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AUTOMATION SYSTEMS – INDUSTRIAL ROBOTS

Prof. Dr.-Ing. Thomas Wich

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1 - INTRODUCTION

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Learning outcomes of this lecture

- According to the module description:
  - Knowledge of the basic methods for modeling, analyzing and controlling robots
  - Application of these methods to various systems of industrial robotics
  - Knowledge of:
    - Functional principles of different sensors
    - basic control concepts
  - Analysis of control concepts with respect to their static and dynamic behavior
  - Programming of an industrial robot, taking into account the advantages and disadvantages of different methods

Bildquelle: ke-next.de

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Learning outcomes of this lecture

- This is what I would like to convey to you:
  - Wide range of applications for robotics (and how does it affect our working lives)
  - Programming of robots with different tools:
    - Python
    - Combination with image processing (Recommendation: Module "Machine Vision" by Ralph Hänsel, https://lernraum.th-luebeck.de/course/view.php?id=4412)
    - Teach-in with cobots
  - Solid basic knowledge
  - Hands-on!

Bildquelle: universal robots

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Contents and structure of this course

- Chapters:
  - Introduction
  - Basics of robotics (structure, hardware, software, handling techniques, etc.)
  - Kinematics (Coordinate systems, calculation methods...)
  - Sensors and image processing
  - Control and programming of robots (classic concepts, combination with image processing)
  - Programming with ROS

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Contents and structure of this course

- Structure:
  - lecture: basic knowledge
  - exercise:
    - Calculation, especially Denavit-Hardenberg
    - Programming tasks with Python
    - Introduction to Python (in combination with control technology)
    - Robot control with Python (implementation of coordinate transformation)
    - project work
  - portfolio exam part 1: coordinate transformation test
  - portfolio exam part 2: project work in small groups

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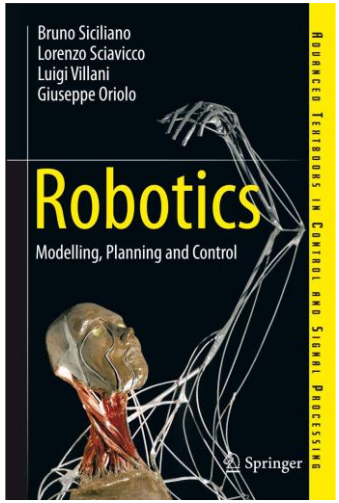
Literature

- Siciliano B., Khatib, O.;
  Handbook of Robotics; Springer Verlag



- Hesse, Stefan; Taschenbuch Robotik –
  Montage – Handhabung; HanserVerlag
- Maier, Helmut; Grundlagen der Robotik; VDE Verlag
- Weber, Wolfgang; Industrieroboter: Methoden der Steuerung und Regelung;
  Hanser Verlag
- Husty, M., Karger, A., Sachs, H., Steinhilper, W.; Kinematik und Robotik;
  Springer Verlag

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Required tools

- project work: we work in small groups (~4 students, depending on the number of participants)
- robotics is IT-heavy!
- you need a computer with:
  - python installation
  - helpful:
    - use a virtual machine (e.g. VMware Workstation)
    - accordingly, memory and processor!
    - linux is appreciated
    - if necessary, you can use a pc from the lab
- calculator

Bildquelle: conrad.de,

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Timetable

Date:	25.09.2023
Week	Topic
1	Introduction
2	Fundamentals of Robotics
3	Kinematics - 1
4	Kinematics - 2
5	Kinematics - 3
6	Exercises: Forward transformation
7	Test, Backward transformation
8	Exercises: Backward transformation
9	Sensors and image processing
10	Sensors and image processing
11	Exercises: image processing
12	Control & programming
13	Control & programming
14	Introduction to ROS
15	Introduction to ROS

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Evolution of robotics

- History (1st generation, 1960-1975)
  - “Rossum's Universal Robots” (1920) (drama by Karel Čapek) coined the term robot from "robota" = hard work
  - 1946: Development of a control unit by G.C. Devol, with which signals could be recorded and replayed (for machine control)
  - 1951: first remote-controlled handling devices (teleoperation)
  - 1960: first industrial robots (hydraulic drives, NC control)
  - From 1973 on: development of specialized programming languages (WAVE, VAL etc.)
  -

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Evolution of robotics

- History:
  - 2nd generation, until the 80s):
    - combination with sensors (force, image)
    - further development of programming languages
    - low robot intelligence
  - 3rd generation (from mid-80s):
    - Computing power increases significantly due to microelectronics
    - Increasing use of sensor technology
    - Development towards autonomy
  - Future:
    - Autonomous robots
    - Mobile robots
    - AI-based sensor data processing

Bildquelle: Euclid Labs Srl

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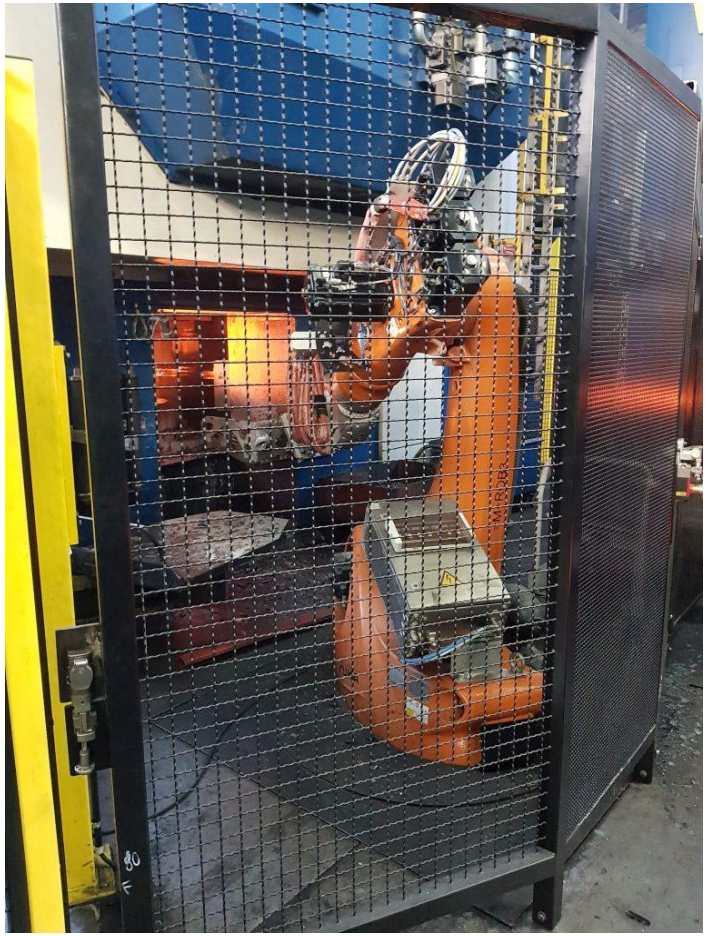
Robotics – old-fashioned vs. modern

- Features of a classic robot systems:
  - repetitive tasks ("assembly line work")
  - stationary systems
  - great forces
  - high (repeat) accuracy
  - fast movements
- But:
  - low flexibility
  - Adaptation to new tasks required (programming)
  - expensive (> 100.000 €)



Bildquelle: momac Robotics GmbH & Co. KG

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Robotics – old-fashioned vs. modern

- Complementary and new features of modern robot systems:
  - complex tasks (sensors, image processing)
  - collaboration with people
  - mobile systems
  - intuitive parameterization
  - low-cost (from 15.000 €)
- Thus:
  - Wide range of applications
  - high flexibility
  - easy to use
  - automation of technically demanding activities becomes economical

Bildquelle: Pilz GmbH & Co. KG

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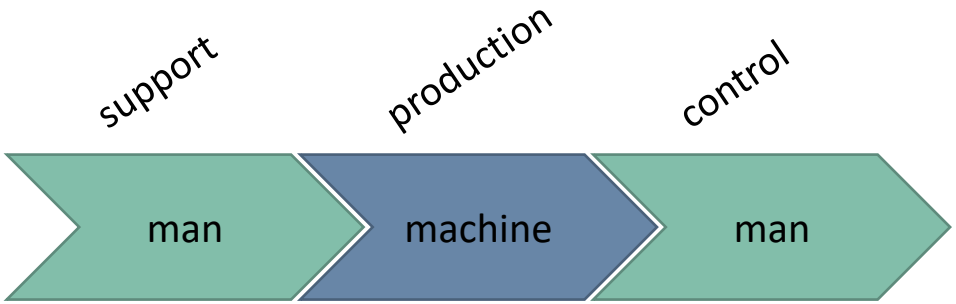
Robotics and Industry 4.0 – How do they link together?

- Hitherto:
  - Automation replaces human work



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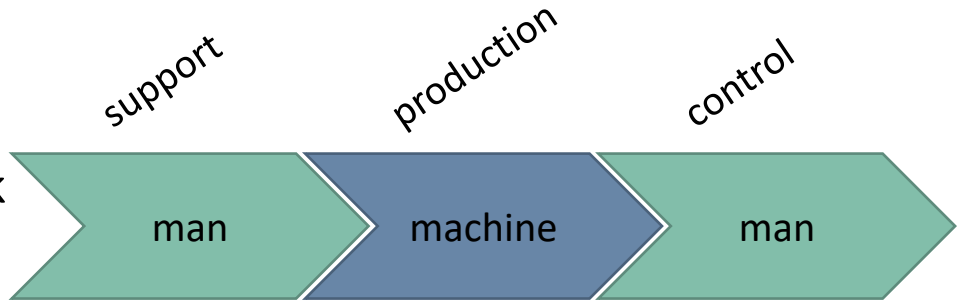
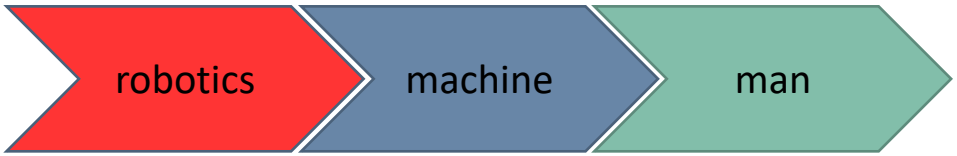


- Currently:
  - robotics replaces basic activities
  - Industry 4.0 supports people in control
  - IT is spreading!



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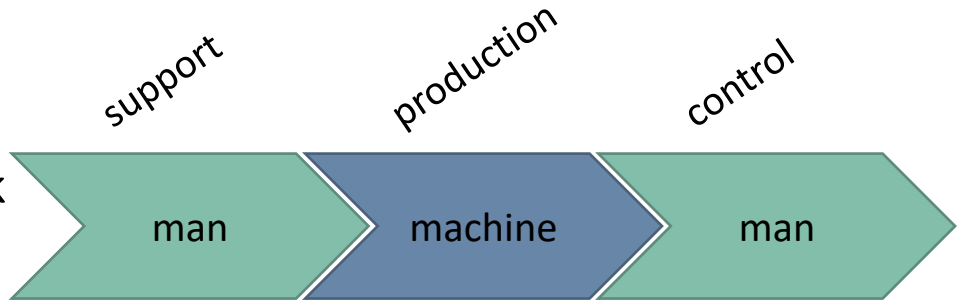

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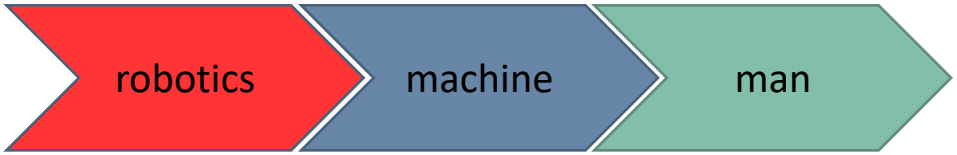
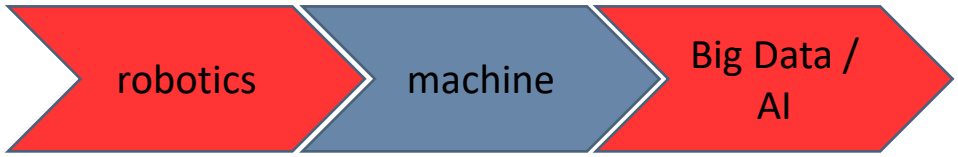


- Perspectively:
  - Control through "Big Data" and Artificial Intelligence (AI)



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What is robotics?

- Included areas of expertise:
  - Mechanical engineering (mechanics, construction, design)
  - Electrical engineering (drive technology, sensors, control)
  - Control technology (position and path control)
  - Computer Science (Programming and Simulation)
  - Production engineering (applications)
  - Artificial intelligence (machine learning, machine vision, speech recognition...)
  - Politics and philosophy (robot displaces humans)
  -

Bildquelle: wikipedia.org, stern.de

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What are robots?

- Definition according to VDI guideline 2860:
  - Industrial robots are universally applicable motion machines,
  - whose movement is freely programmable in terms of sequence of movements and paths or angles - i.e. without mechanical intervention - and, if necessary, sensor-guided.
  - They can be equipped with grippers, tools or other means of production and
  - are able to perform handling and manufacturing tasks.

Bildquelle: sps-magazin.de, faz.net

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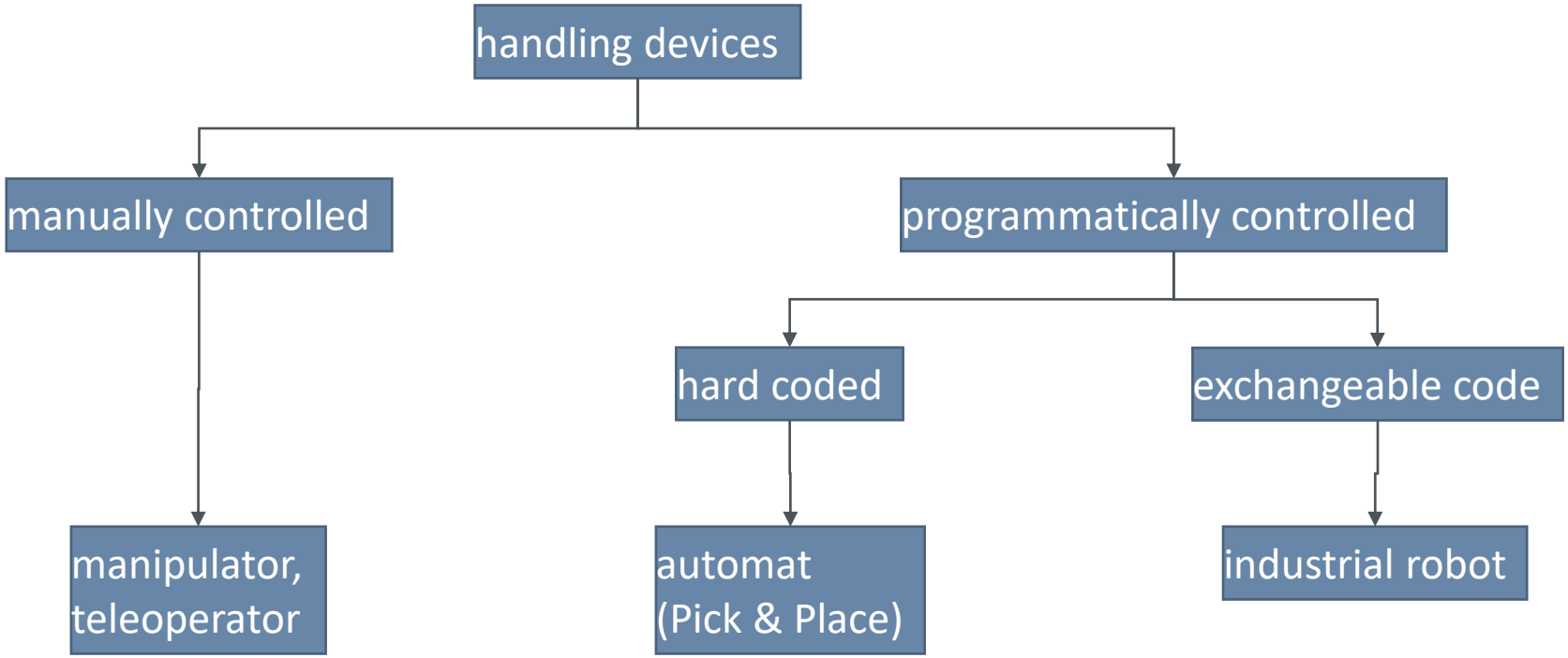
What are robots?

- (stationary) Industrial robots, according to VDI guideline 2860



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What are robots?

- Mobile robots
  - not permanently mounted at a specific point
  - (autonomous) free movement in a specific environment
  - Independent decisions despite incomplete knowledge
  - key words: self localisation, path planning

- Automated Guided Vehicles (AGVs), VDI guideline 2510: "[AGVs] are internal, floor-based conveyor systems with automatically controlled vehicles whose primary task is the transport of materials, but not the transport of persons. They are used inside and outside buildings."

Bildquelle: dvz.de

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Areas of application

- Industrial robots: Pick-Place

Bildquelle: kuka.com

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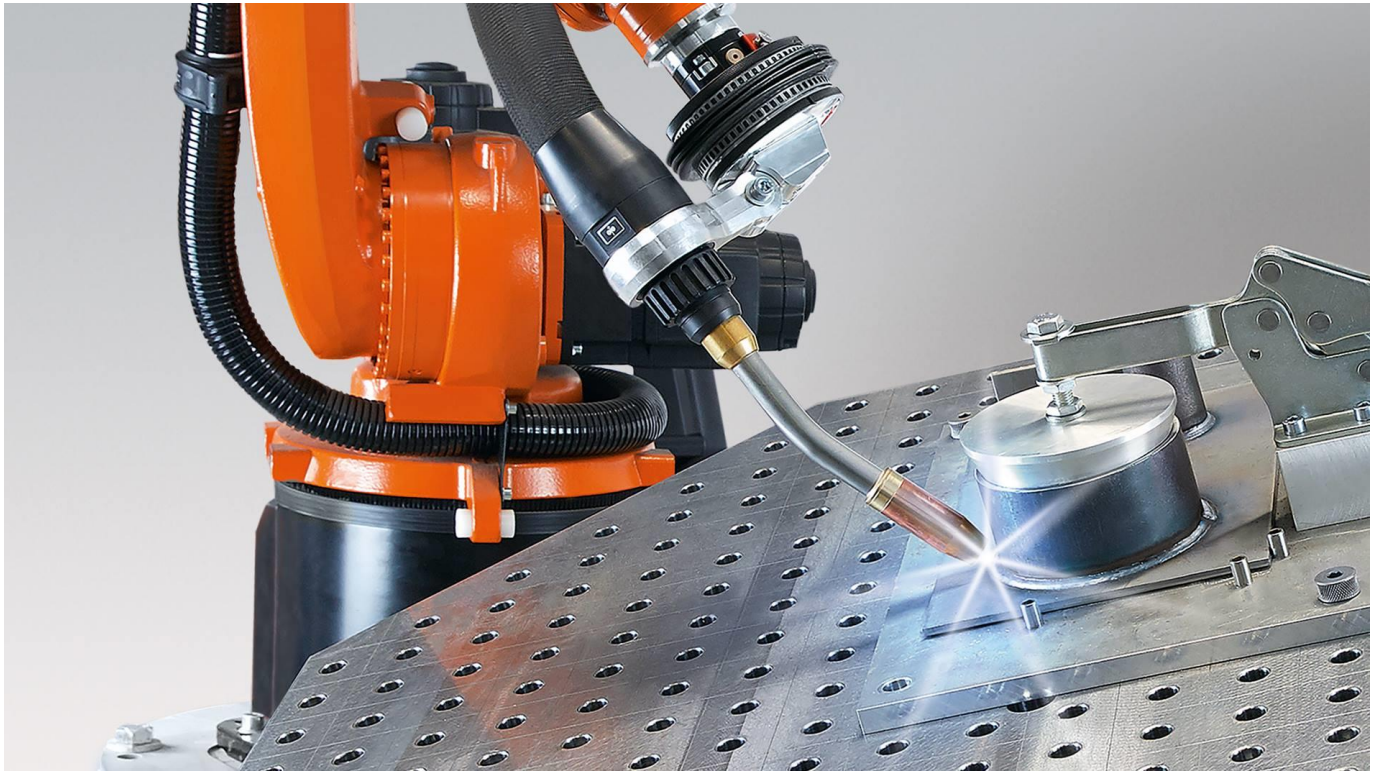
Areas of application

- Industrial robots: welding



Bildquelle: kuka.com

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Areas of application

- Industrial robots: painting

Bildquelle: besserlackieren.de

Areas of application

- Insustrial robots: pick-place food industry

Bildquelle: cognex.com, foodaktuell.ch

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Areas of application

- Industrial robots: nuclear power plant

Bildquelle:: automationspraxis.industrie.de

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Areas of application

- Industrial robots: cobots

Bildquelle: industrie.de

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Areas of application

- Industrial robots: mobile platforms

Bildquelle: vogel.de

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Areas of application

- mobile robots for surveillance and exploration

Bildquelle: heise.de

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Areas of application

- Autonomous robot

Bildquelle: amazon.de

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Areas of application

- Autonomous robots, combined with a robot arm

Bildquelle: Pilz GmbH & Co. KG

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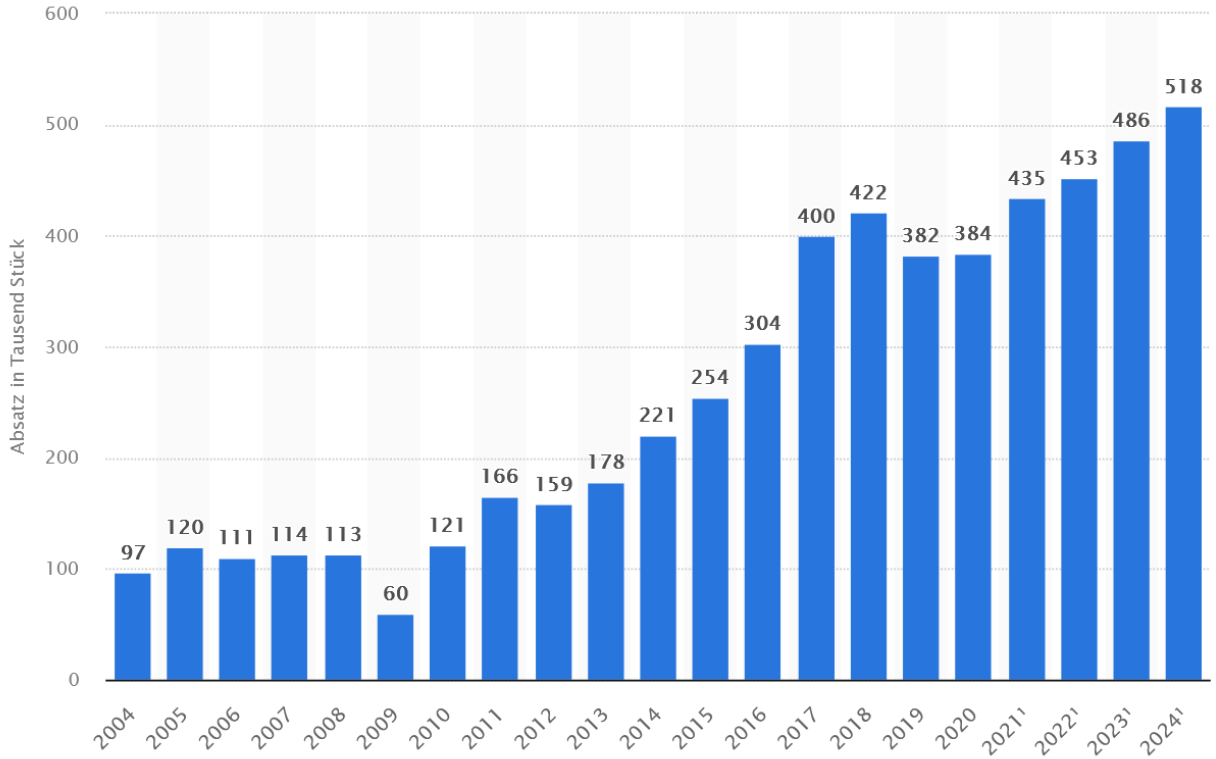
Fundamental requirements

- What requirements for the robot can you derive from the images in the script?
- Which special topics of robotics are affected?
- How can these requirements be met?
-
- Categorize the answers to the above questions and try to derive questions for this lecture.

Current market situation

- Sales of industrial robots worldwide in the years 2004 to 2020 and forecast by 2024 in 1000 pcs. (Source: statista.com)
-



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Current market situation

- Sales of industrial robots worldwide in the years from 2018 to 2025 (in billions of US dollars); Source: statista.de
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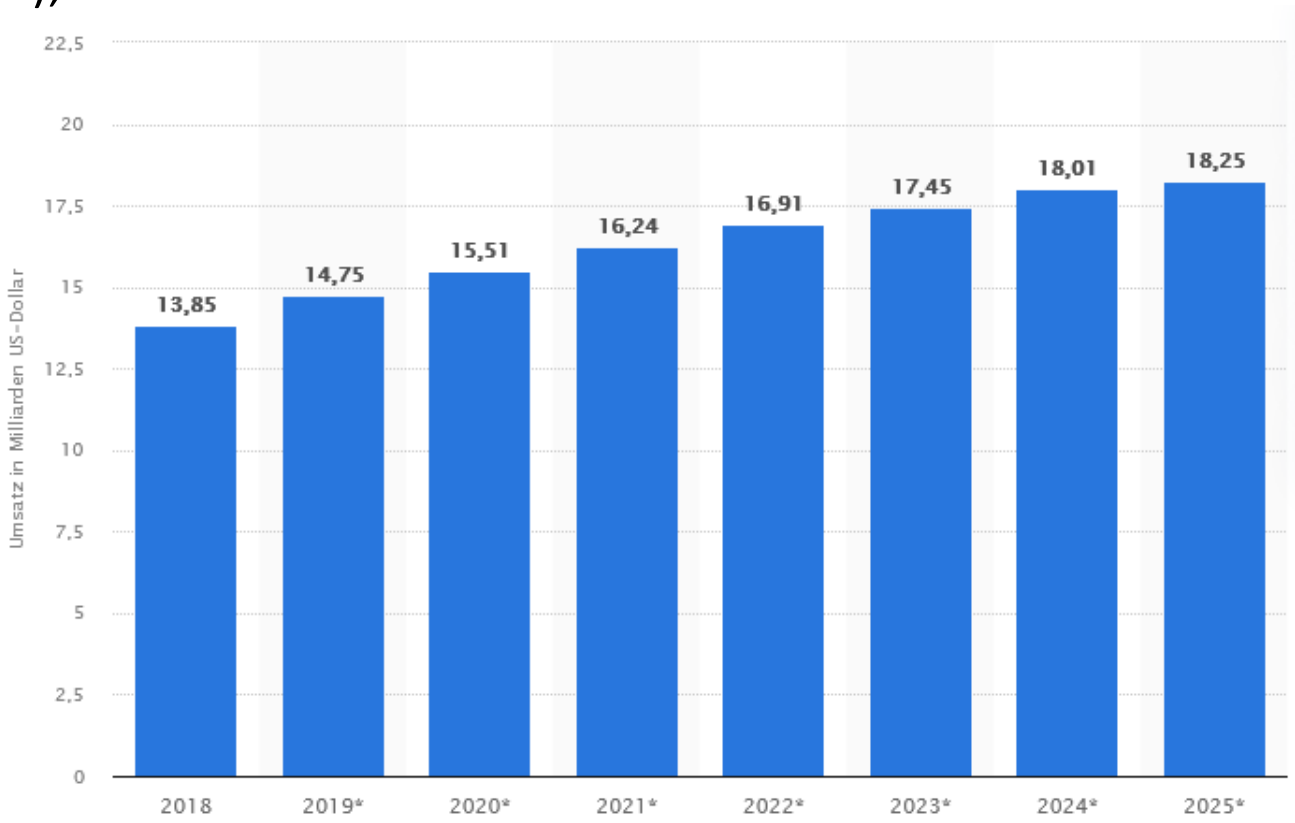

Current market situation

- Robots by application area / industry
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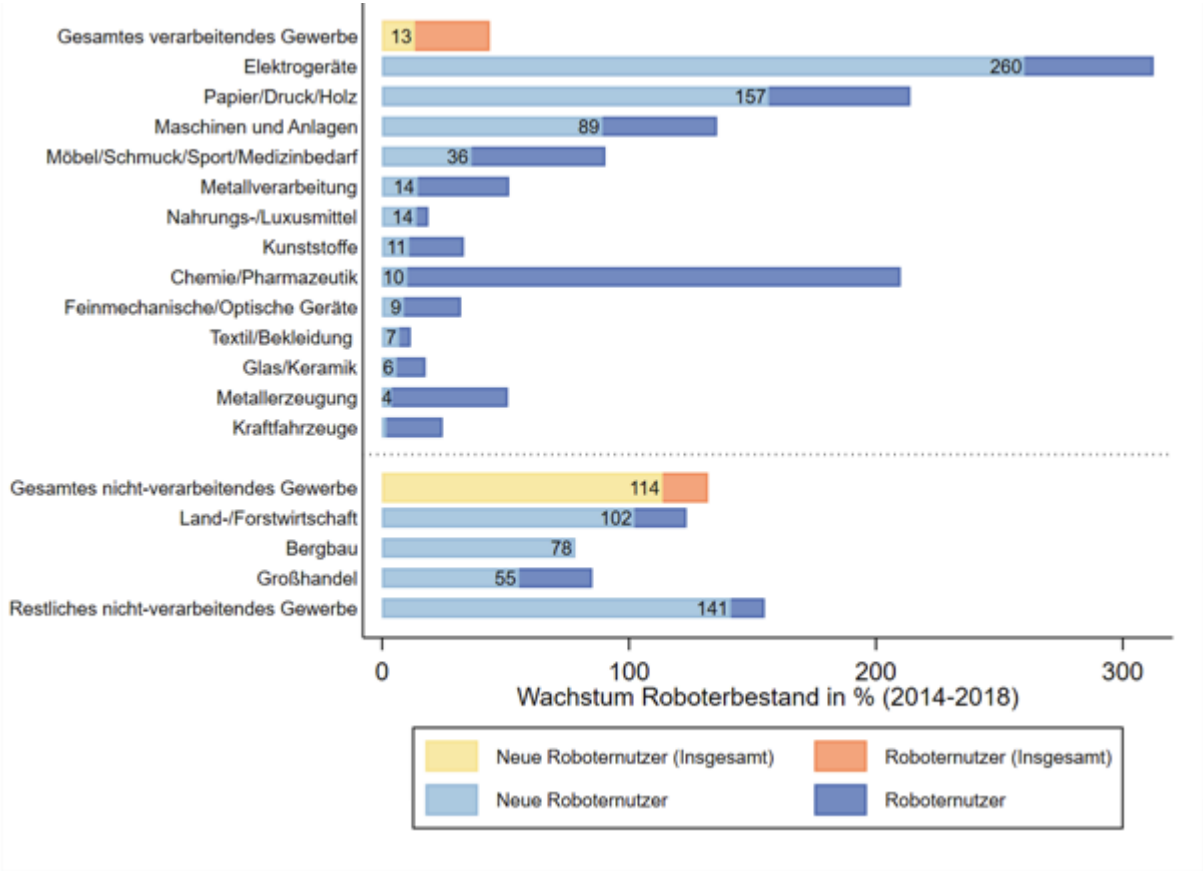

Bildquelle: https://www.oekonomenstimme.org/artikel/2021/05/automatisierung-in-deutschland-was-treibt-die-vermehrte-roboternutzung/

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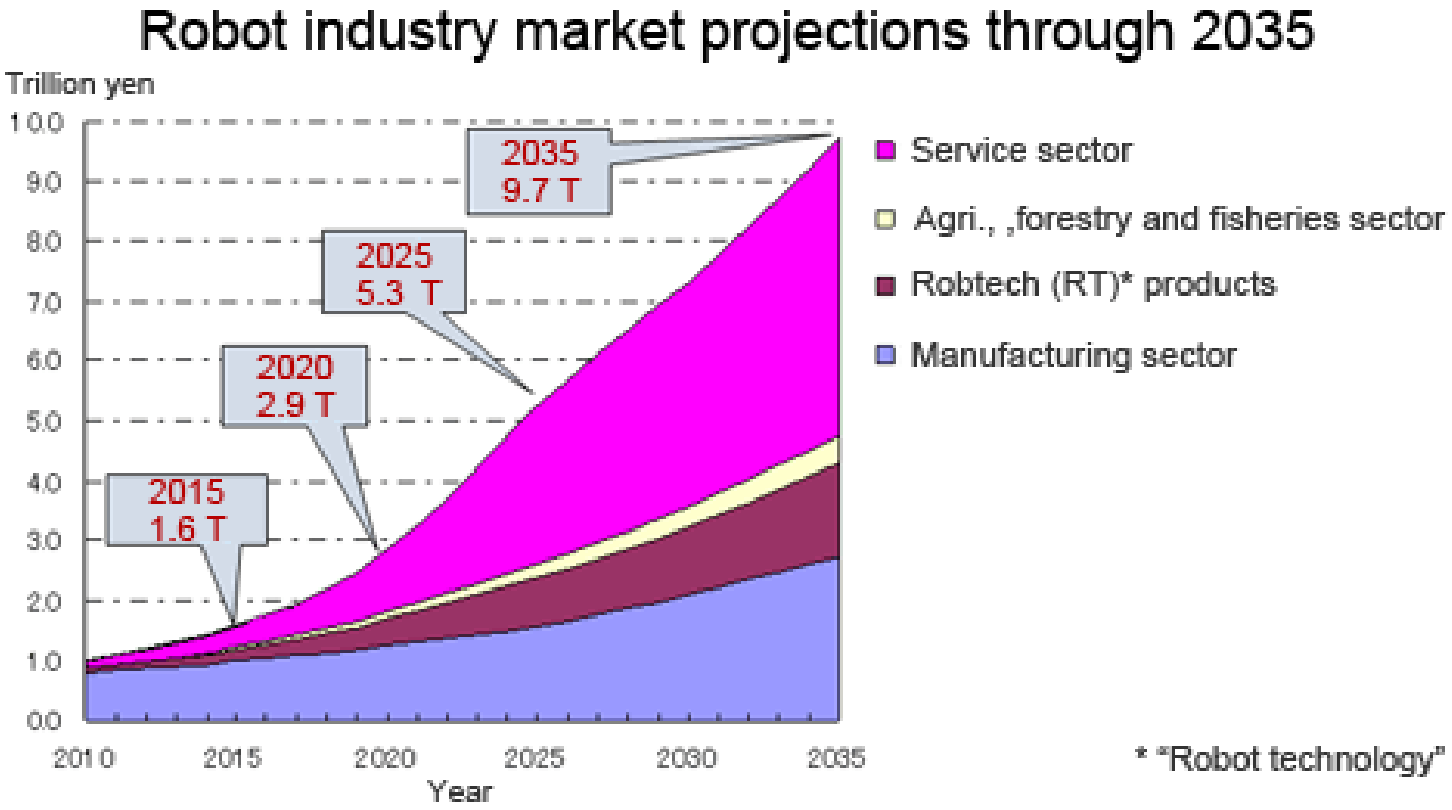
Current market situation

- Trends



Quelle: Ministry of Economics and Trade (METI). (2010). 2035nen ni muketa robotto sangyou no shourai shijou yosoku (Market forecast of robot industry in 2035)

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Summary

- What goals are we pursuing through the use of robots?