Industrial Robotics

Prof. Gionata Salvietti

Course Info

- Lessons: Tuesday 14.00 – 16.00, Wednesday 11.00 – 13.00, Room 18
- Website: http://control.dii.unisi.it/ir/index.htm
- Exam: ROS Project (30%) + Oral (70%)

Contacts

- Email: gionata.salvietti@unisi.it
- Students' meetings: Tuesday 11.00 – 12.30 after mail confirmation
- Shared folder, list of students?

Program

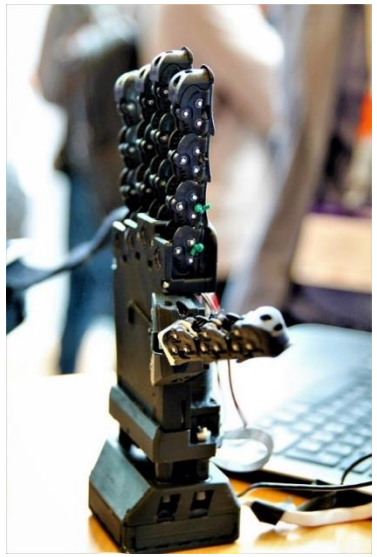
- Recall of robotics foundations
- Trajectory and motion planning
- Robot Dynamic System Learning
- ROS – lab activity
- Innovative applications

iCub

Parrot Quadrotor

KUKA LBR iiwa

What is a robot?



Pisa/IIT SoftHand

Ocean One

Pioneer mobile robots

Definition

A robot is an **artificial system** that acts in the environment following a **list of commands**

Atlas, Boston Dynamics

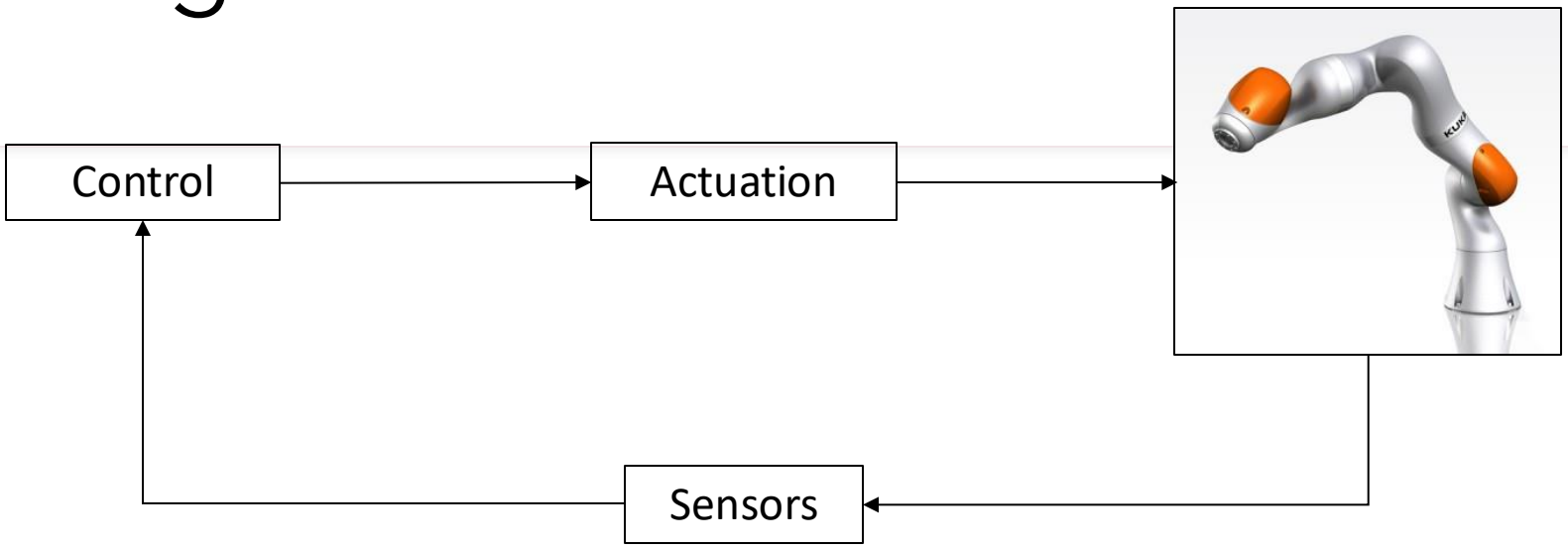
```
#!/bin/python
# -*- coding: utf-8 -*-

# Add the path to our custom python
import sys
sys.path.append("../../python/lib")

import numpy
import time
from pneumaticbox import api, io
import os, sys

class PostureHand():
    def __init__(self, pbox):
        self.pbox = pbox
```

Block diagram

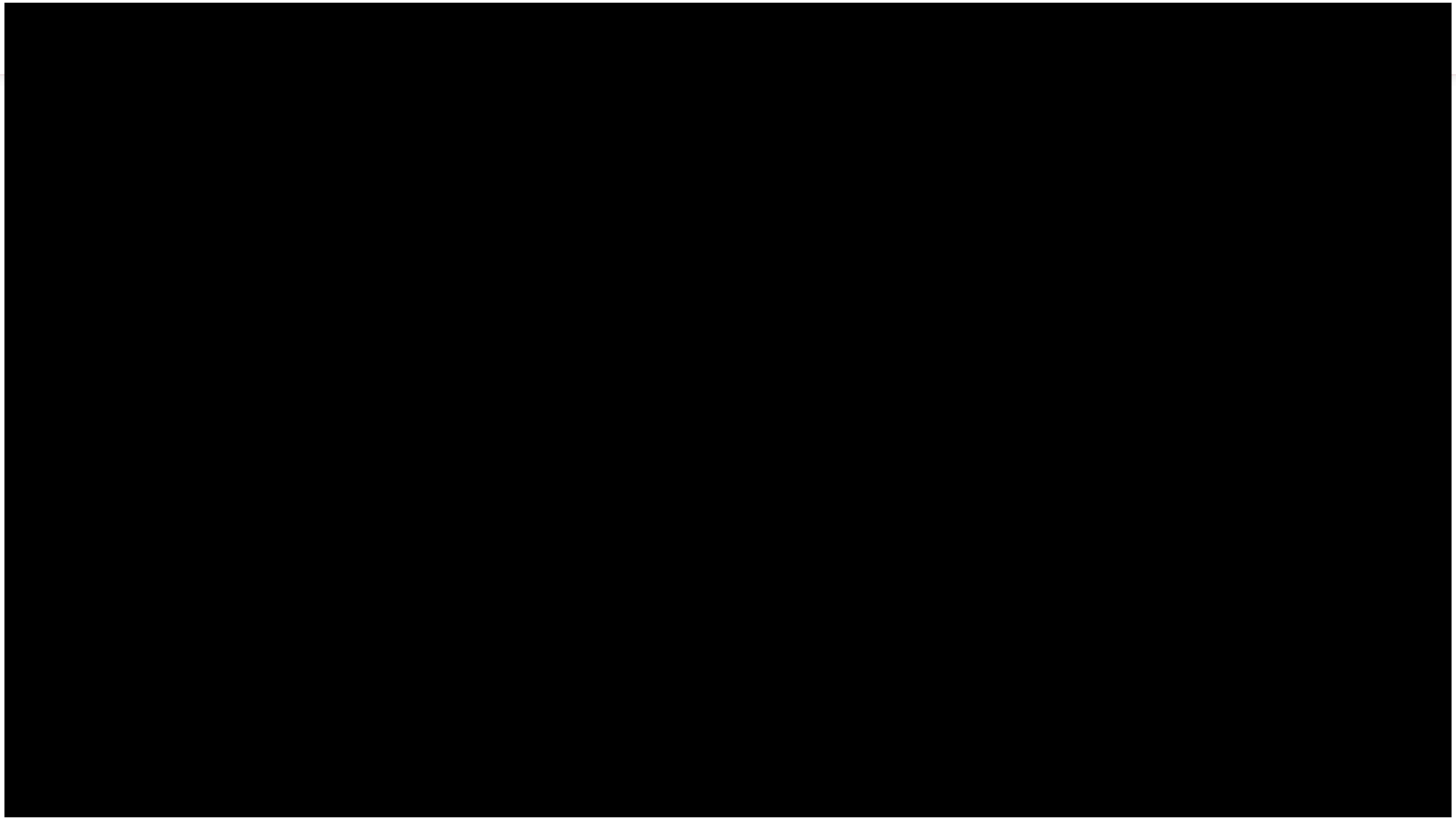


Robotics studies the intelligent interplay between **action** and **perception**

The name «robot»

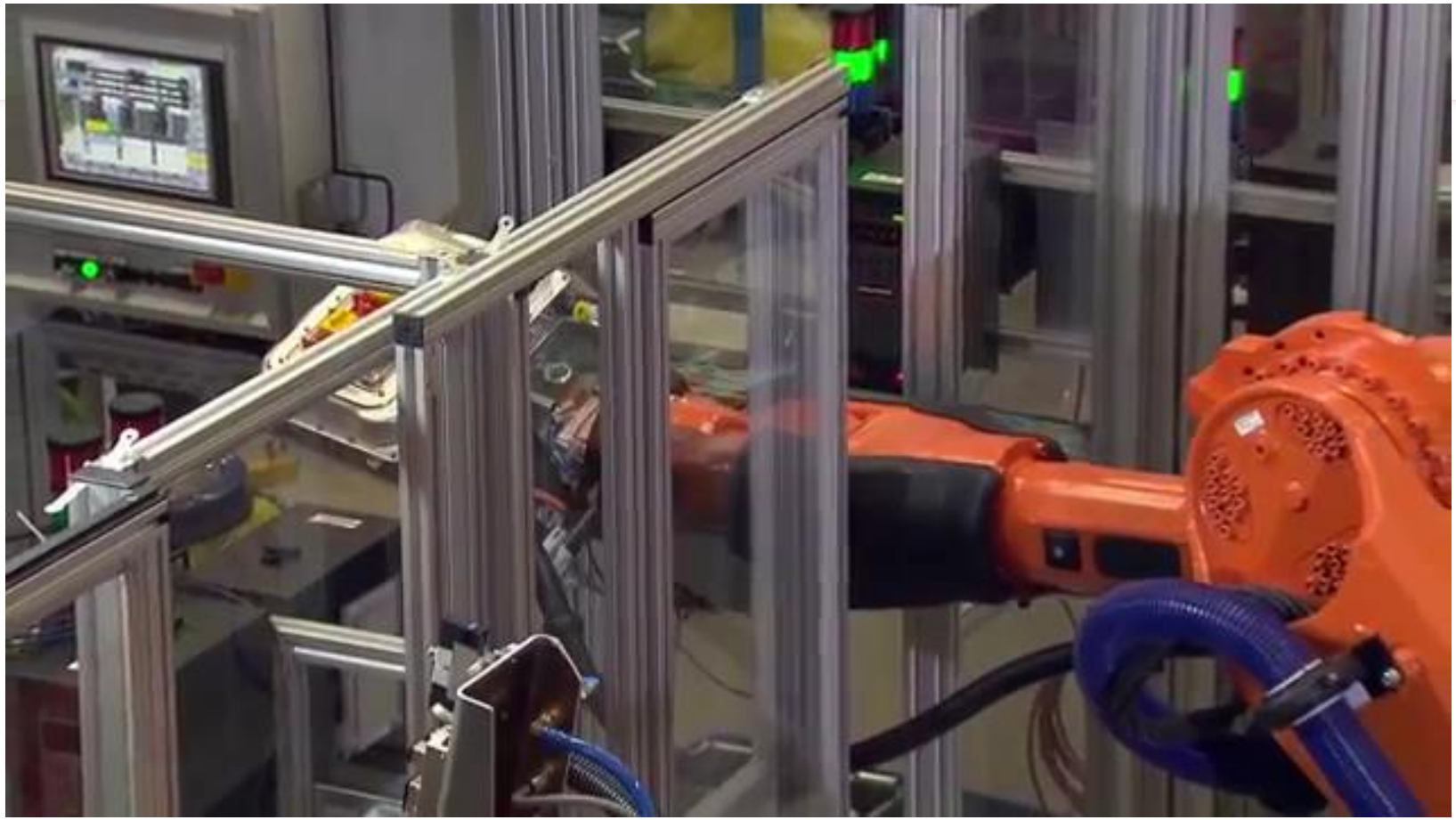
- The name **robot** comes from che slavian word *robota* (=work) introduced by Karel Capek in *Rossum's Universal Robots* (1920).

Examples of industrial robots (1/2)



https://youtu.be/1u7XiBnwPCw?t=856

Industrial robotics (2/2)



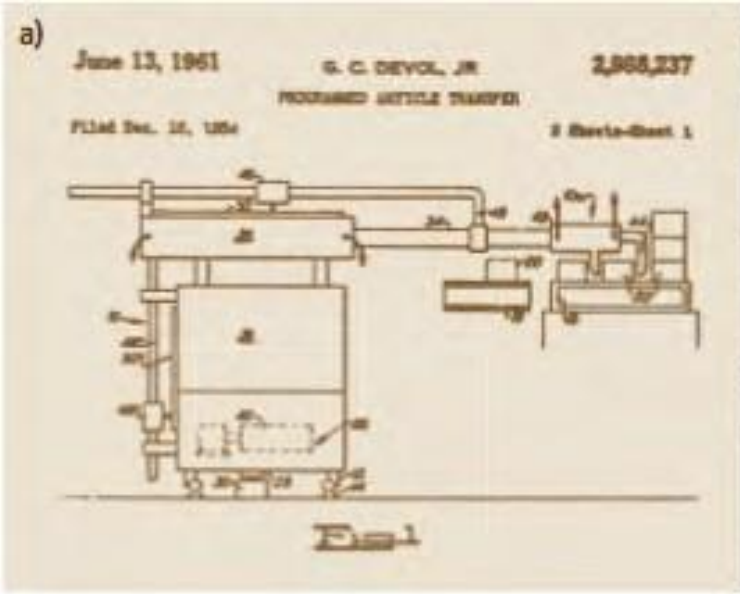
https://youtu.be/1u7XiBnwPCw?t=561

What is an industrial robot?

Industrial robot
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.

ISO 8373:2012(en), Robots and robotic devices — Vocabulary

The first industrial robot



US Patent

General Motors, 1961

G. Devol e J. Engelberger (Unimation)

More info on Robot History:
International Federation of Robotics (ifr.org)

Typical applications

- Spot welding
- Arc welding
- Assembly
- Loading/unloading, pallettazing
- Packaging
- Gluing and sealing
- Manipulation
- Line automation

Source: Comau Robotics

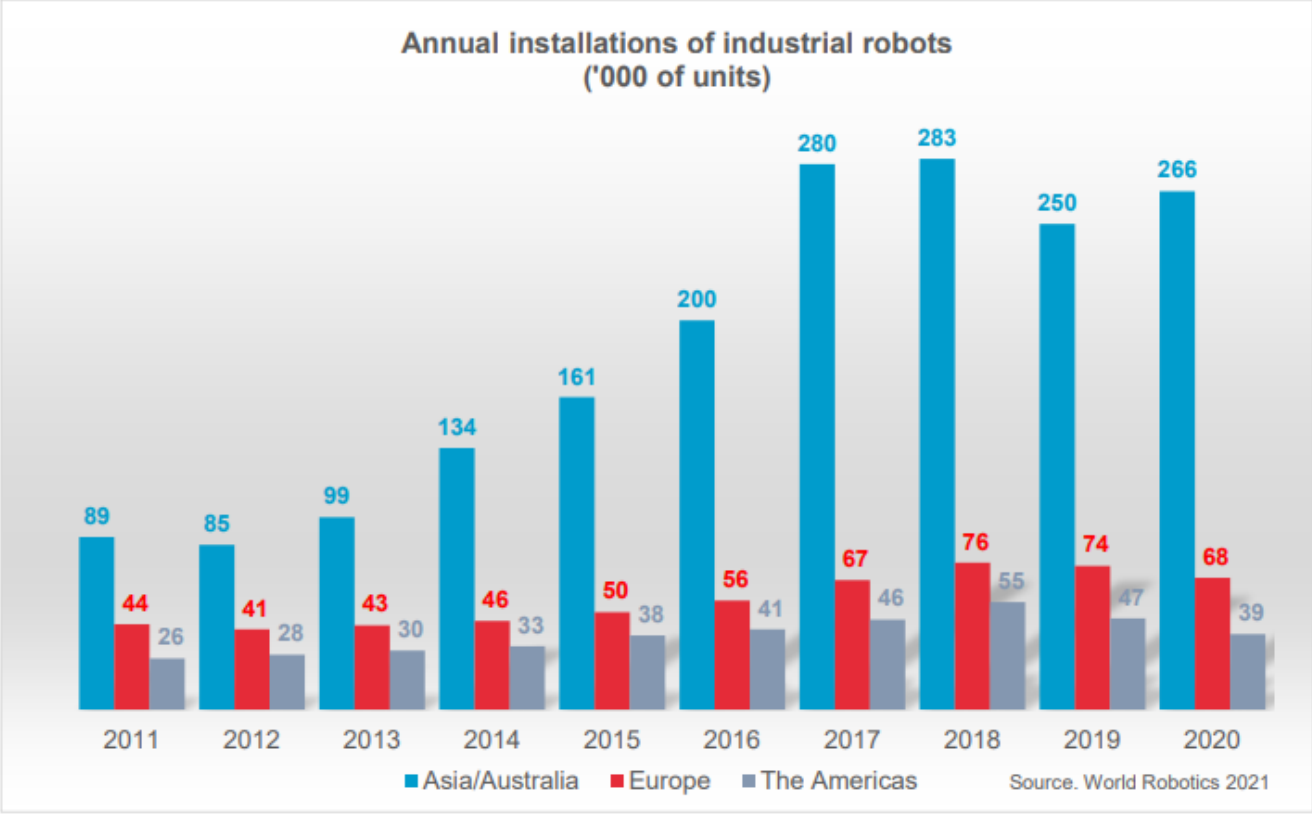
Welding

Ten Popular Industrial Robot Applications

- https://www.jabil.com/blog/ten-popular-industrial-robot-applications.html

Executive Summary World Robotics 2021 Industrial Robots – Annual Installations

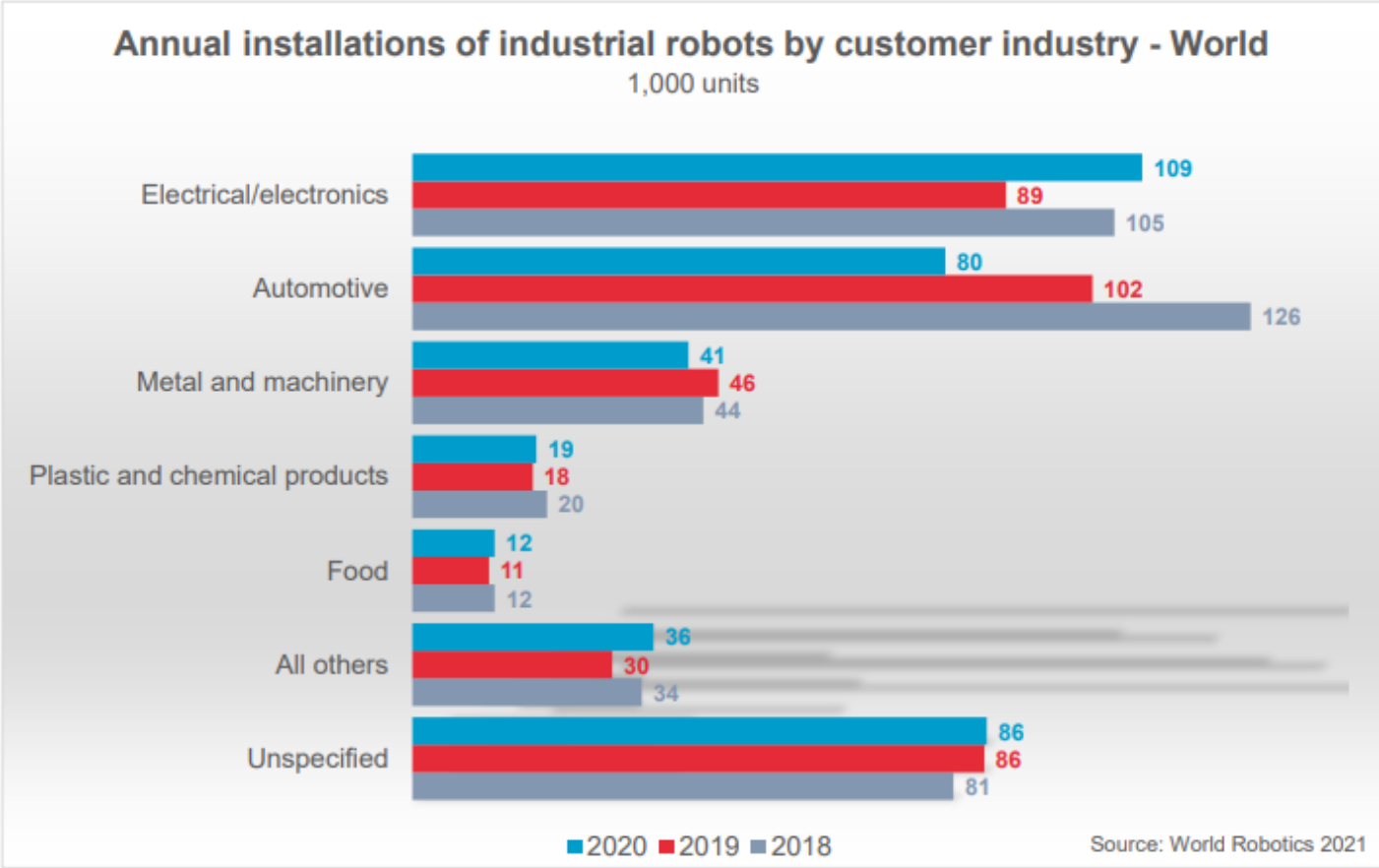
The five major markets for industrial robots are China, Japan, the United States, the Republic of Korea and Germany. These countries account for 76% of global robot installations.



Source: IFR (International Federation of Robotics)

Executive Summary World Robotics 2021 Industrial Robots – Applications

The year 2020 created a historic moment in the history of robotics. The automotive industry lost its position as the largest customer of industrial robots.



Source: IFR (International Federation of Robotics)

Outlook: 2020 - 2024

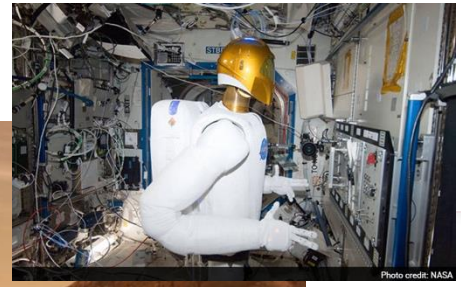
- The ongoing year 2021 is characterized by the recovery from the Covid-19 pandemic. Global robot installations are expected to rebound strongly and grow by 13% to 435,000 units in 2021.
- The “boom after crisis” is expected to fade out in 2022 on a global scale. From 2021 to 2024, average annual growth rates in the medium single-digit range are expected.

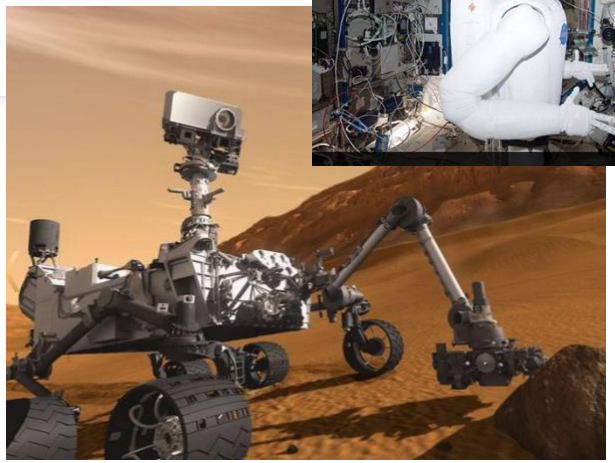
Source: IFR (International Federation of Robotics)

Service Robotics

Ocean One, Stanford Robotics Lab

Robonaut 2, Nasa, ISS





The Mars Science Laboratory Rover, “Curiosity”

Da Vinci Surgical System

Autonomous van, VisLab, Parma

Robotic surgery

Johnson & Johnson Developing Robot-Assisted Knee Surgery

By Steven Crowe | February 23, 2018

The Robot Report

Autonomous vehicles

AutoX fleet grows beyond 1,000 AVs - The Robot Report

Agricultural robotics

Researchers complete automated crop plant and harvest

By Alex Beall | September 13, 2017

Credit: Hands Free Hectare

A team from Harper Adams University and agricultural solutions company Precision Decisions successfully planted, tended and harvested a crop of barley using only autonomous machines, a project they called Hands Free Hectare.

"This project aimed to prove that there's no technological reason why a field can't be farmed without humans working the land directly now and we've done that," Precision Decisions mechatronics researcher Martin Abell said in a press release. "We set-out to identify the opportunities for farming and to prove that it's possible to autonomously farm the land and that's been the great success of the project."

[The Robot Report]

Executive Summary World Robotics 2021 Service Robots

- Autonomous guided vehicles (AGVs)
- Maintenance and inspection robots
- Defense applications
- Powered Human exoskeletons
- Field robots
- Medical robots
- Domestic/household tasks
  - vacuuming and floor cleaning
  - lawn-mowing
  - pool-cleaning
- Entertainment
  - toys
  - hobby systems
  - education and research

2020: Still growing strongly

New **professional service robots***

- 131,800 units (+41%)
- Turnover: USD 6.7 billion (+12%)

New **consumer service robots**

- 19 million units (+6%)
- Turnover: USD 4.4 billion (+16%)

Source: IFR (International Federation of Robotics)

Automation: motivation

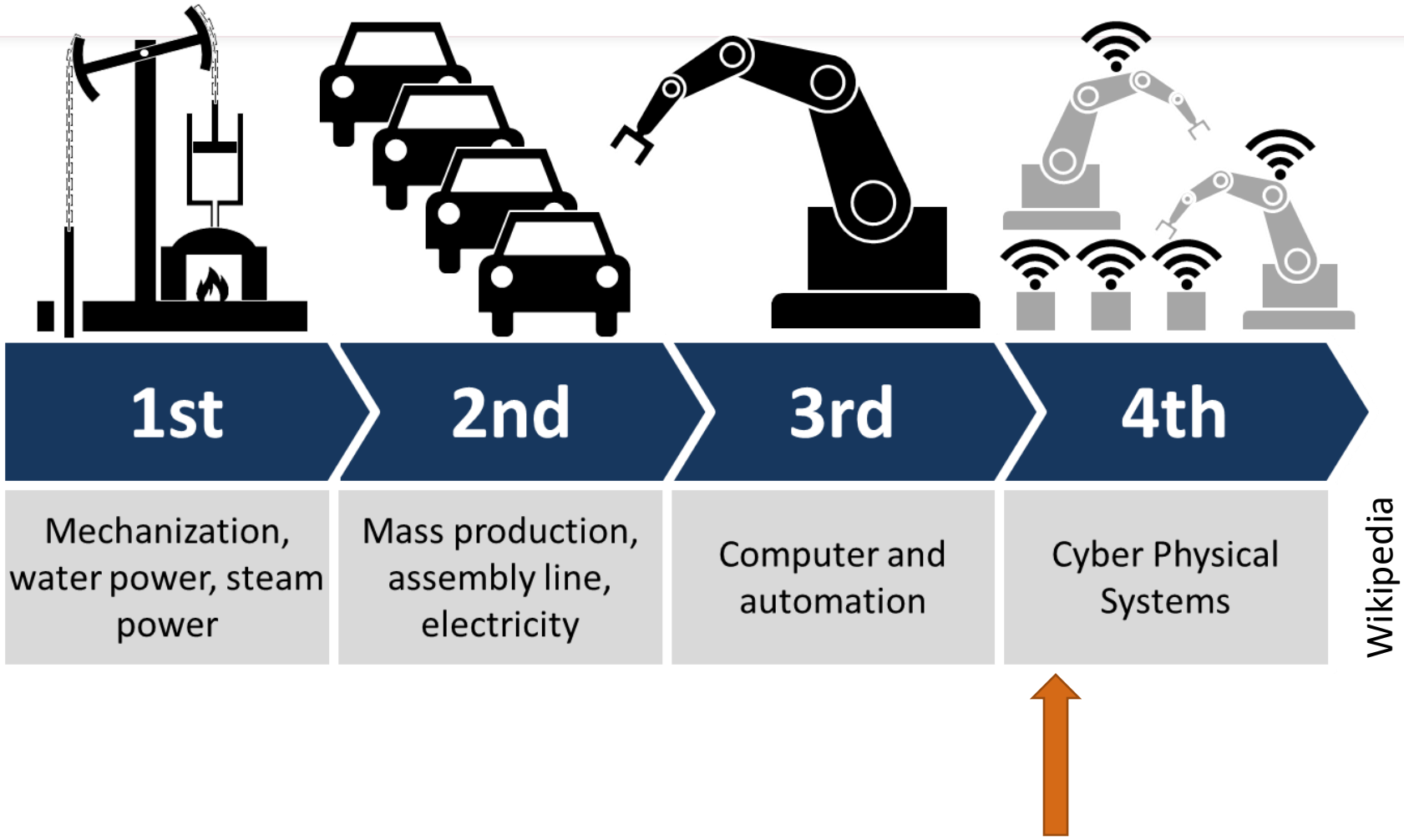
- Human labour:
  - Energy (muscles)
  - Information (sight, touch,...)
  - Control (brain)

- The objective of **automated production processes** is to totally or partially eliminate human intervention for what concerns the 3 basic ingredients.
  - energy - human labour is not enough
  - Information and control – usually humans don't have enough capabilities and does not guarantee precision

Collaborative robotics and industry4.0

New challenges and perspectives

Industrial revolutions in an image



Definition (1/2)

- Industry 4.0 is the trend towards automation and data exchange in manufacturing technologies and processes which include cyber-physical systems (CPS), the internet of things (IoT), industrial internet of things (IIOT), cloud computing, cognitive computing and artificial intelligence. *(Wikipedia)*

Definition (2/2)

- The term Industry 4.0 was used for the first time in 2011, during the Hannover Messe.
- It is, in short, the result produced by the enormous growth of the Internet, both in terms of the scope of data traffic and its diffusion, combined with the so-called **Internet of Things**, which refers to the possibility of connecting to the network **objects that collect information and exchange it**: simple appliances but also more complex appliances.

Business People

Characteristics

When compared with previous industrial revolutions, the Fourth is

- evolving at an **exponential** rather than a linear pace.
- disrupting almost every industry in every country.
- The breadth and depth of these changes herald the **transformation of entire systems** of production, management, and governance.

World Economic Forum

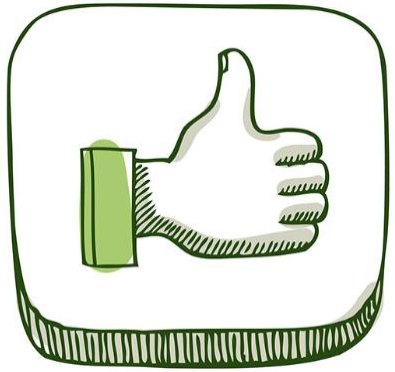
Enabling technologies

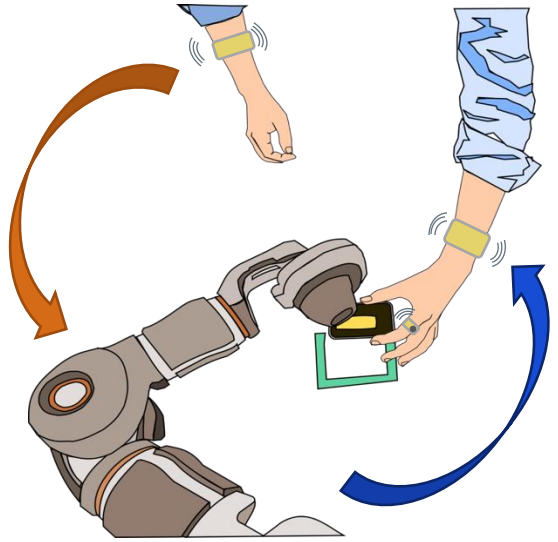
- **Advanced production systems**, interconnected and modular systems that allow increased flexibility and performance.
  - Advanced robotics → **collaborative robots** or cobots.
- Additive manufacturing
- Augmented reality
- Big Data Analytics
- Simulation
- Horizontal and vertical integration
- Cloud
- Cyber-security

A collaborative robot, or cobot, is a type of robot intended to physically interact with humans in a shared workspace.

Collaborative robots

- Low inertia (lightweight robots)
  - reduced risk when impact
- High compliance
- Redundant proprioceptive sensorization
  - Position, velocity, torque
- Compact design
- Low power consumption
- Protective fences are not needed
- Particularly interesting for SMEs (reduced cost, reduced foot print)



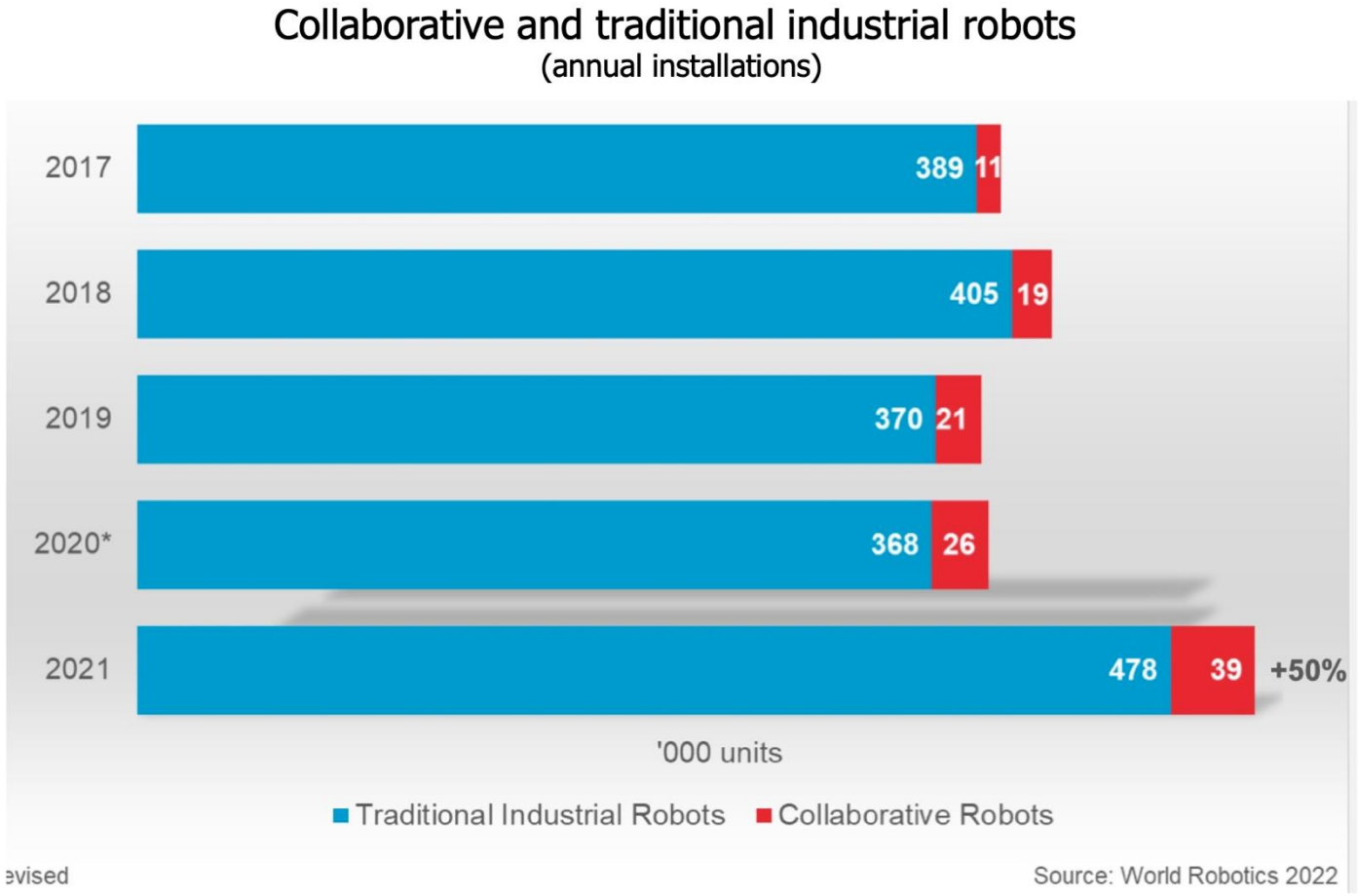


Collaborative robots

- Low payload
- Low precision
- Low velocities

- … but the number of available models is increasing
- https://www.motoman.com/en-us/products/robots/industrial/assembly/hc/hc20xp

Market

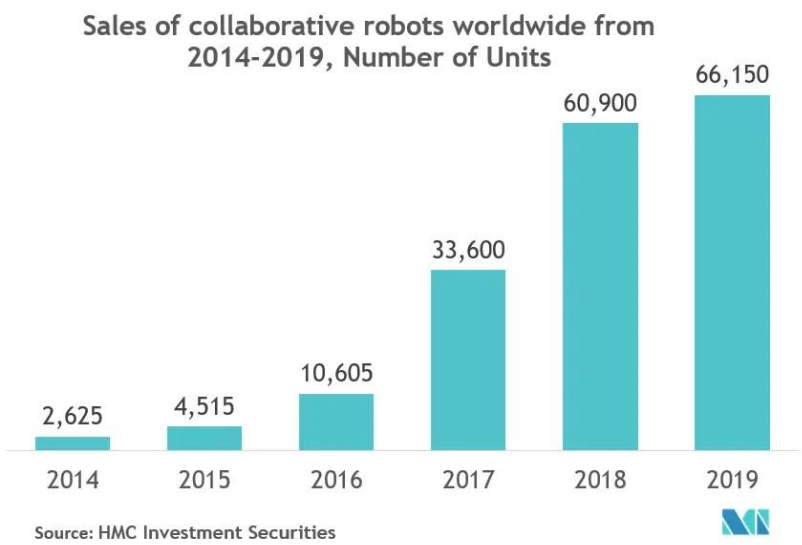


a smaller but steadily **growing market share** in industrial setting

Forecasts

- (MAR 2020, Markets and Markets) The collaborative robot market is projected to grow
- from USD 981 million in 2020 to USD 7,972 million by 2026;
- at a Compound Annual Growth Rate (CAGR) of 41.8% during 2020–2026.

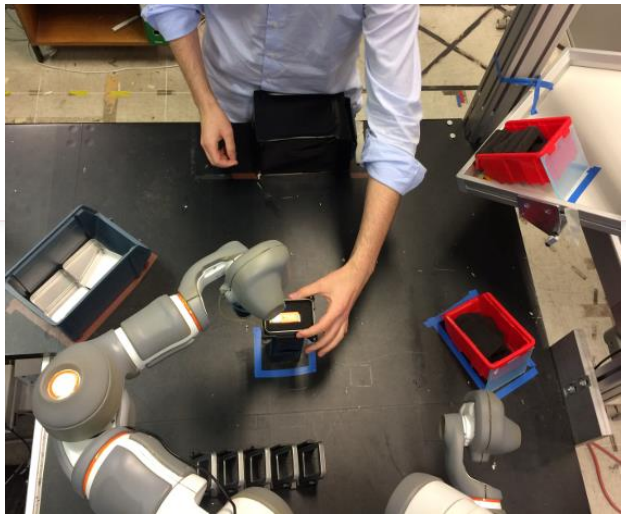
- (JAN 2021, Mordor Intelligence) The global collaborative robot market
- was valued at USD 573.12 million in 2020, and it is expected to reach USD 1,870.59 million by 2026
- CAGR of 23.06%, during 2021-2026.

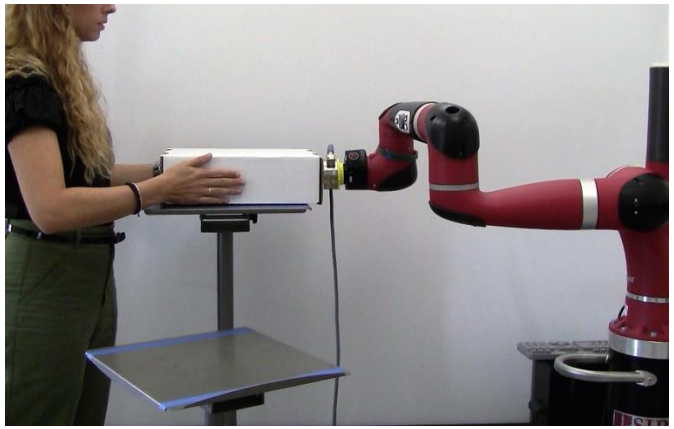


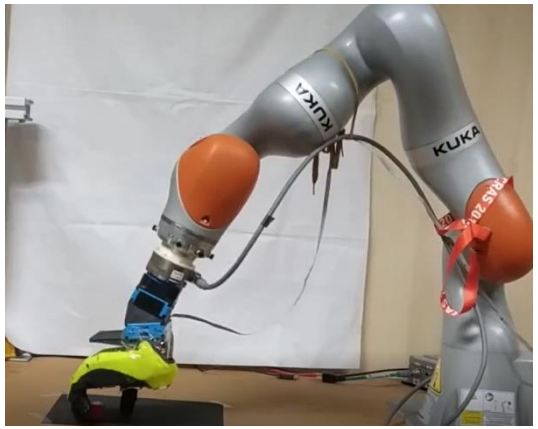
- Drivers for the adoption of cobots:
- Unlike traditional industrial robots, collaborative robots (cobots)
- provide a fast ROI (as low as 6 months in many cases)
- Emerging companies offering low-cost cobots.

Examples

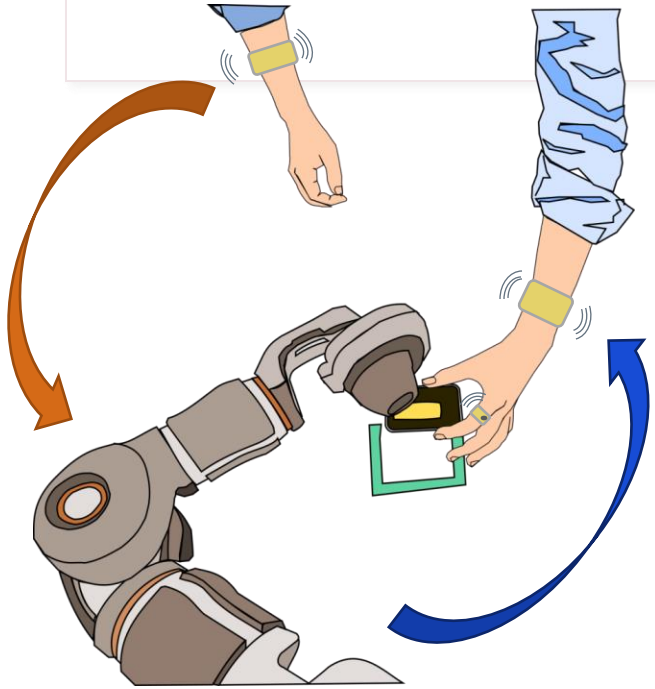
- ABB Yumi
- Universal Robot
- KUKA LBR iiwa
- Sawyer (Rethink Robotics)
- Baxter (Rethink Robotics)



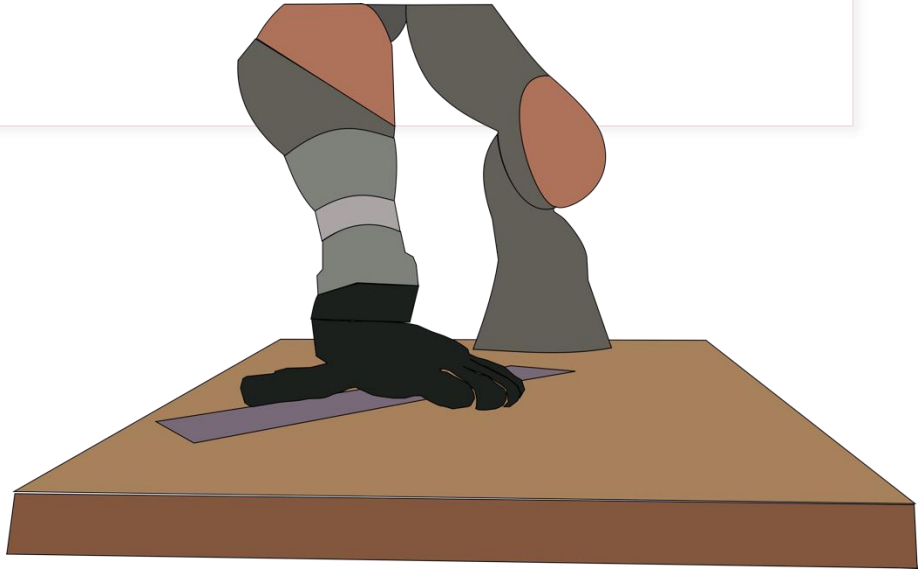




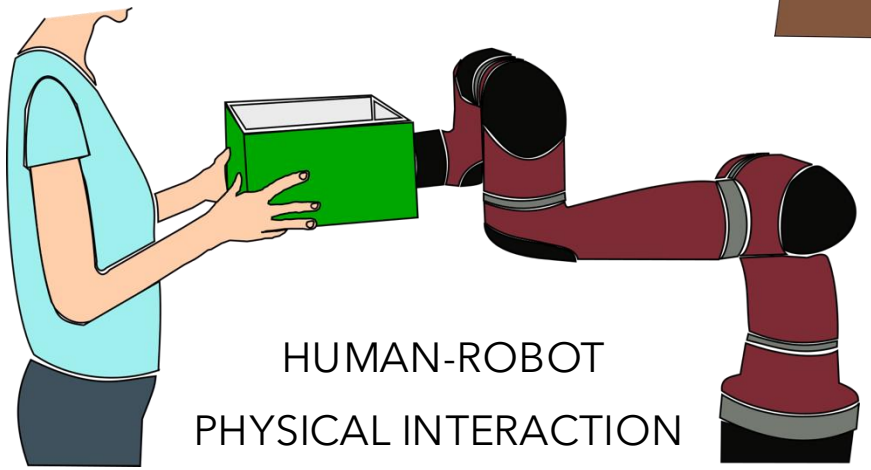
Interfaces in collaborative robotics (concepts)



HUMAN-ROBOT COMMUNICATION



ROBOT-ENVIRONMENT PHYSICAL INTERACTION

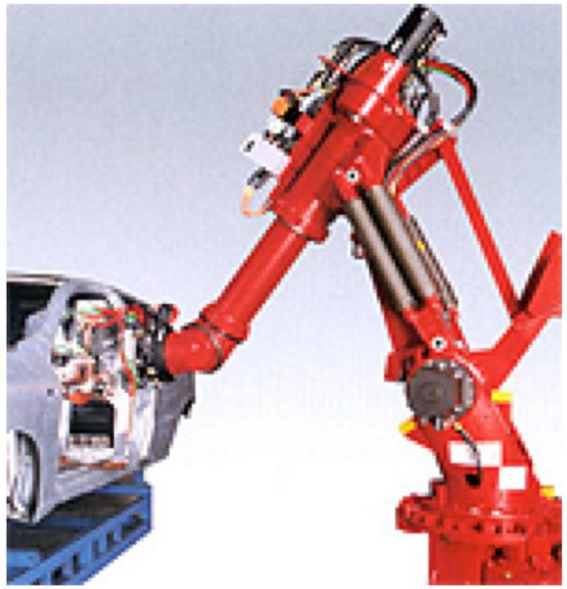


HUMAN-ROBOT PHYSICAL INTERACTION

Industrial robots

Robot manipulator kinematics

Kuka 150_2 S2000
open kinematic chain
(series of rigid bodies
connected by joints)



Comau
Smart H4
closed kinematic chain

Fanuc
F-200iB
parallel kinematics

SCARA-type robot

Mitsubishi RP
(repeatability 5 micron,
payload 5 kg)

Mitsubishi RH
(workspace 850 mm,
velocity 5 m/s)

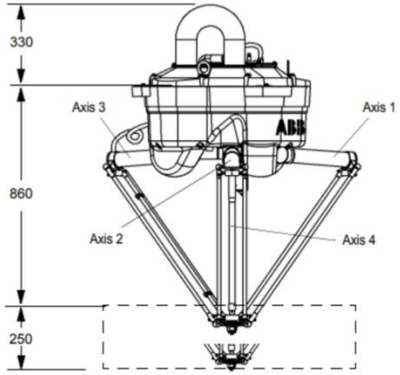
Bosch Turbo

SCARA (Selective Compliant Arm for Robotic Assembly)

- 4 degrees of freedom (= joints): 3 revolute + 1 prismatic (vertical) axes
- compliant in horizontal plane for micro-assembly and pick-and-place

Other type of robot

Comau Mast gantry robot
3P linear/prismatic joints
with 3R spherical wrist
payload up to 560 kg



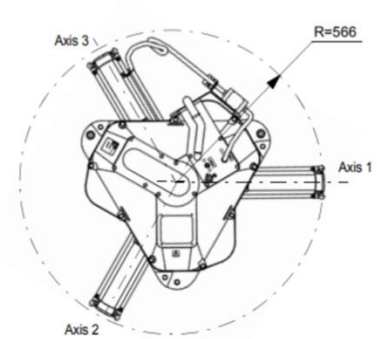
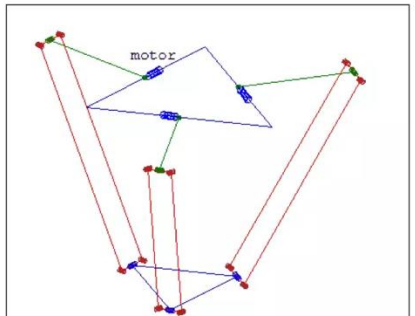


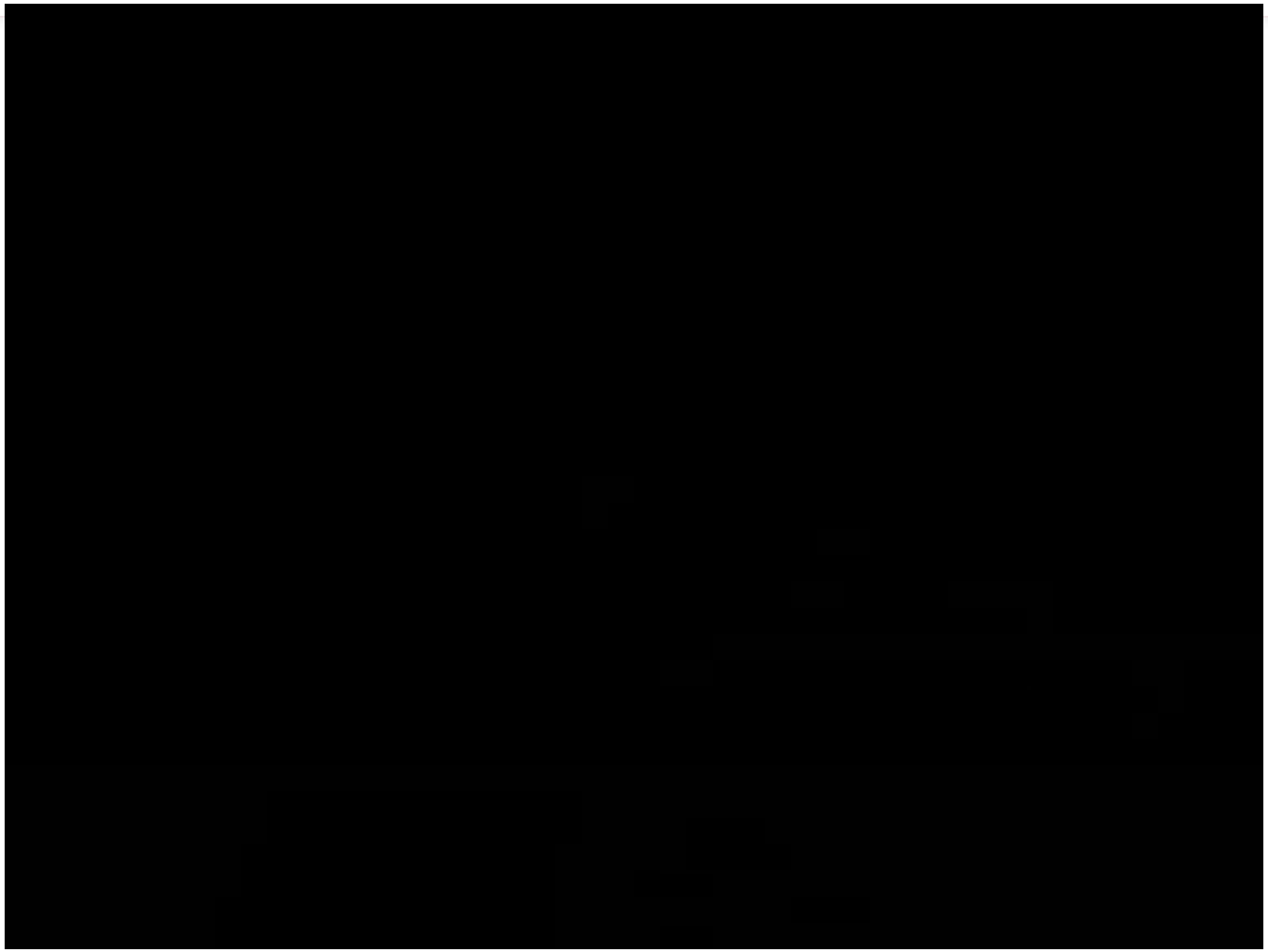
ABB 340 Flexpicker
4 DOFs Delta parallel kinematics
1-2 kg payload, max speed 19 m/s
150 pick-and-place ops/minute

Delta in motion
(https://link to web)



Delta robots are replacing
SCARA-type robots for
planar pick-and-place
and assembly tasks

Delta robots



Automated Guided Vehicle AGV

- AGV (Automated Guidance Vehicles) for material and parts transfer on the factory floor: wire- or laser-driven along predefined paths

https://www.youtube.com/watch?v=fTdpBM6SWMU

What’s next?

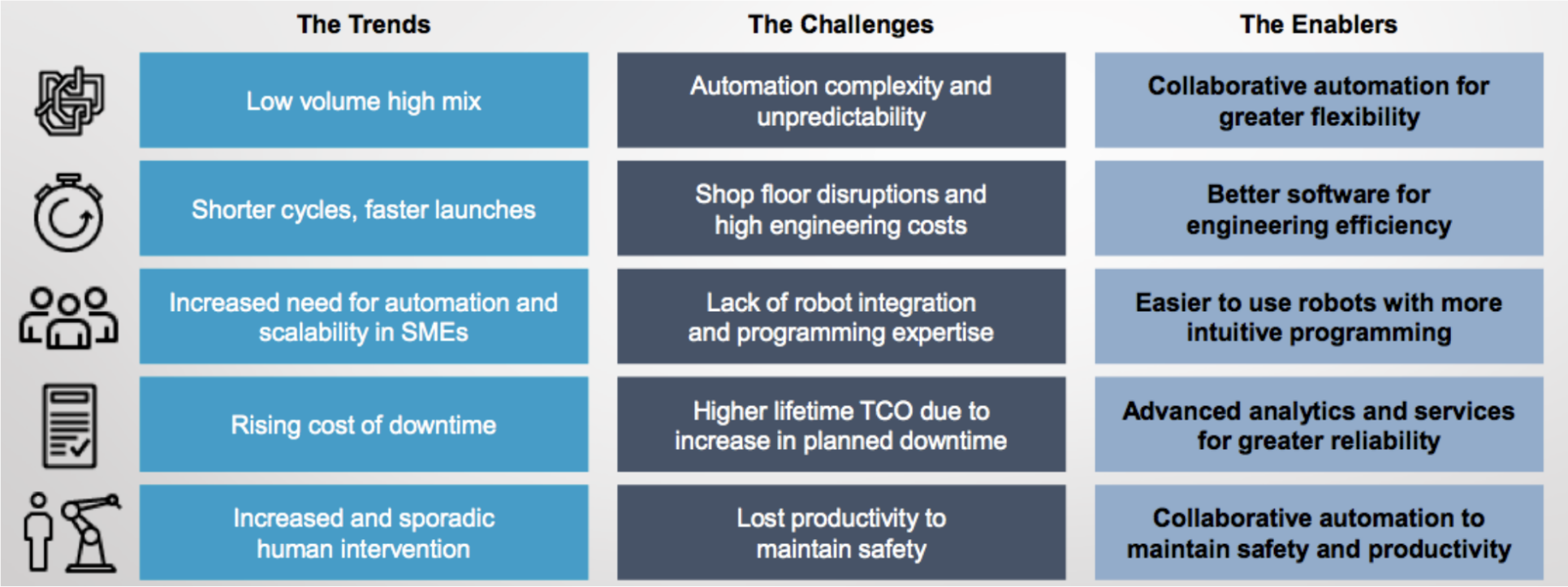
… and what it is worth exploring. Credits to Prof. De Luca, Universita la Sapienza, Rome

Changing nature of manufacturing

- growing shift from high volume/low mix to low volume/high mix is having a deep impact on manufacturing
- many industries are facing acute shortages of skilled labor
- quicker return-of-investment (ROI) of automation and rising wages are eventually discouraging labor arbitrage
- increased focus is being placed on workplace safety
- securing supply chains, increasing **resilience** and **sustainability**

New opportunities

addressing some real facts opens huge opportunities



answers to these challenges lie in
Simplification, Digitalization, and Collaboration

Simplification, digitalization, cooperation

Simplification (critical for SME, but also for large global manufacturers)

- robots **easier** to install, program (with open source) and operate will unlock entry barriers to the large market of small and medium enterprises (SMEs)
- trend towards having production closer to the end consumer is driving the importance of **standardisation** & consistency across global brands

Digitalization (Big Data allows taking better decisions on factory operations)

- Industry 4.0 & 5.0, linking the real-life factory with a **virtual/digital** twin, will play an increasingly important role in global manufacturing
- **vision and sensing** devices, coupled with analytics platforms, will pave the way for new industry business models
- IoT/AI/Machine Learning will drive many robotics developments in coming years

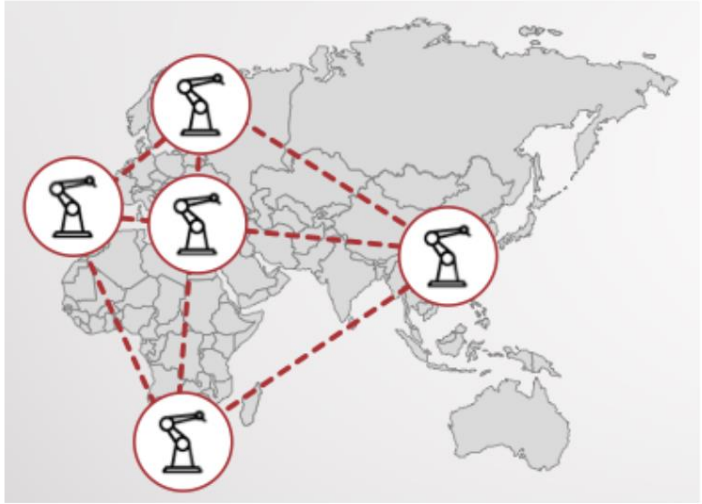
Collaboration

- **collaborative robotics** is shifting traditional limits of "what can be automated?"
- cobots increase manufacturing flexibility as 'low-volume, high-mix' becomes the main standard
- collaboration is also about productivity with increased physical and cognitive **human/robot interaction**

Smart manufacturing

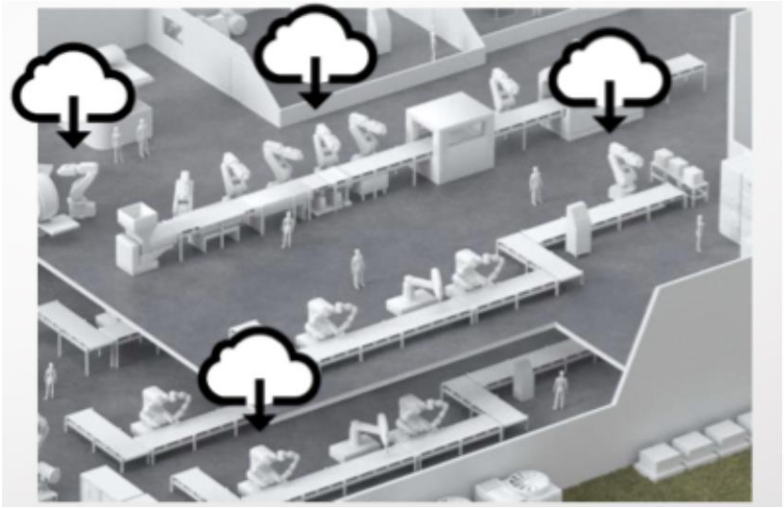
"connected" future of robotics

self-optimizing production



- robots doing the same task connect across all global locations so performance can be easily compared and improved

self-programming robots



- robots automatically download what they need to get started from a cloud library and then optimize through "self-learning"

connected and collaborative robots will enable SMART Manufacturing for both SMEs & Global Enterprises

Novel generation of collaborative robots