POLITECNICO
MILANO 1863

Cognitive Robotics

2017/2018

Course Introduction

Matteo Matteucci
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Artificial Intelligence and Robotics Lab - Politecnico di Milano

About me and my lectures …

Lectures given by Matteo Matteucci

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

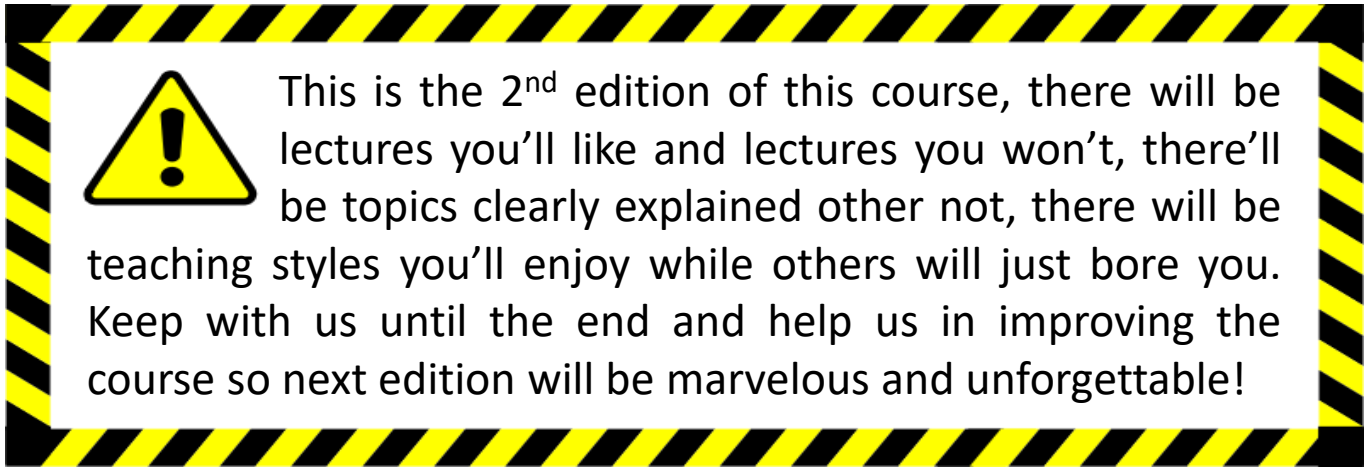
Research Topics

- 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 robot/system (e.g., symbolic planning, behavior based architectures, neural networks, human robot interaction, natural language processing, …)

Course objectives and disclaimer

"This course addresses the methodological aspects of Cognitive Robotics. Cognitive Robotics is about endowing robots and embodied agents with intelligent behavior by designing and deploying a processing architecture making them apt to deliberate, learn, and reason about how to behave in response to complex goals in a complex world.



Course syllabus

Cognitive Robotics introduction
- Cognition and the sense-plan-act architecture
- Deliberative, reactive, and hybrid approaches

Deliberative systems for cognitive robots
- Symbolic planning and PDDL

Bioinspired controllers for autonomous robots
- Behavior based architectures
- Neural networks and learning

Human-Robot interaction
- Non verbal human robot interaction
- (Natural language processing)

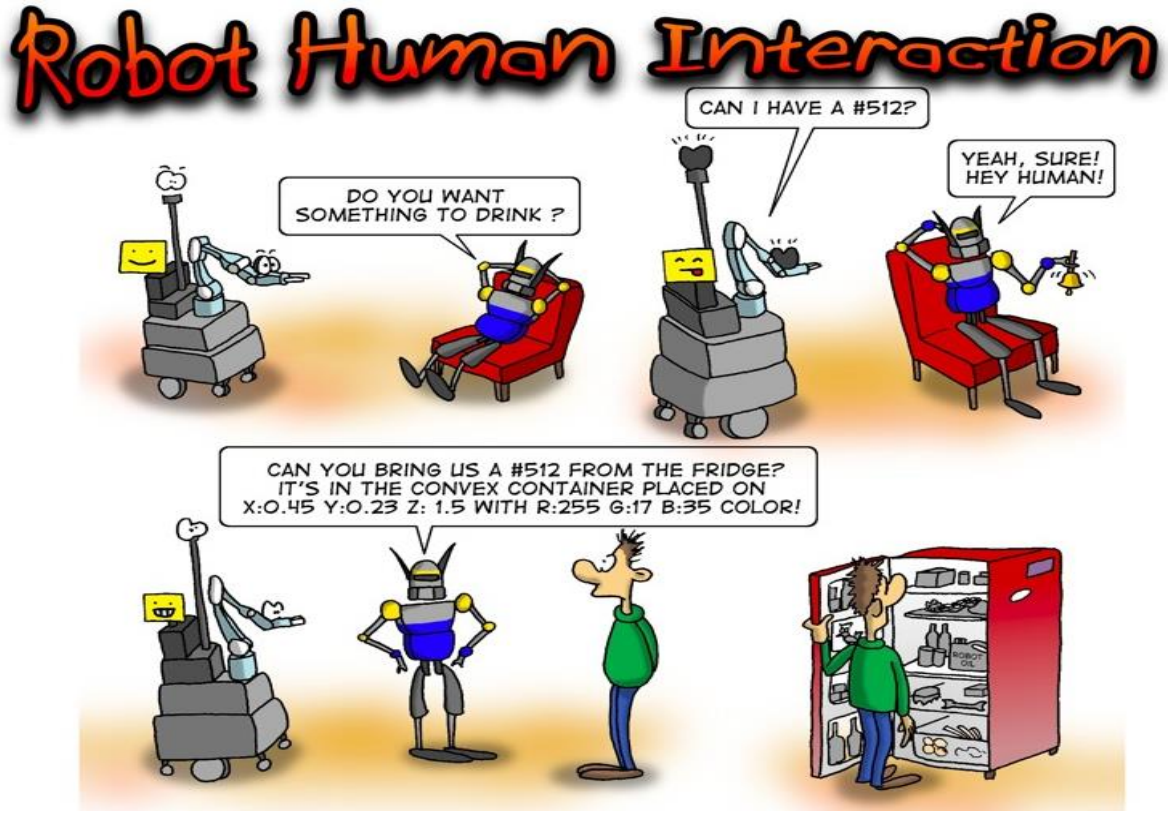
Seminars from the students

How does a machine take "intelligent" decisions to interact with the world

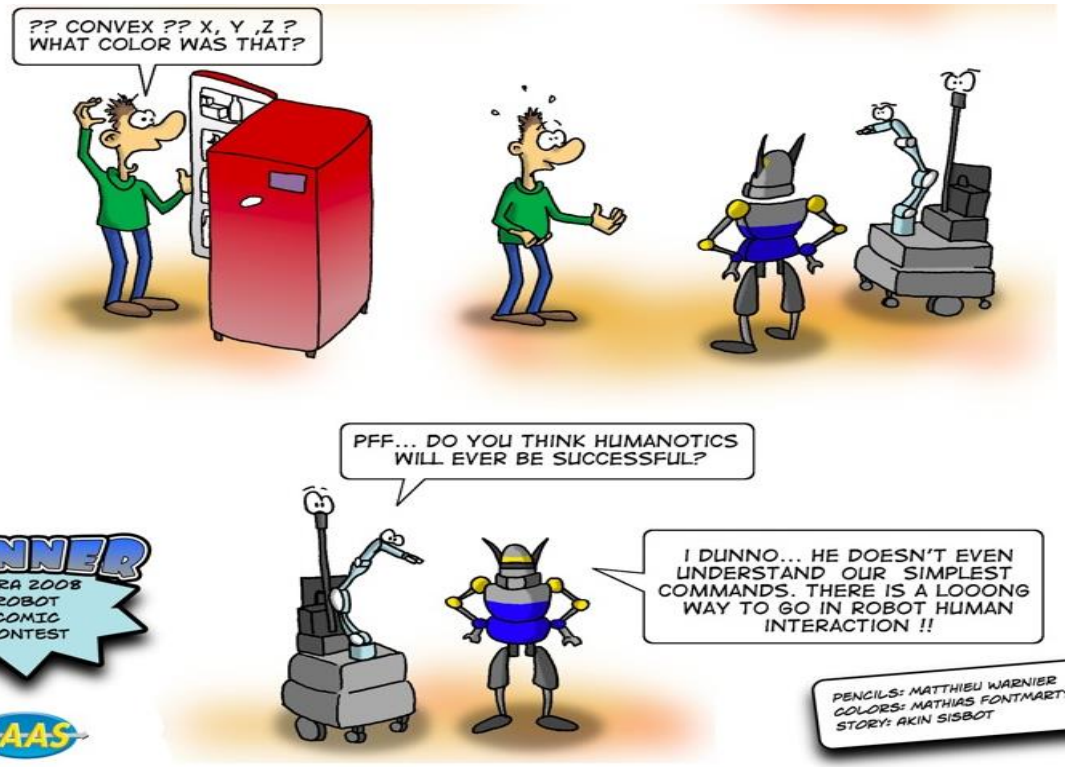
30h lectures

How does a machine interact with humans

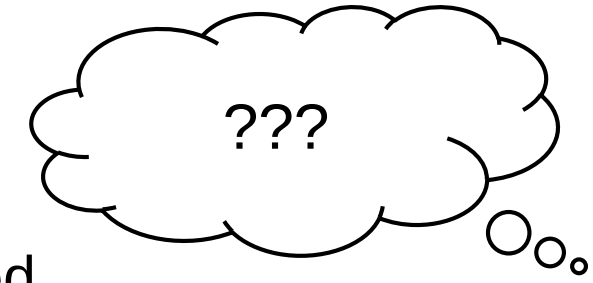
20-30h lectures and seminars



It will sound less weird in a few weeks!



What is going to happen in these few weeks???



Second course edition …

- The program will be refined ongoing
- Lectures might look a little disconnected
- Little previous experience about exams
- … not necessarily a negative thing ;-)

Additional lecturers will help me:

- Andrea Bonarini (Non Verbal Human-Robot Interaction)
- Simone Mentasti (TBD)

All the infos on the course website

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

Course organization / rules

Classes (no distinction between lecture and exercise):

- Tuesday, 08:15 – 10:15, in V.S7-A
- Friday, 10:15 – 13:15, in V.S7-A

These overlap with ...

Detailed calendar online (updated weekly)

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

Grading policy:

- Written examination covering the whole program up to 27/32 +
- Seminar on a course topic graded up to 5/32 =
- Final score will be the sum of the two grades … 32/32

Topic proposed later in the semester, suggestions are welcome

Based on theoretical questions ...

Might be replaced by a coding project ...

Questions ?

…

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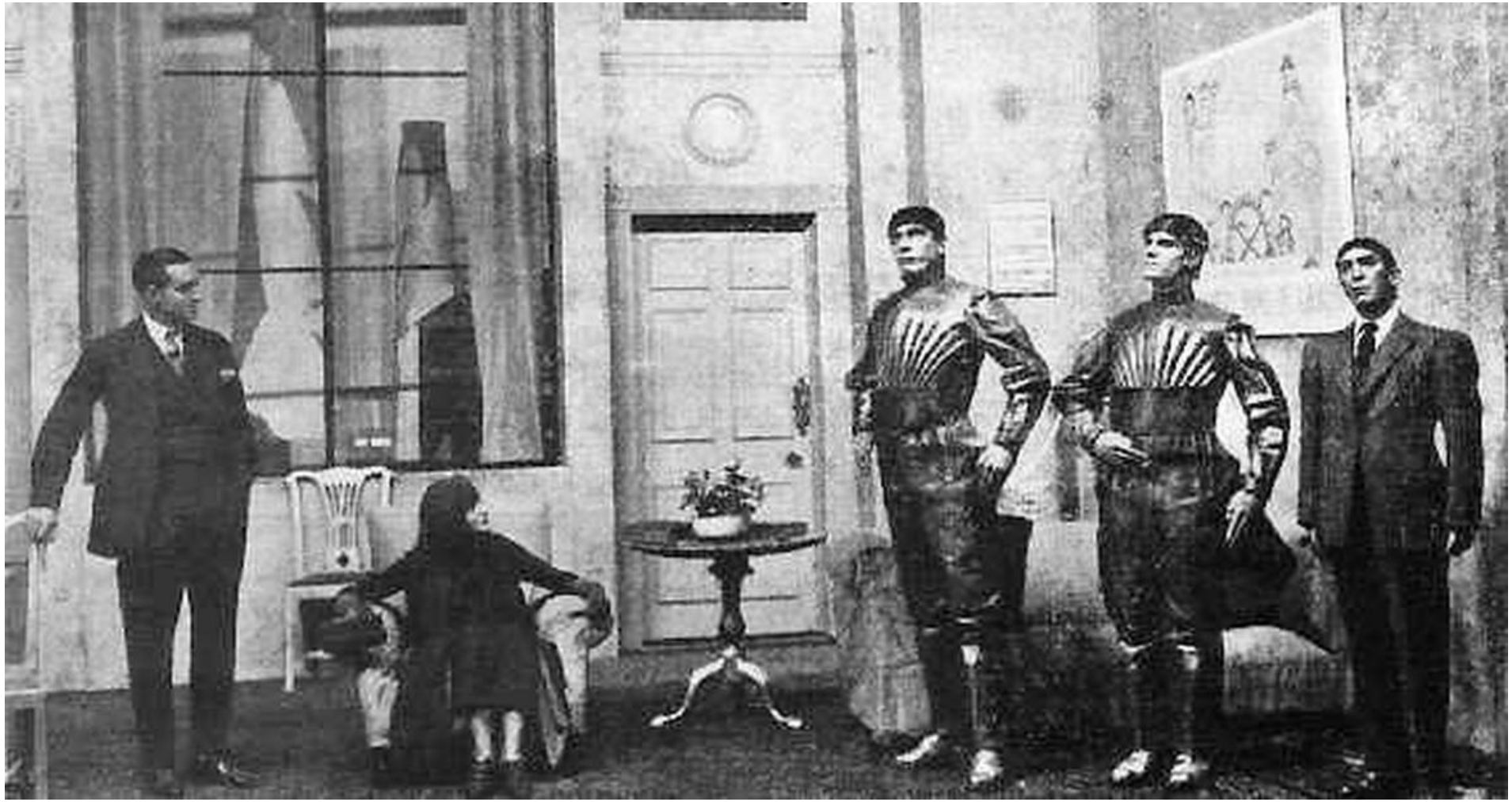
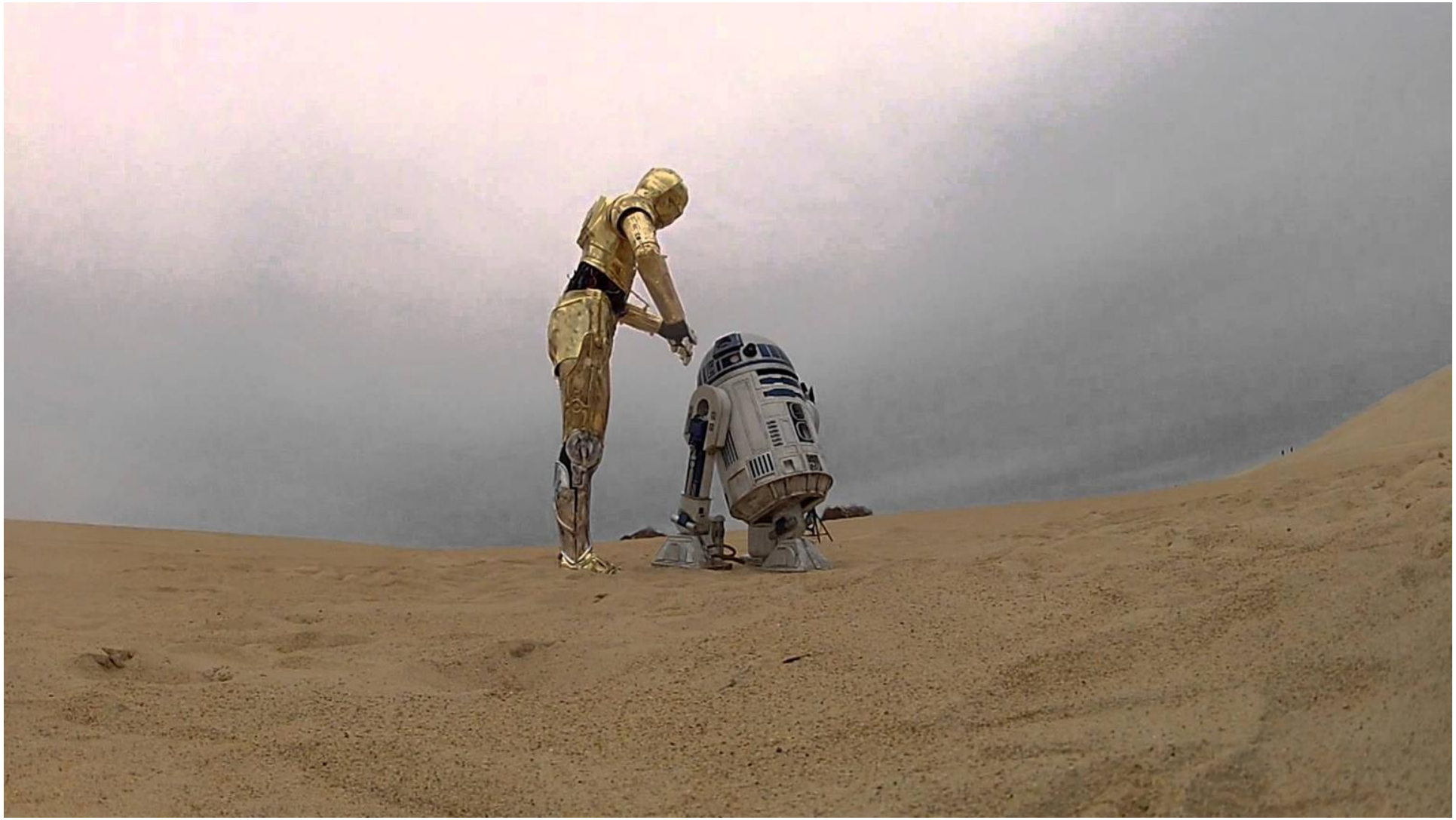
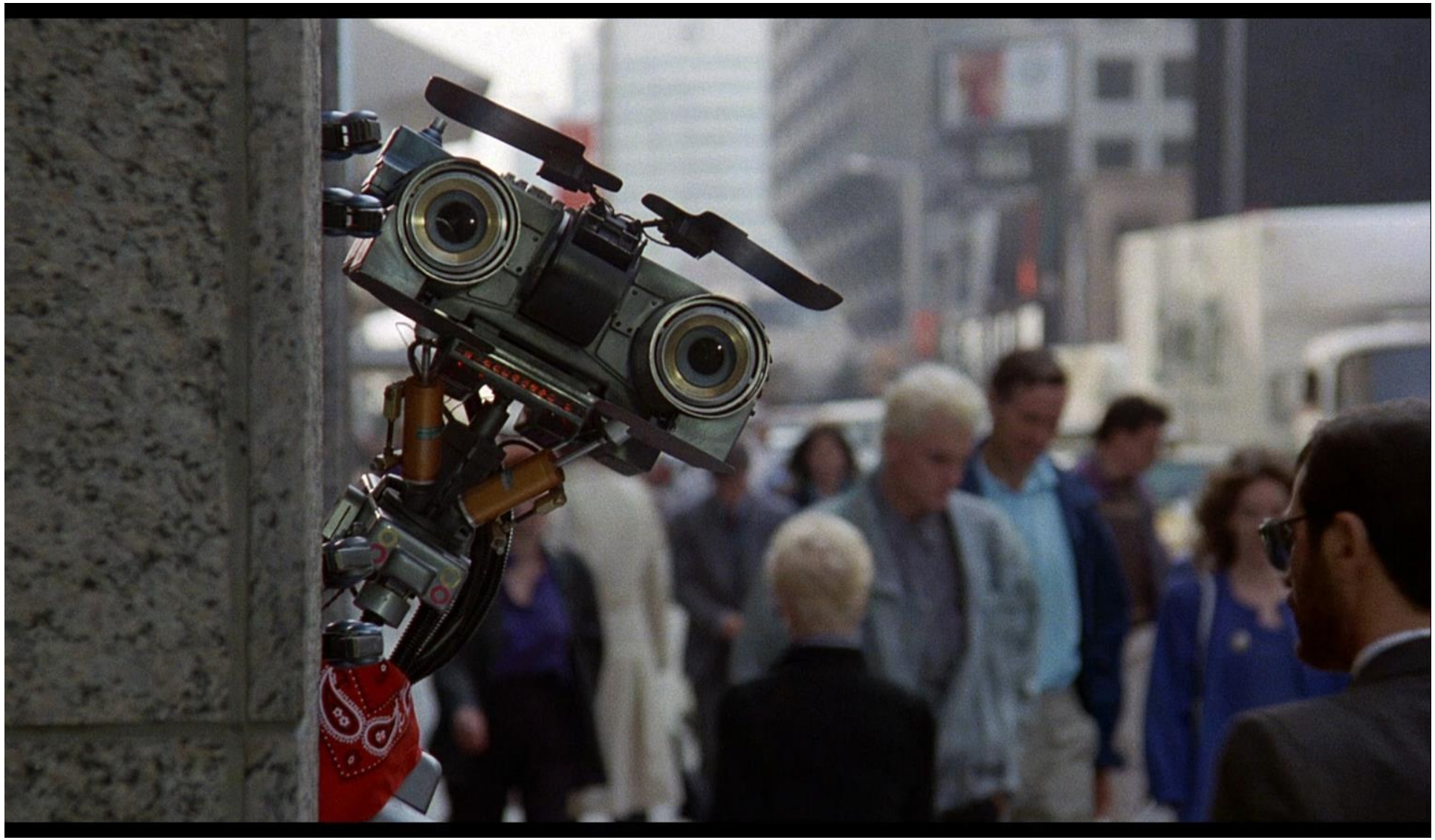
Rossum Universal Robots (1920)



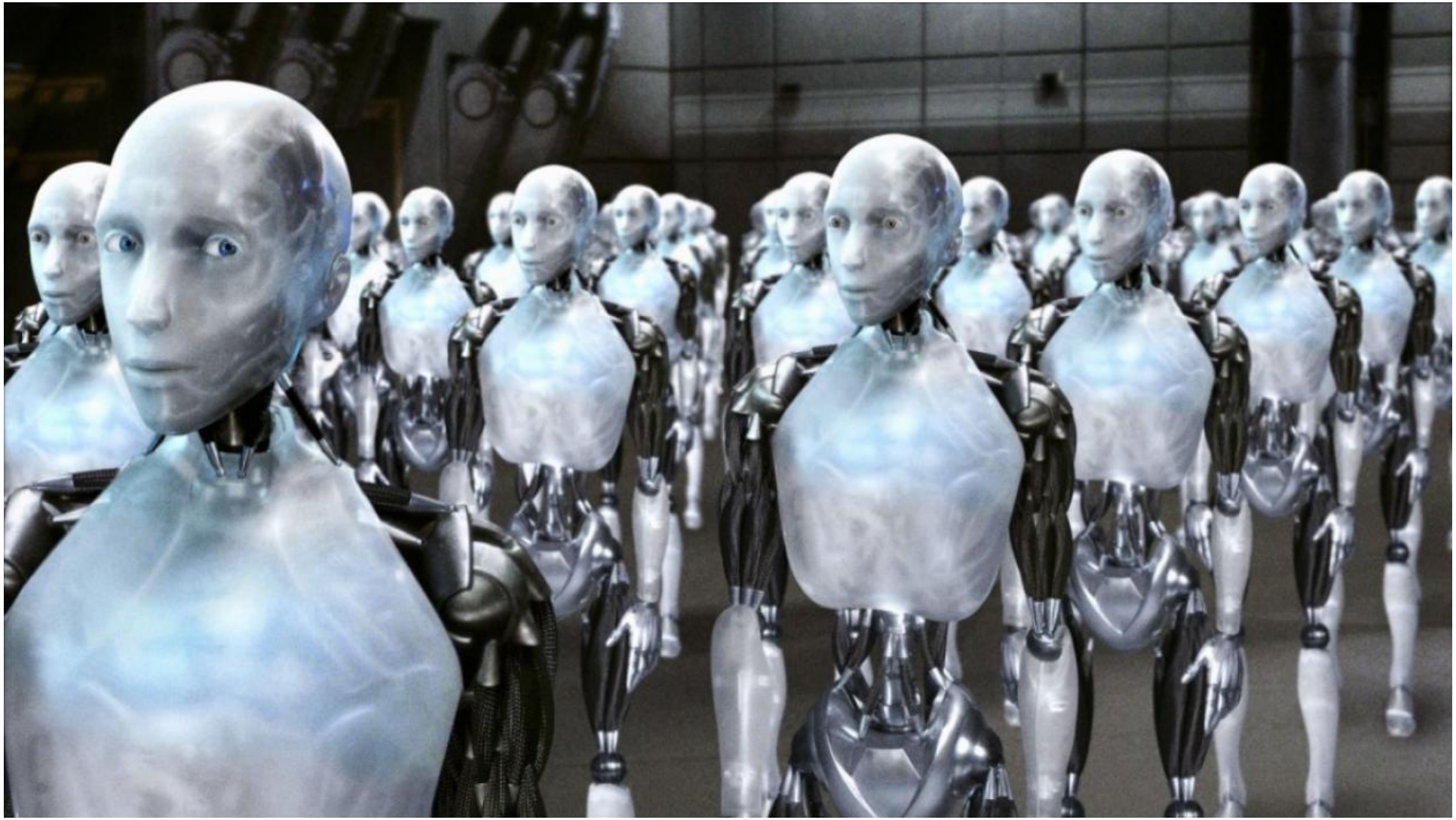
Star Wars (1977)



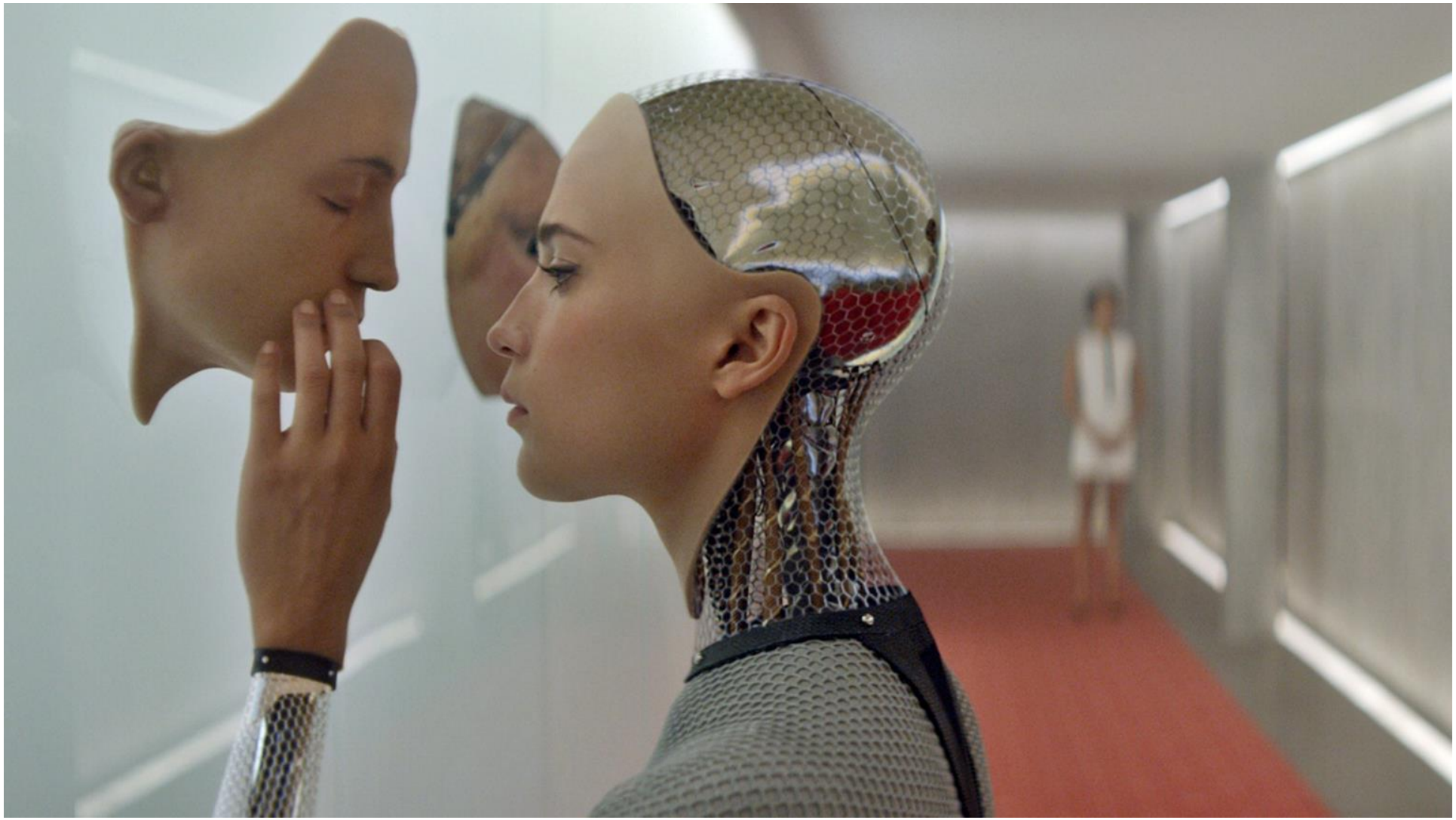
Short Circuit (1986)



I Robot (2001)

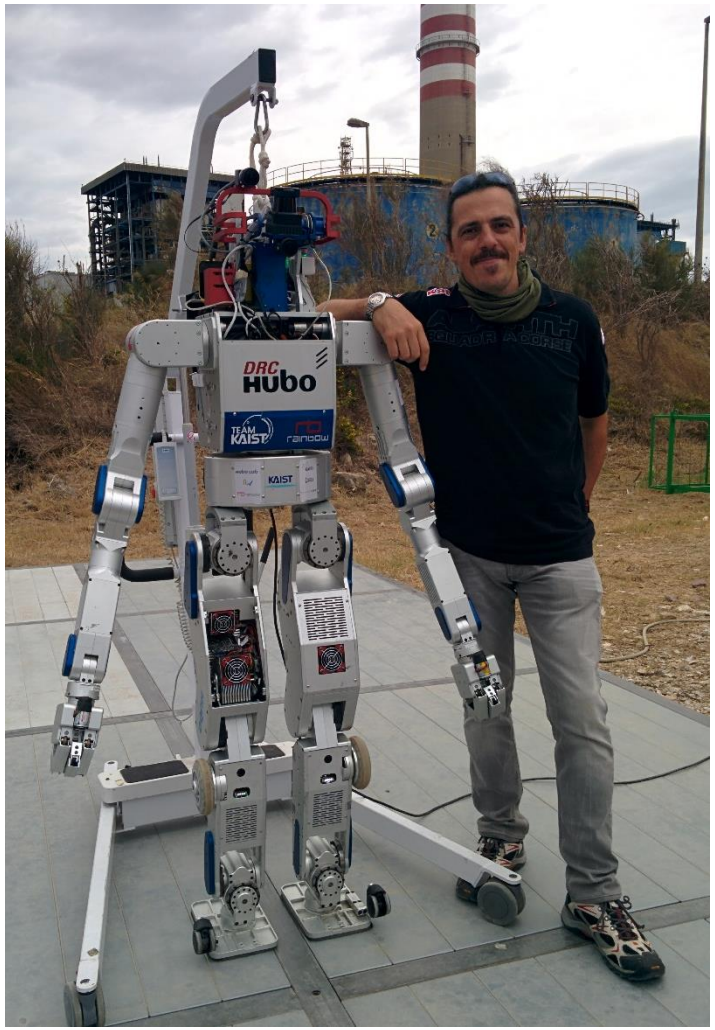


Ex Machina (2015)



Sometimes reality is different...

... and the winner is ...



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

... and every year it gets 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

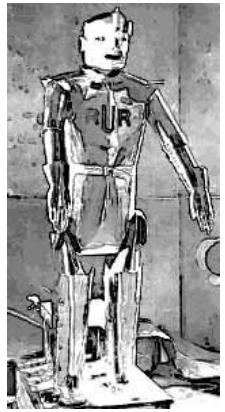
Mechanical era (1700):
- automata
- karakuri-ningyo

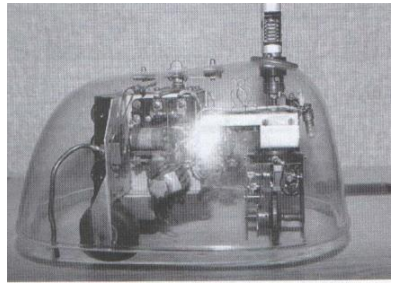
Fiction era (’20s):
- *Rossum Universal Robot*

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!

3D Robotics

jibo

STARSHIP

Steps in robot history

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

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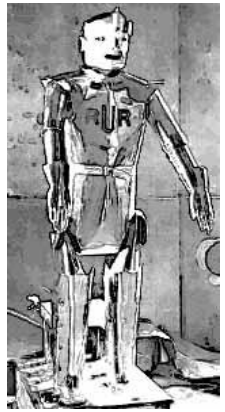
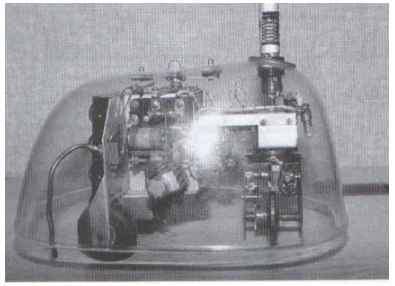
- *Rossum Universal Robot*

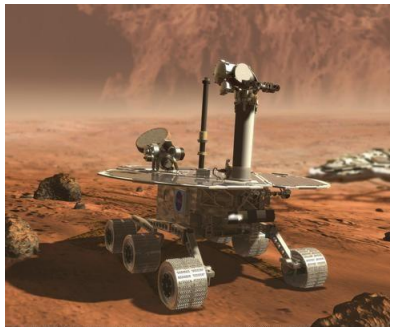
Cybernetics era (‘40s):
- Turtle and telerobot

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

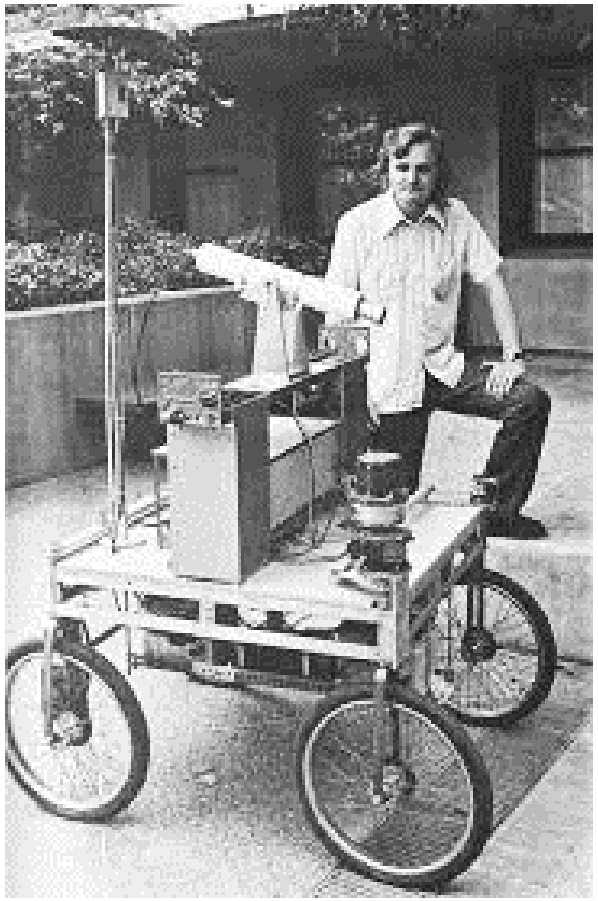
Information era (from the ‘90s):
- Intelligence
- Autonomy
- Cooperation






Shakey (1972) and the Stanford Cart (1970)

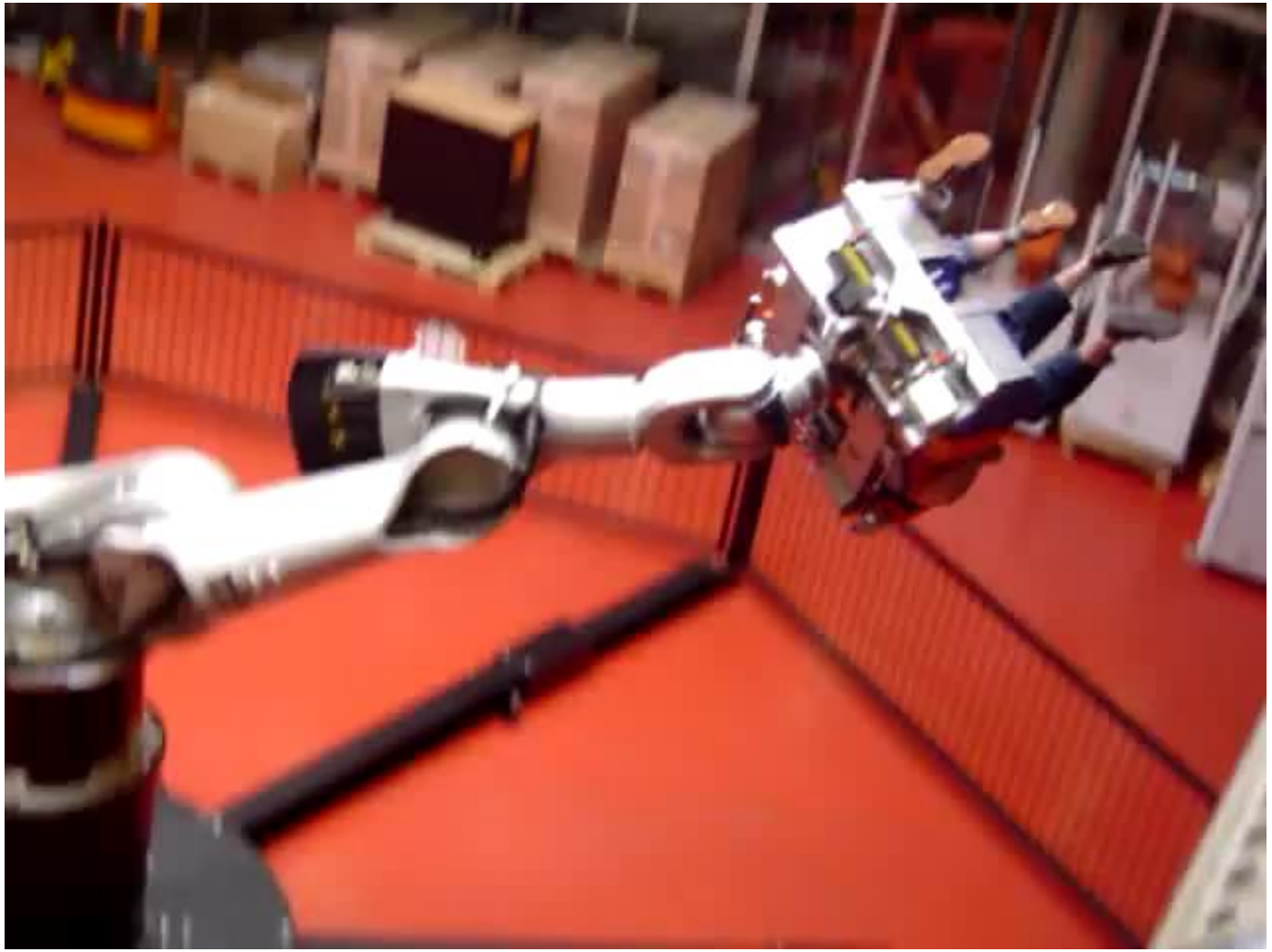


ISO 8373:2012 - Robots and robotic devices

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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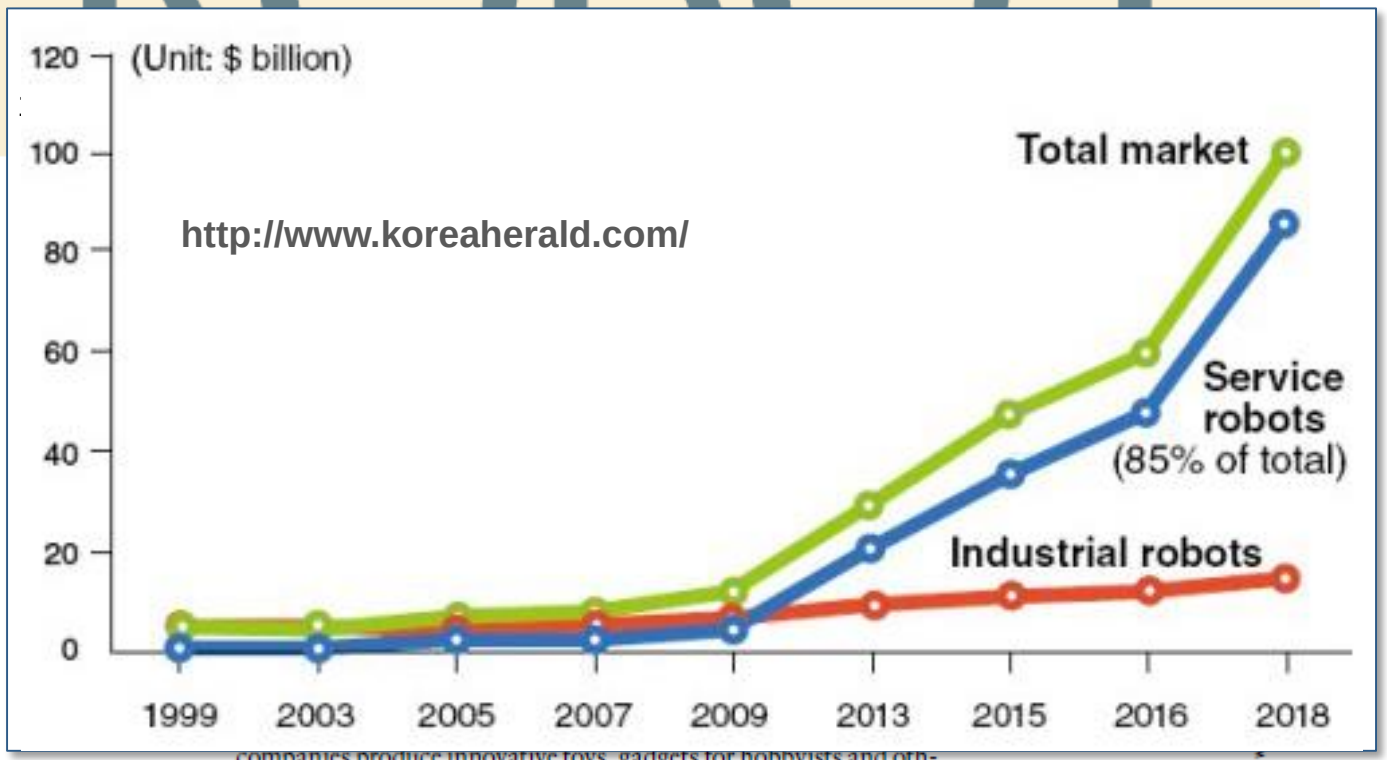
- ✓ A service robot is a robot that performs useful tasks for humans or equipment excluding industrial automation application.
- ✓ A personal service robot or a service robot for personal use is a service robot used for a non-commercial task, usually by lay persons. E.g., domestic servant robot, automated 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.

The Bill Gates “Prophecy” …

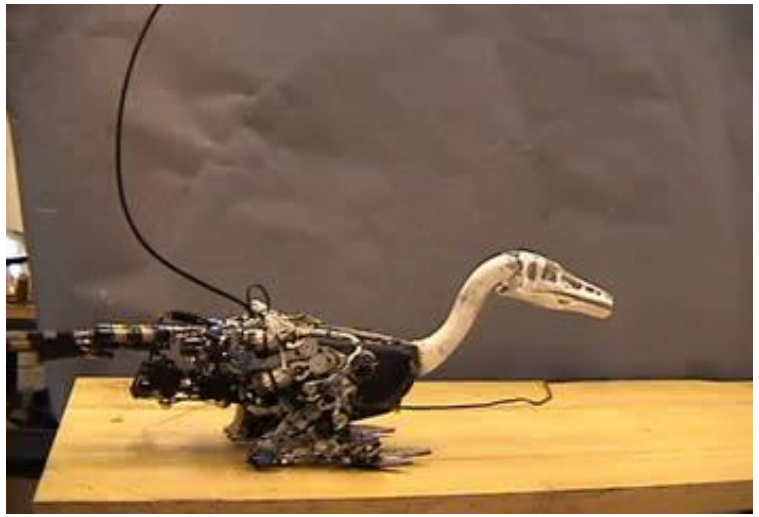
A

ROBOT



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

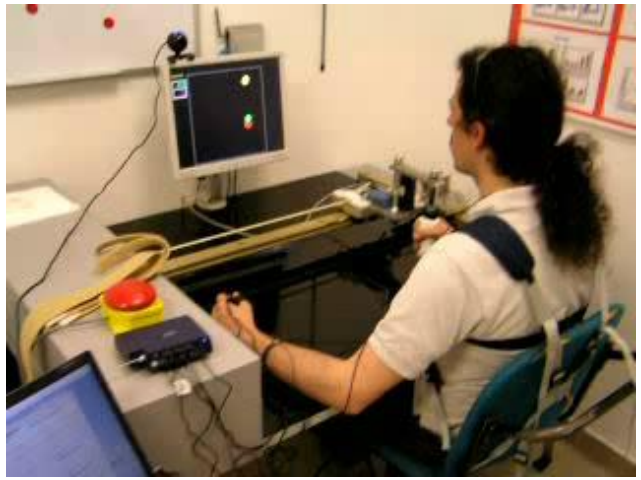
Autonomous service robot

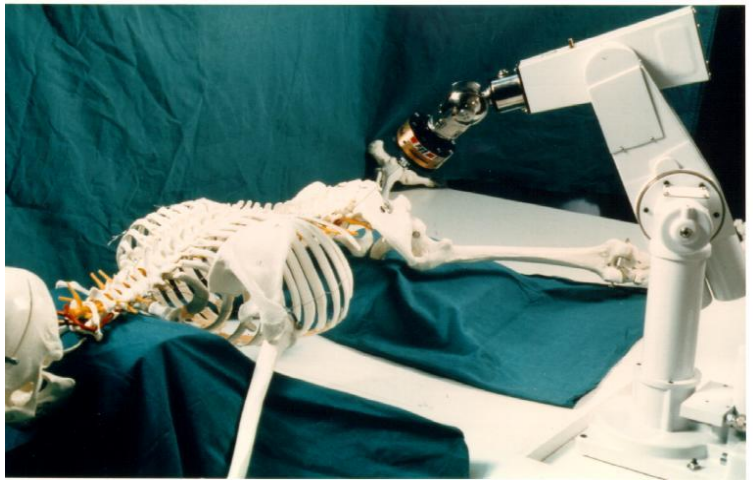


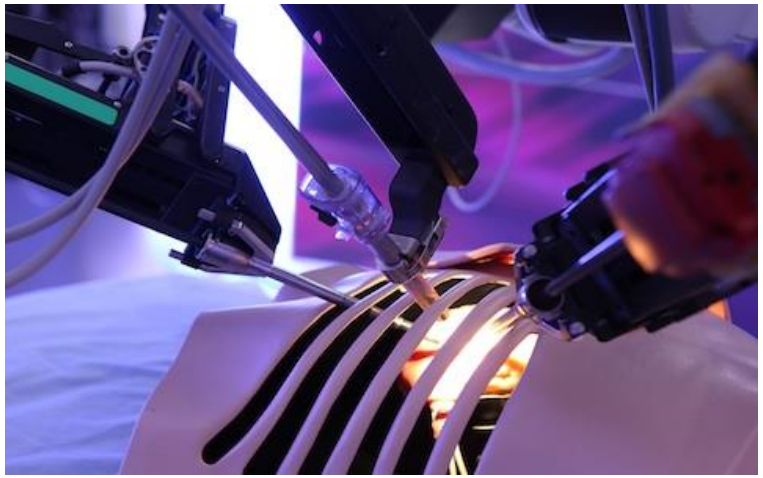
Some notes about the ISO definitions

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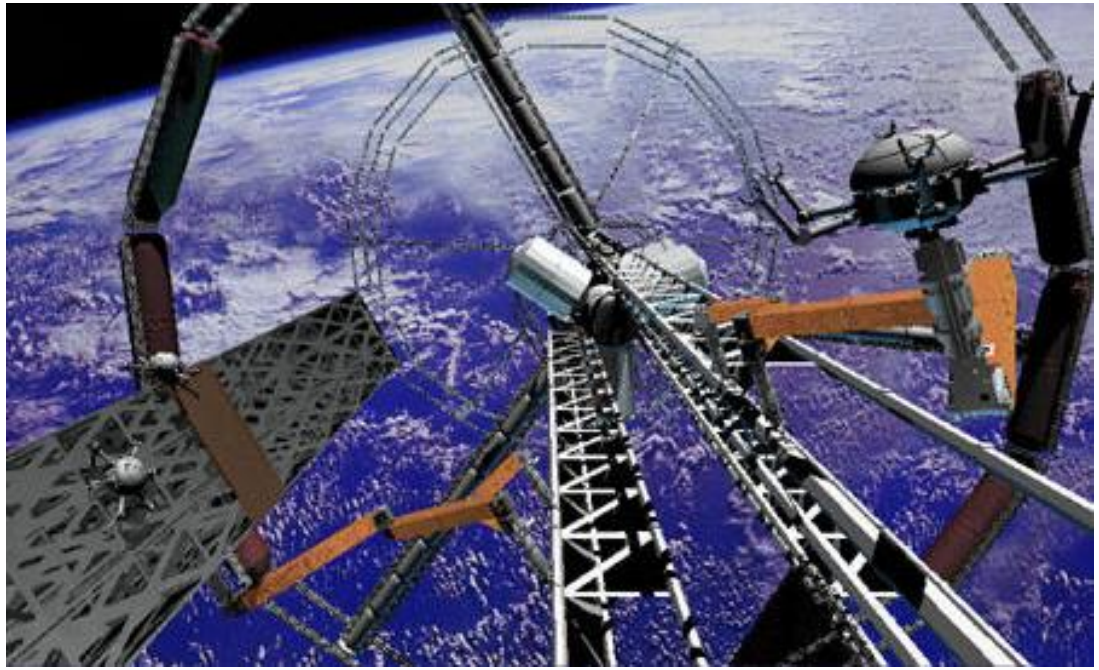
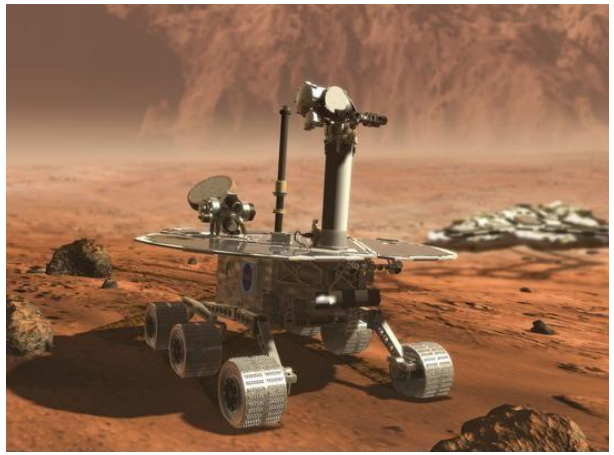
- ✓ Manipulating industrial robots (which can be either fixed in place or mobile) could also be regarded as service robots, provided they are installed in non-manufacturing operations. Service robots may or may not be equipped with an arm structure as is case with some industrial robots. Often, but not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

Space robots





Autonomous vehicles

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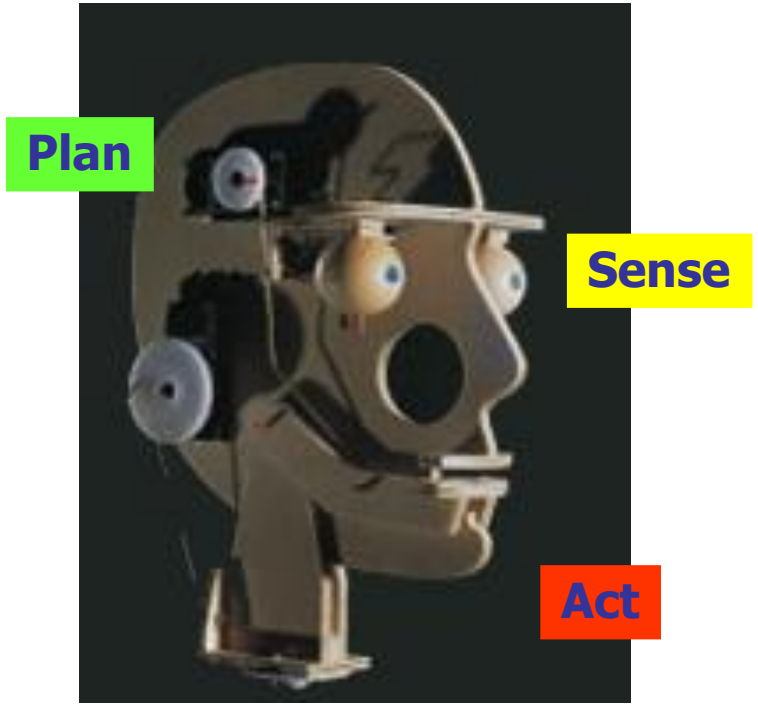
- ✓ In some cases, service robots consist of a mobile platform on which one or several arms are attached and controlled in the same mode as the arms of industrial robot. Furthermore, contrary to their industrial counterparts, service robots do not have to be fully automatic or autonomous. In many cases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

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Two Kinds of Robots: From a D to a C!

The ‘Automaton’ Robot is characterized by the 3D of its tasks

- Dull
- Dirty
- Dangerous

D as Dumb!

The ‘Autonomous’ Robot of our “dreams” is characterized by Cs

- Clever
- Charismatic
- Creative

C as Cognitive!

What is Cognitive Robotics?

"The Cognitive Robotics group is concerned with endowing robotic or software agents with higher level cognitive functions that involve reasoning, for example, about goals, perception, actions, the mental states of other agents, collaborative task execution, etc."

– University of Toronto Cognitive Robotics group

"Cognitive robotics is a new approach to robot programming based on high level primitives for perception and action. These primitives draw inspiration from ideas in cognitive science"

– CMU's Cognitive Robotics course website

What is Cognitive Robotics?

"Cognitive robotics (CR) is concerned with endowing robots with mammalian and human-like cognitive capabilities to enable the achievement of complex goals in complex environments. Cognitive robotics is focused on using animal cognition as a starting point for the development of robotic computational algorithms, as opposed to more traditional Artificial Intelligence techniques, which may or may not draw upon mammalian and human cognition as an inspiration for algorithm development."

– Wikipedia

Robotics + Cognitive Science = Cognitive Robotics

Robotics + Cognitive Science

- Create robots with cognitive abilities
- Create robots that are “human-like”

Cognitive Science → Robotics

- Use cognitive science to improve robots

Robotics → Cognitive Science

- Use robots to test cognitive science theories
- Use robots to compare different cognitive architectures
- Use robots to identify problems and questions about cognition
- Use robots as a platform to learn about cognition

Improving robots capabilities with cognition

Cognitive Robotics provides cognitive building blocks to robots:

- High-Level Perception and Action
- Attention
- Memory
- Learning
- Concept Formation
- Reasoning and Problem Solving
- Communication and Use of Language
- Theory of Mind
- Social Interaction
- ...