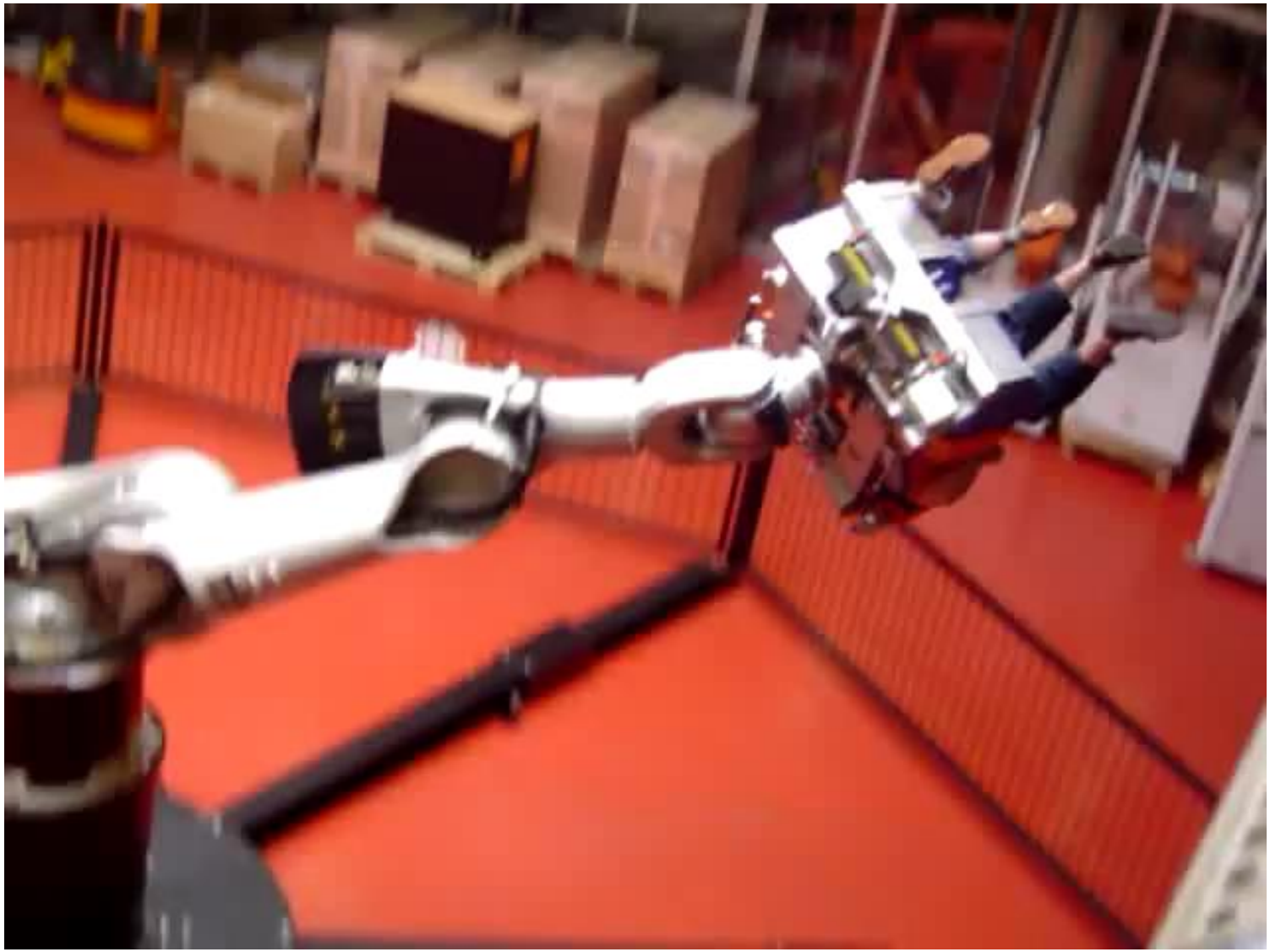
Information era (from the ‘90s):
- Intelligence
- Autonomy
- Cooperation




ISO 8373:2012 - Robots and robotic devices

- ✓ 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.



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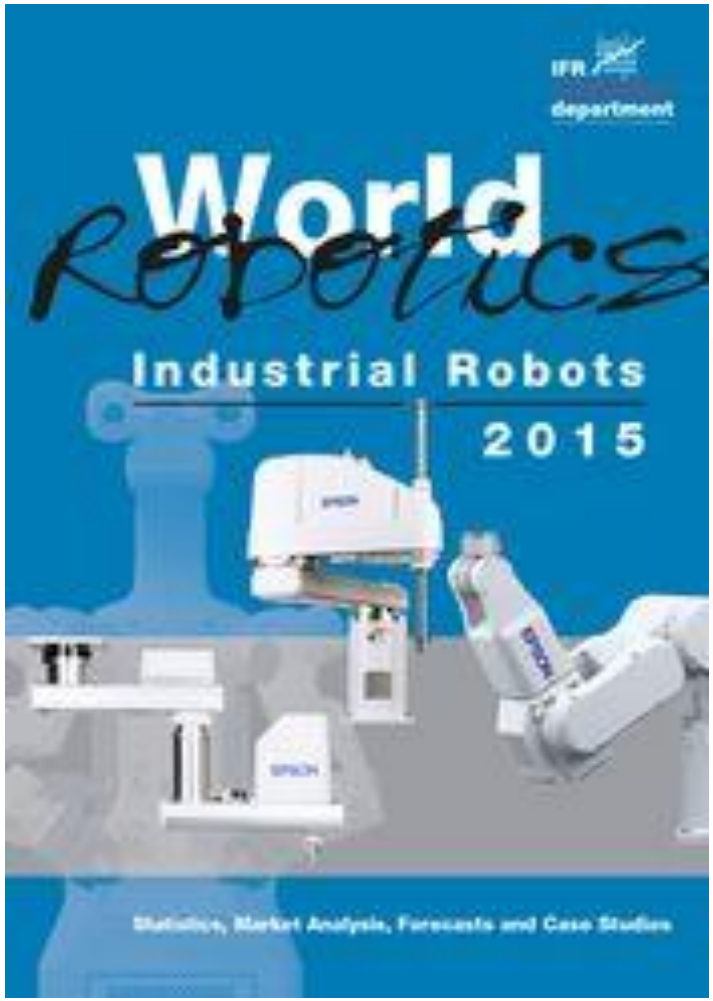
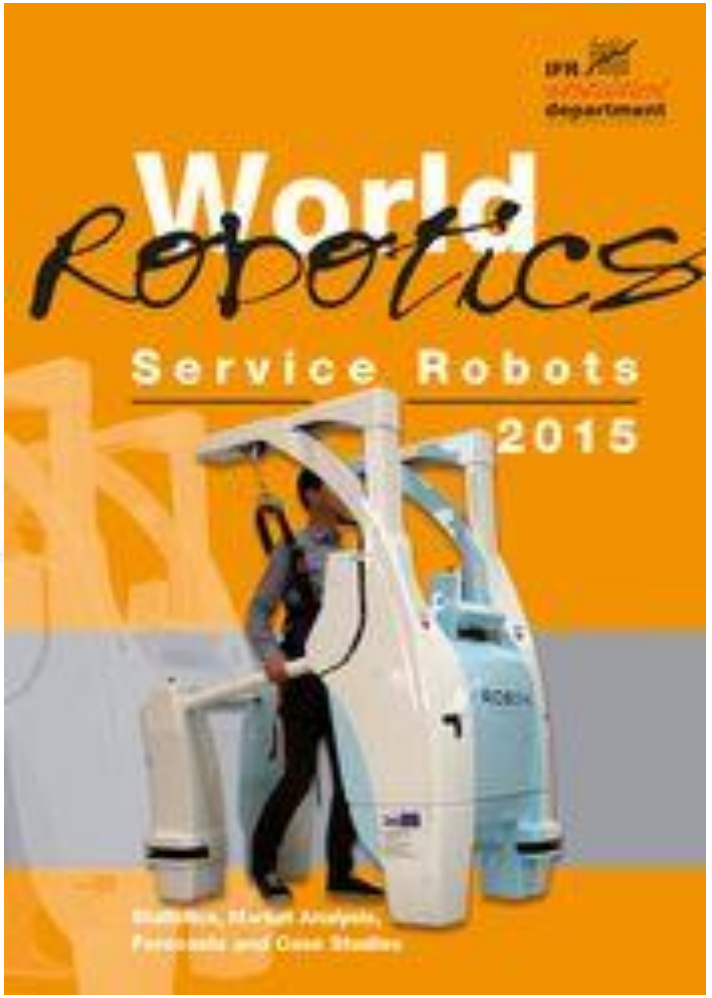
- ✓ A personal service robot or a service robot for personal use is a service robot used for a non-commercial task, usually by lay persons. E.g., domestic servant robot, automated wheelchair, personal mobility assist robot, and pet exercising robot.
- ✓ A professional service robot or a service robot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

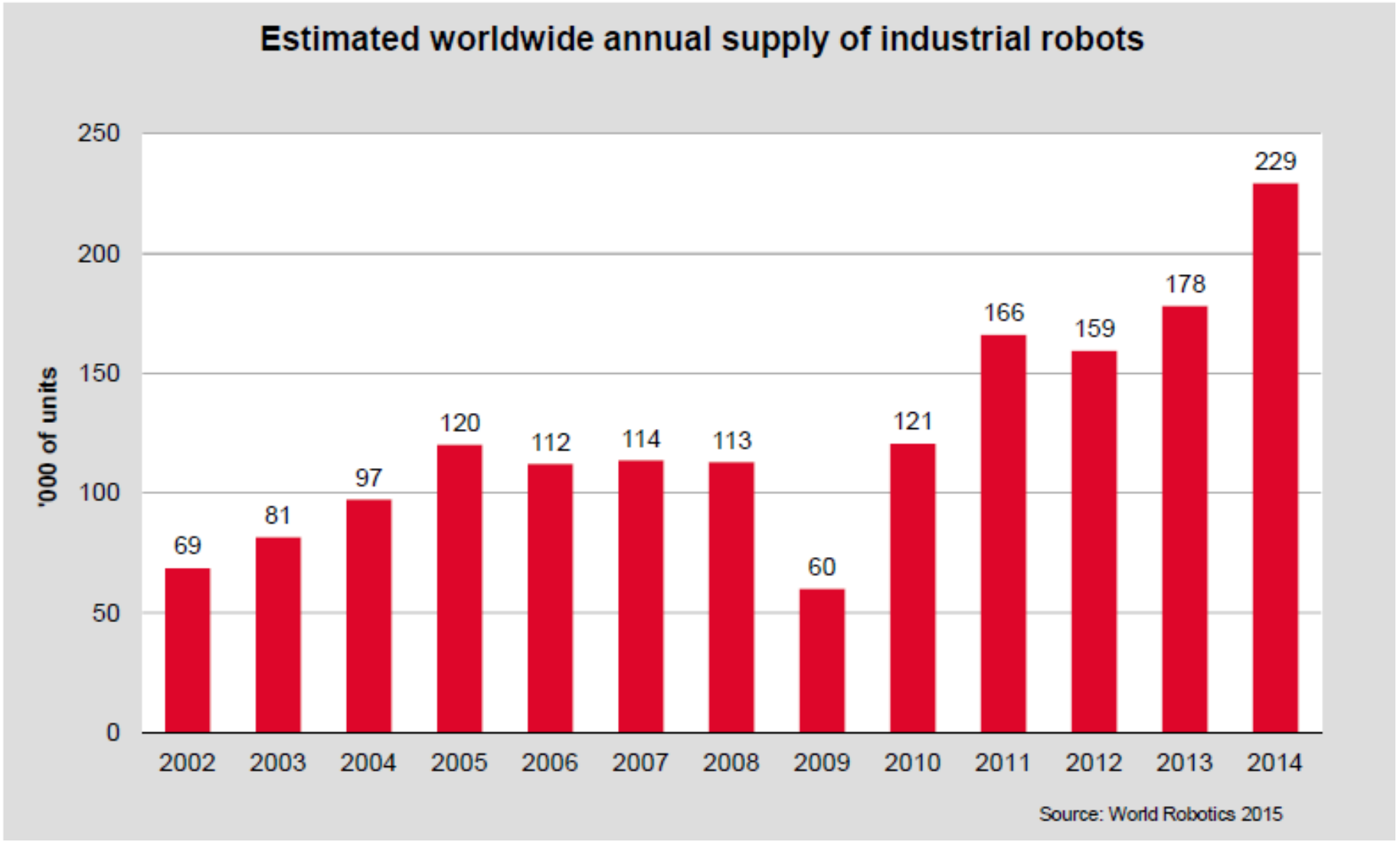
Industrial or Service Robots (IFR report 2015)



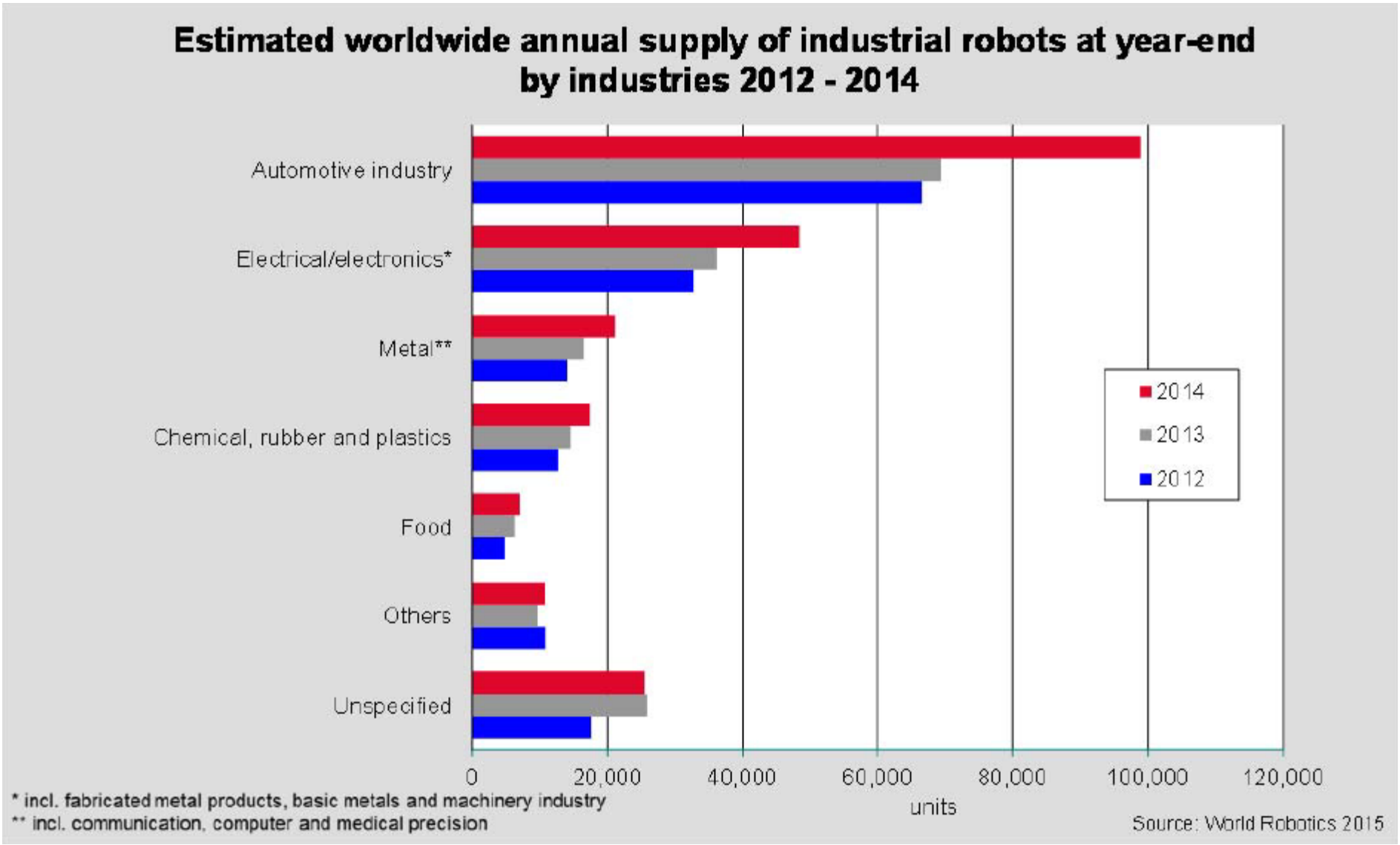
VS



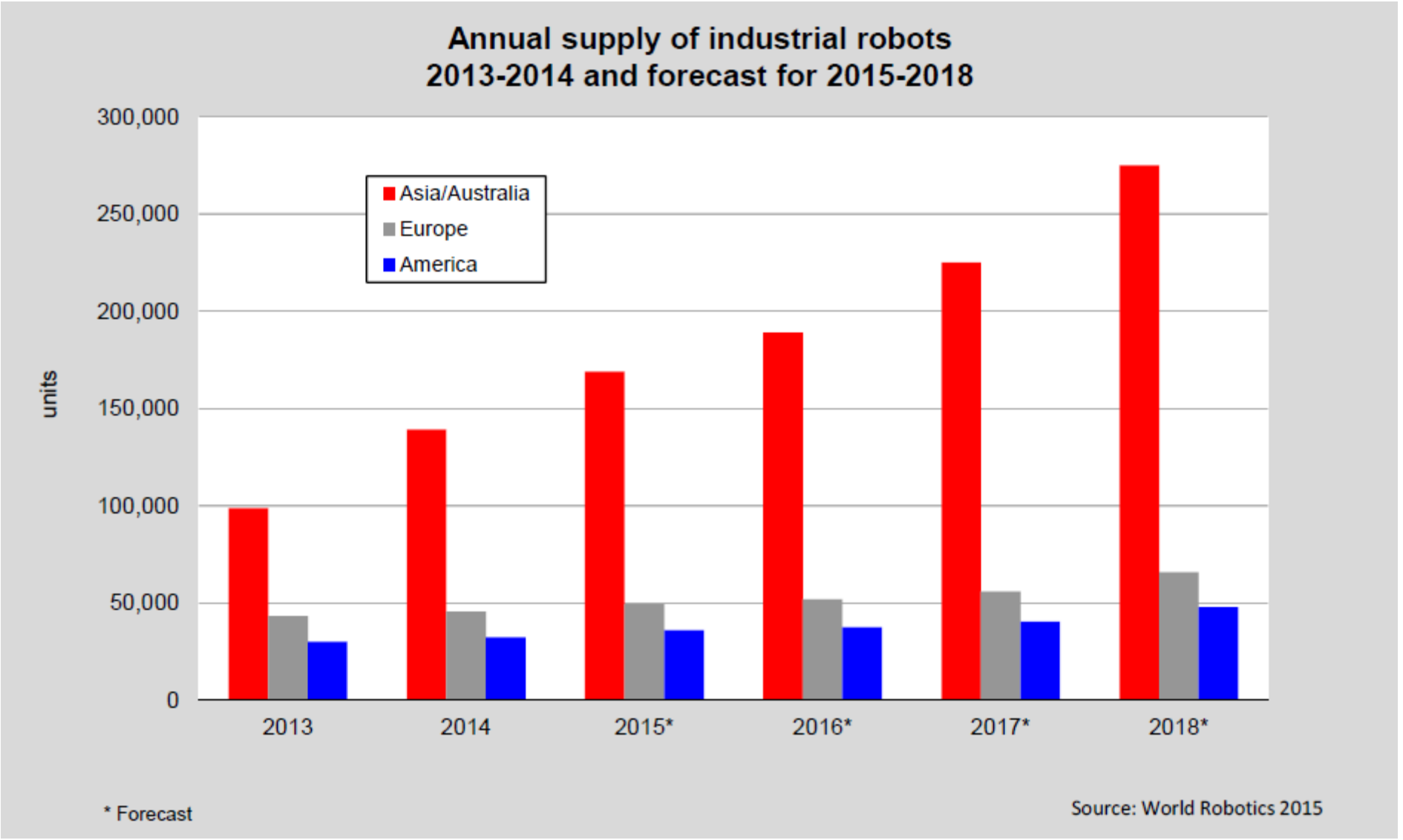
Industrial Robot are selling well ...



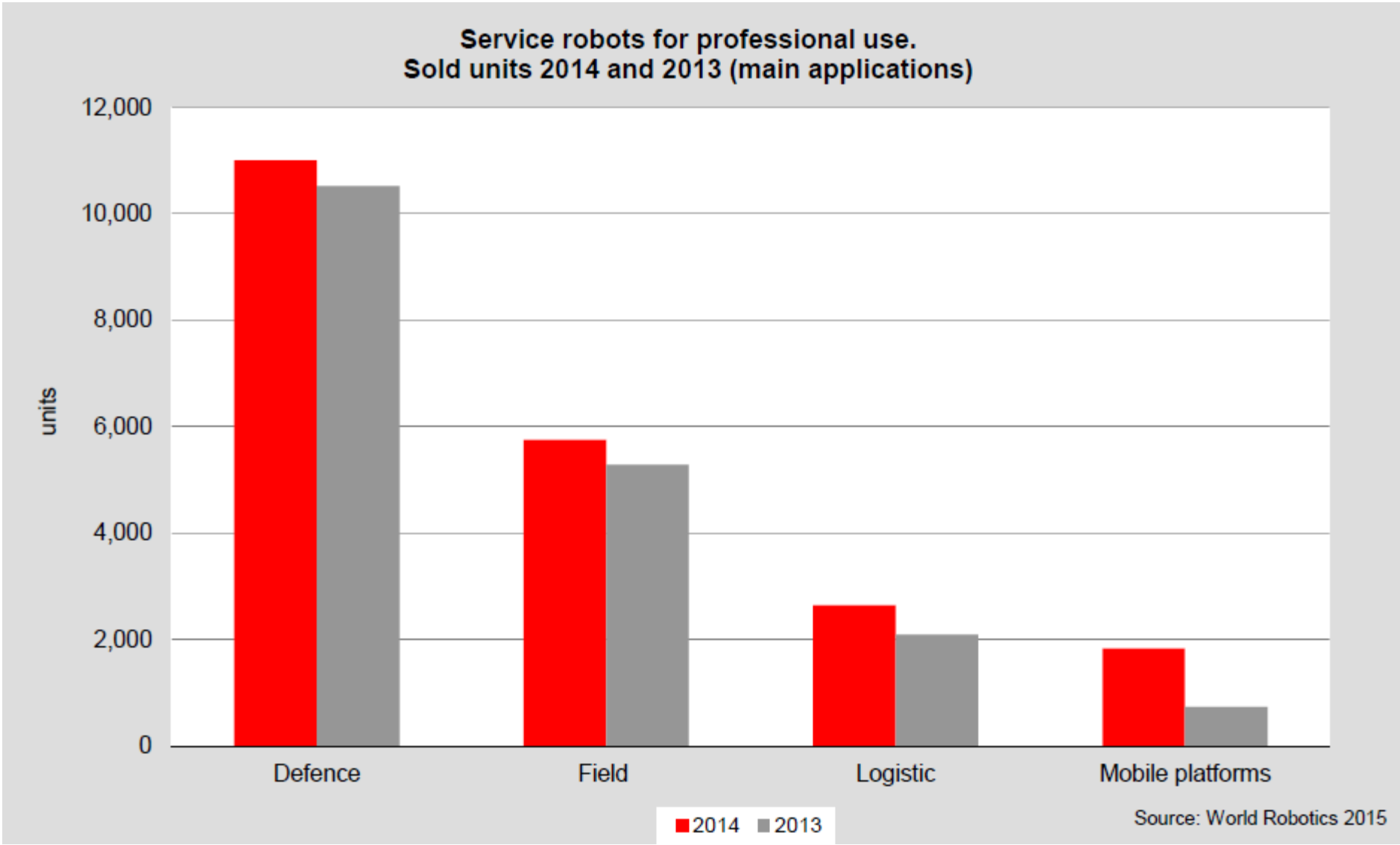
... growth is roughly 20% ...



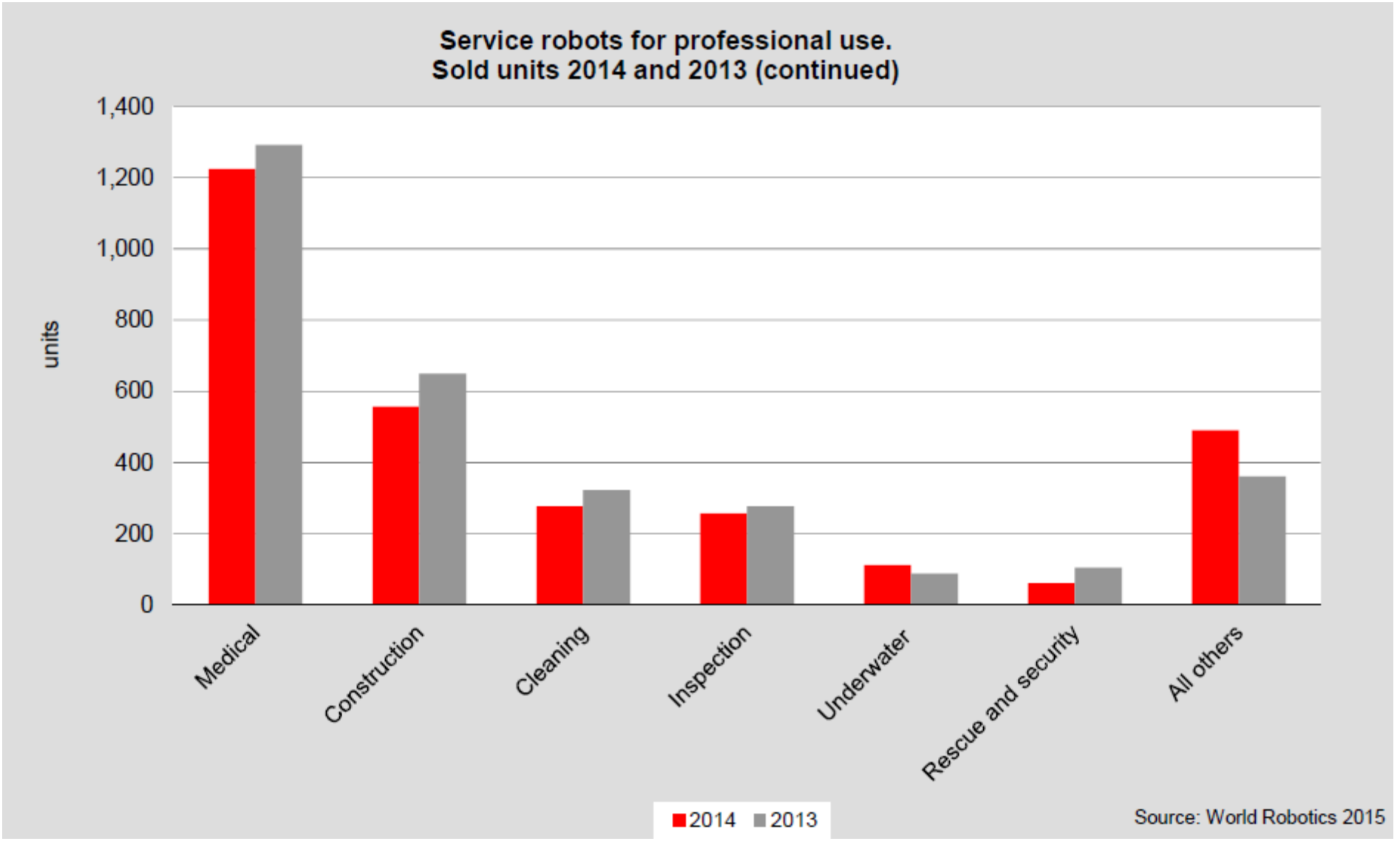
... all across the world ...



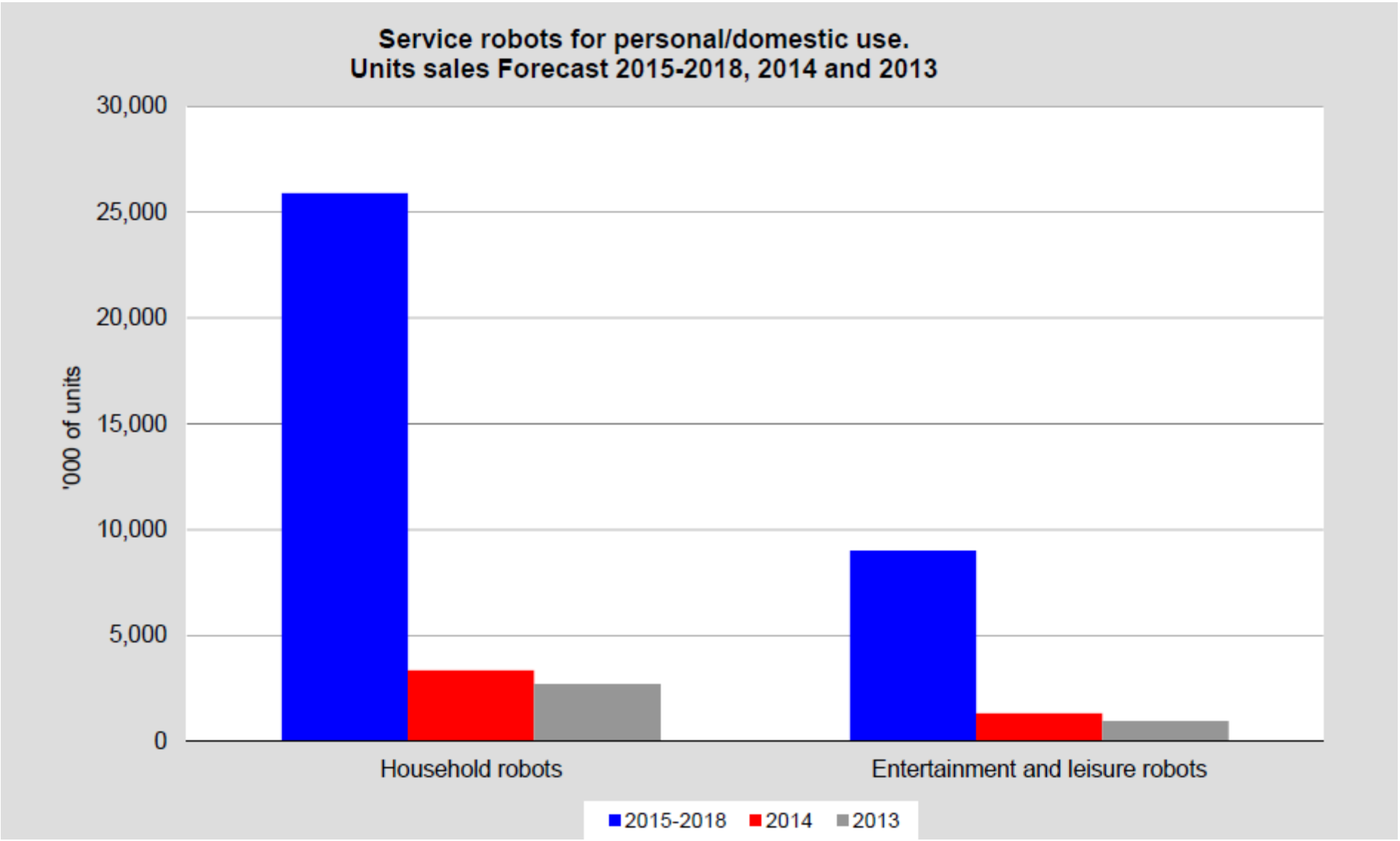
... service robot are catching up ...



... with small numbers in professional use ...



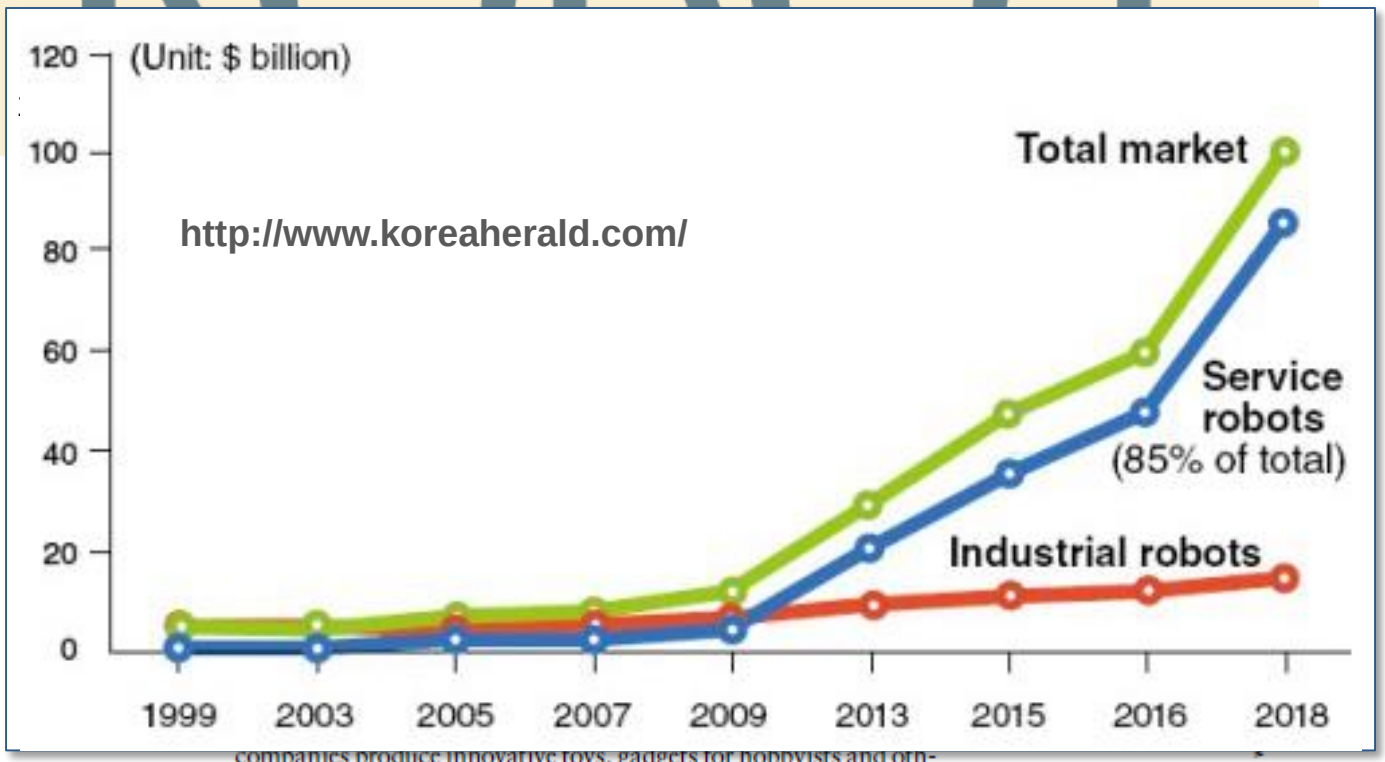
... but personal ones have a different pace ...



… until the "The Prophecy" comes true!

A

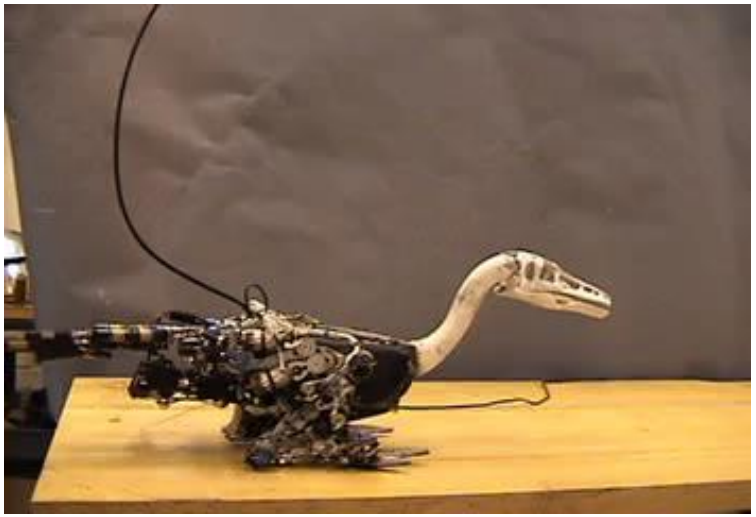
ROBOT



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

Autonomous service robot

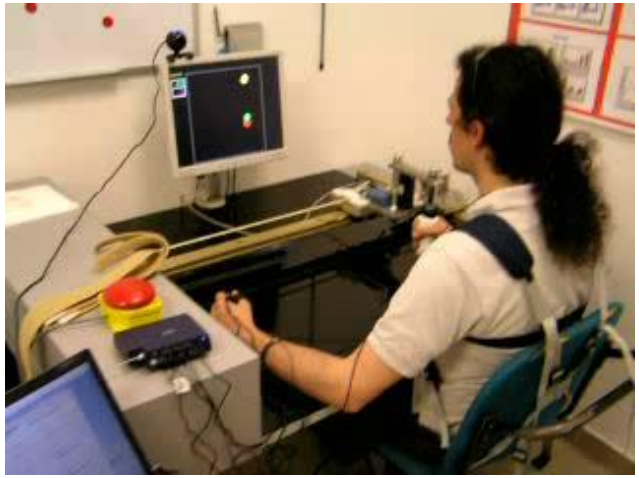


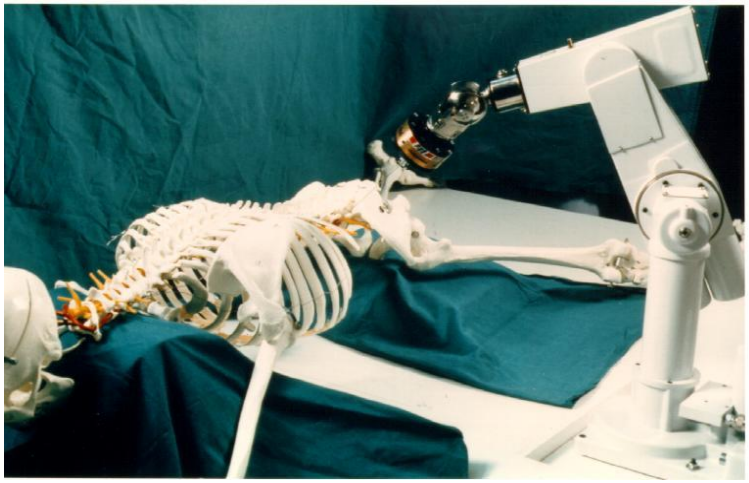
Some notes about the ISO definitions

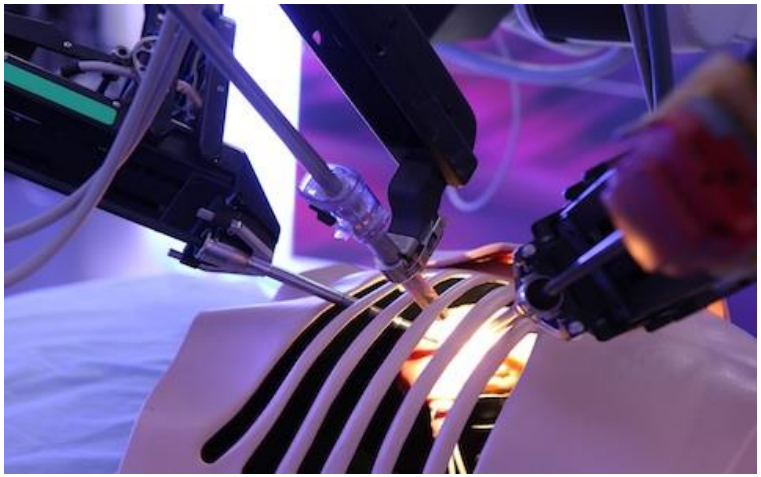
A robot system is a system comprising robot(s), end-effector(s) and any machinery, equipment, or sensors supporting the robot performing its task.

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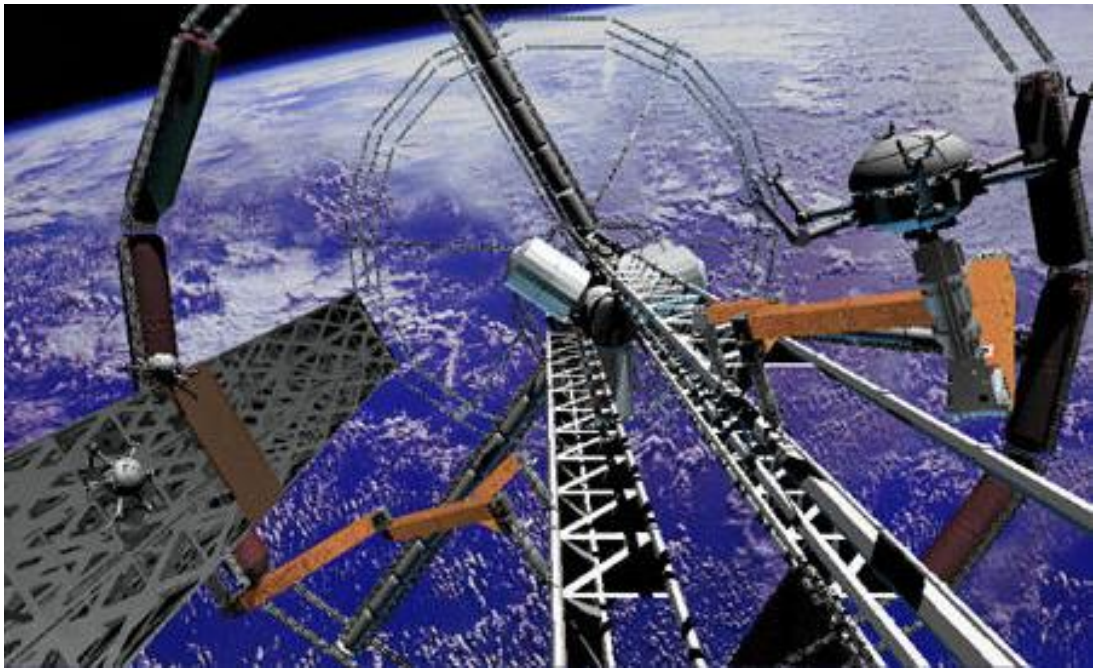
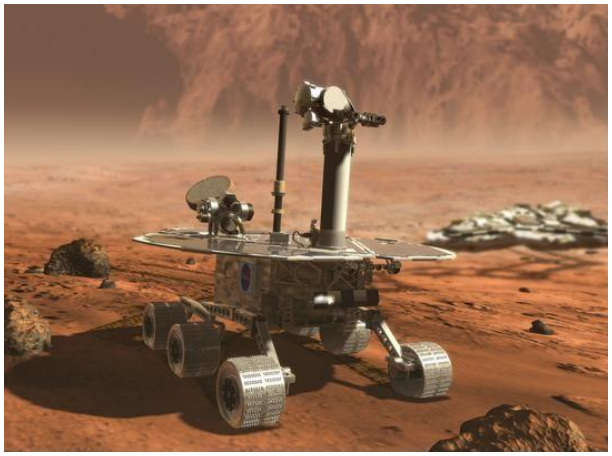
Manipulating industrial robots (which can be either fixed in place or mobile) could also be regarded as service robots, provided they are installed in non-manufacturing operations. Service robots may or may not be equipped with an arm structure as is case with some industrial robots. Often, but not always,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

Space robots





Autonomous vehicles

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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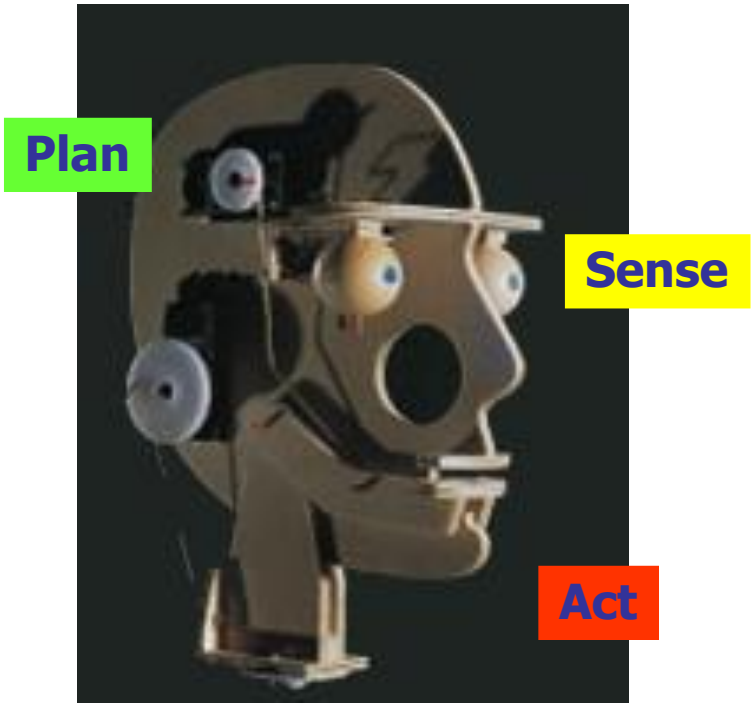
In some cases, service robots consist of a mobile platform on which one or several arms are attached and controlled in the same mode as the arms of industrial robot. Furthermore, contrary to their industrial counterparts, service robots do not have to be fully automatic or autonomous. In many cases these 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?

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