RRLAB
THE ROBOTICS RESEARCH LAB

# Foundations of Robotics - Introduction

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TU Kaiserslautern, Germany

# Content

- General aspects
  - Information about the lecture
  - Courses offered by the RRLab
  - Research of RRLab
  - Overview of the lecture
- Introduction to robotics
  - Research fields
  - History
  - Applications
  - Future

# About the Lecture

- Lecture: Monday 15:30 – 17:00, Room 42/115
- Exercise: Wednesday 11:45 – 13:15, Room 46/210
- Mode of exam: Oral, see exam regulations
- Consultation hours: Wednesdays 10:00 – 12:00

- Homepage: http://www.rrlab.cs.uni-kl.de
- Course material
  - Slides and additional material under
  - https://agrosy.cs.uni-kl.de/en/teaching/offered-courses/
  - https://olat.vcrp.de/url/RepositoryEntry/3392340683

# Exercise and Exam

- Exercise Sheets
  - Available every 2nd-Friday on OLAT
- Exercise - "Schein"
  - Register on OLAT till 04.11.2022
  - Exercise sheets have to be solved in a meaningful way
  - Delivery in groups of max. 3: Fridays till 10 AM on OLAT
  - Random selection of groups for presenting their solution at the blackboard
  - One member of each group must be available at each exercise -> otherwise no "Schein"
- Exam
  - Prerequisite: "Schein"
  - Examination dates are scheduled with RRLab secretary Mrs Broschart (room 48/358)

# Other Lectures given by RRLab

Foundations of Embedded Systems (8 ETCS ) (Bachelor/Master)

1. Introduction
2. Electro technical basics
3. Electrical networks
4. Basic electronic circuits
5. System Theory
6. Control Theory
7. Signal Processing
8. Sensor data processing
9. Actuators
10. Processing units for embedded systems
11. Communication
12. Software modeling and analysis
13. Real-time systems
14. Summary

# Other Lectures given by RRLab

Autonomous Mobile Robots - AMR (8 ETCS ) (Master)

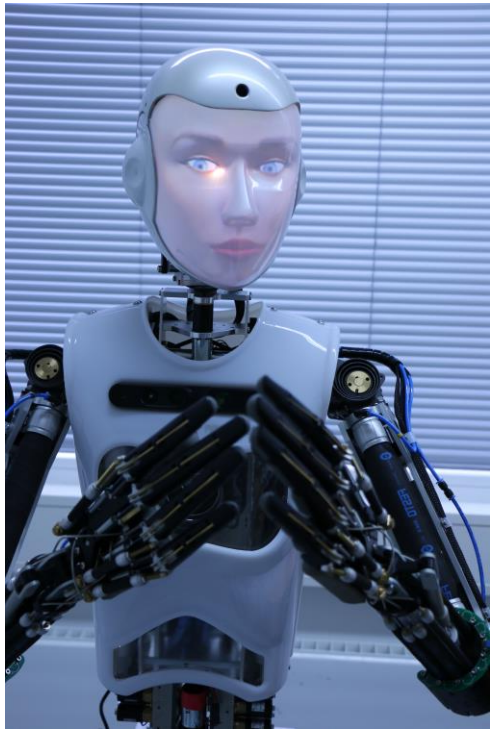

1. Overview
2. Sensor system
3. Feature extraction, object recognition
4. Localization
5. Mapping
6. Simultaneous localization and mapping
7. Navigation
8. Control architectures
9. Complex AMR systems and their applications

# Other Lectures given by RRLab

Biologically inspired Robots - BioBots (6 ETCS ) (Master)

(Mon. 13:45 - 15:15, Room 11-241)
(Wed. 13:45 – 15:15, Room 42-110)

1. Biological concepts in robotics
2. Mechatronics system design
3. Control architecture and methods
4. Bipedal locomotion
5. Human robot interaction
6. Embodiment and situatedness
7. Applications of BioBots



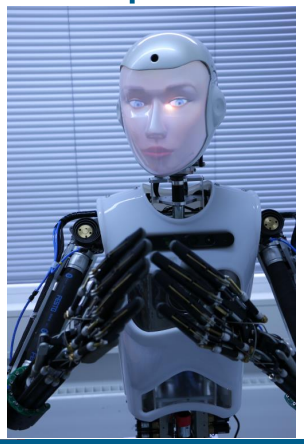
# Other Courses given by RRLab (Winter Term)

- Bachelor/Master-Seminar „Embedded Systems and Robotics“
  - Wed. 26.10.22, 15:30, Room 48/379
- Master-Seminar „Robotics and Artificial Intelligence“
  - Wed. 26.10.22, 15:30, Room 48/379
- Bachelor Project “Mobile Roboter” (half-day WS)
  - Wed. 26.10.22, 10:00, Room 48/379
  - 4 – 5 pre-exercises/experiments
  - Building a robot system in team (5 persons)
  - Develop an autonomous RC-Unimog
  - Presentation of results: final presentation
  - Written report on the results

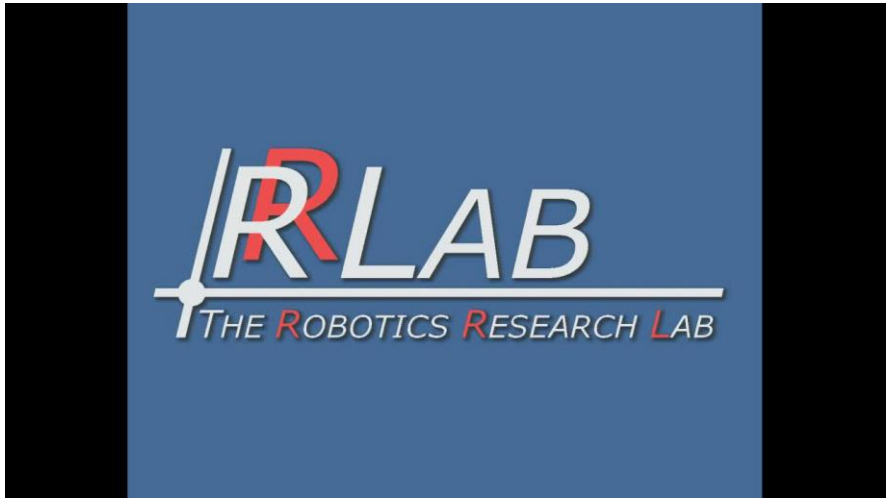
# Competition – Mobile Robots

# Topics for Master, Project and Bachelor Thesis

- Human-robot-interaction
- Biped locomotion
- Autonomous vehicles
- Sensor systems
- Perception
- Control architecture (iB2C)
- Computer architecture

# Off-road Vehicles

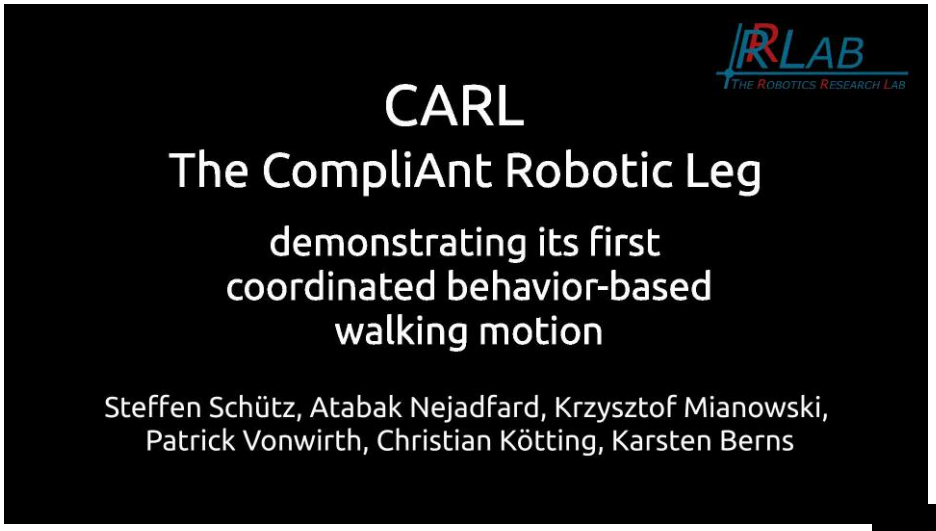




# Excavators and Pobo-Project



# Humanoid Robots



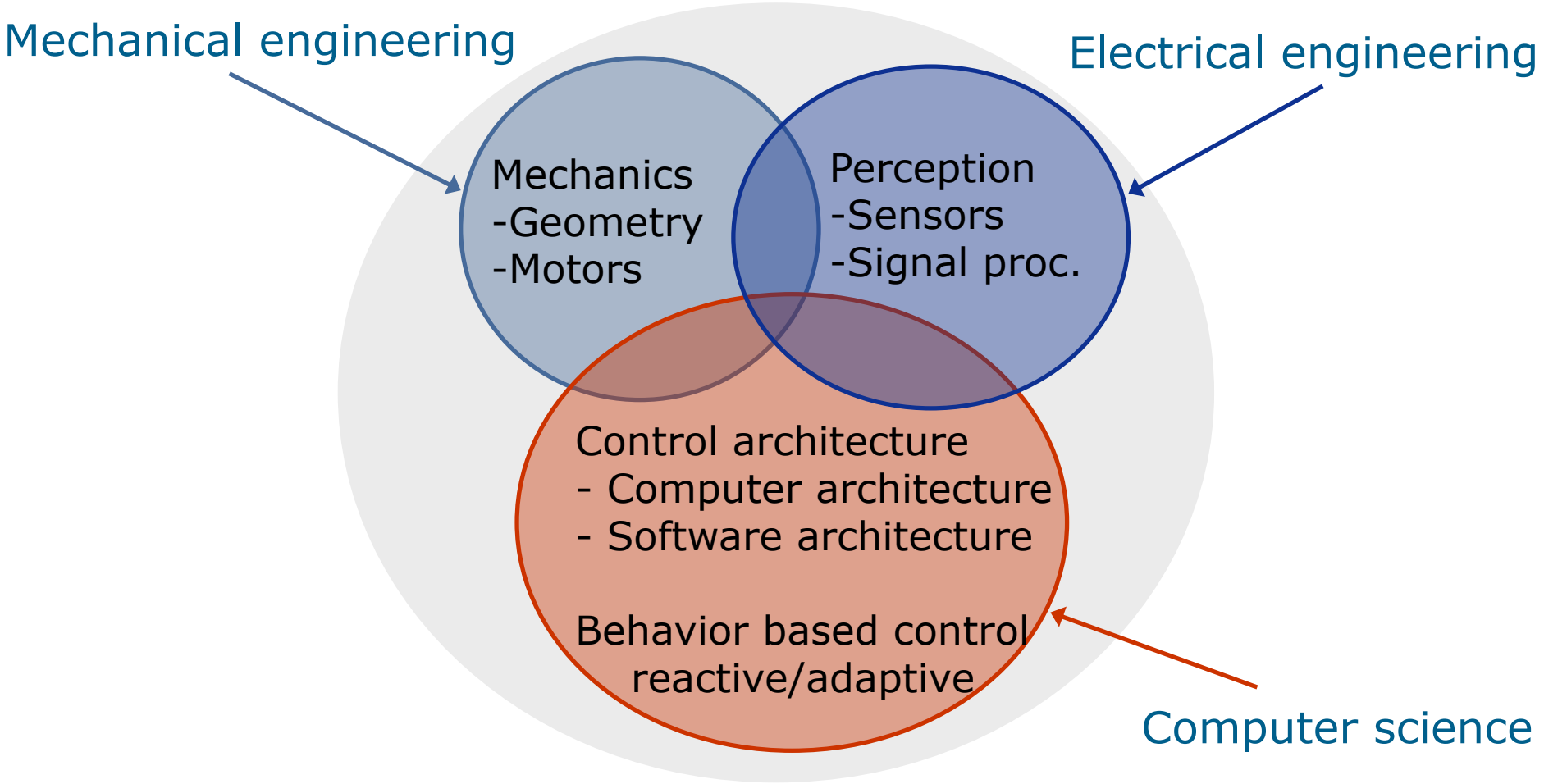

# Questions and Remarks about Robotics

1. What is a robot?
2. Which applications exists in which robot products are used?
3. Robots in science fiction movies
4. Which subsystems belong to complex robots?
5. Which applications of robots will be available during the next few years?
6. What is the future of robotics?
7. What do you expect from the lecture?

# Content of the Lecture "Foundation of Robotics"

1. Introduction
2. Subsystems of robots
3. Spatial kinematics
4. Robot modelling (kinematics and dynamics)
5. Path planning
6. Gripping
7. Task planning, control architectures
8. Robot programming
9. Applications and summary

# Robotics – An Interdisciplinary Research Area



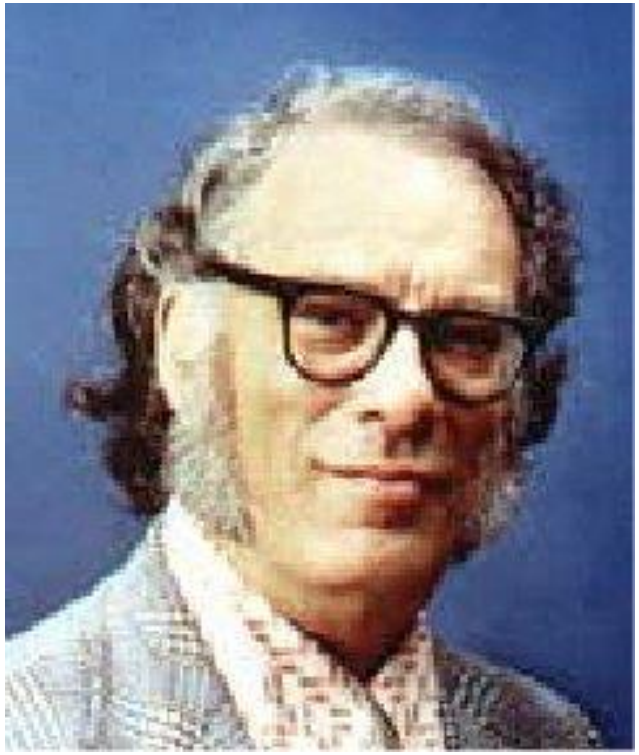
# The Term Robot

- Around 1920, Karel Capek defines the term “robota“ (Slovakian word for Hard/Heavy working )
- For Capek, a robot (unlike humans) is "restlessly working".
- „Rossum‘s Universal Robot“ von Karel Capek
  - Development of a chemical substance for the production of robots
  - Robots should serve people and do heavy work
  - Scientist Rossum develops "perfect" robot
  - Robots do not obey humans anymore, they rebel and kill entire human life

# The Problem of Safety

# Asimov's Laws of Robotics (1942)

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.



# Definition: Robot

- General Definitions
  - Working machine
  - Artificial human
  - Combat/war machine
  - Science Fiction: thinking machine
- Technical Definitions
  - Flexible manipulation apparatus (Grippers/Sensors)
  - Machines that receive information (sensors) and has an impact on its environment (actuators)
  - Machine with the ability to move itself and/or other objects

# Definition: Robot

- Robot – Machine Man (cyborg); Movements caused by electric waves (wireless), and electronically controlled automaton.
  [*Kleines Lexikon der Büchergilde 1973*]
- A **robot** is **defined** as 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.
  [*according to „The Robot Institute of America" 1979*]
- A machine resembling a human being and able to replicate certain human movements and functions automatically. A machine capable of carrying out complex series of actions automatically, especially one programmable by a computer
  [*Oxford Dictionary*]

# Definition: Robot (Neumann)

Robotics is an interdisciplinary field of research in which mechanical devices and suitable control units are at the center of complex tasks.

Although robots are mostly presented with human-like shape and sensory capabilities robotic science fiction, the robots used in practice are stationary manipulators that can be used by programming for changing industrial tasks, e.g. welding or painting work in the automotive industry.

[*NEUMANN, Lexikon der Informatik und Datenverarbeitung*]

# Definition: Robot (VDI)

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

[*VDI-Richtlinie 2860, 1990*]

# Definition: Robot (Christaller)

Robots are sensorimotor machines that expand human skills. They consist of mechatronic components, sensors and computing architecture as well as a complex control. The complexity of a robot differs significantly from other machines due to the greater number of degrees of freedom and the variety of behaviors.

[*T. Christaller, 2001*]

# Skills and Components

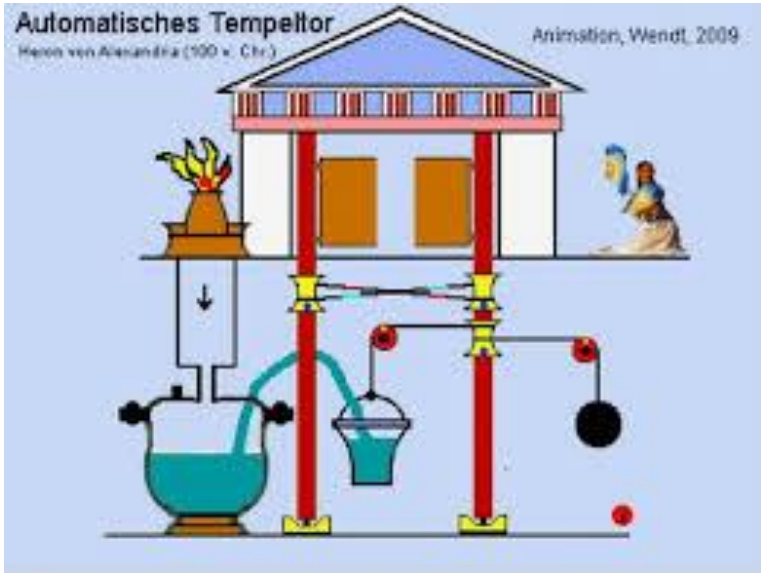
- Skills
  - Able to move itself and/or other objects
- Components
  - Arm, wrists & effector for object manipulation
  - Wheels, legs or similar devices for mobility
  - Actuators and controllers for joint movements
  - Computer and complex software systems for decision making and control
  - Sensor system for the measurement of the robot state and its environment

# Sensor System

- Measurement of contacts, forces, torques
- Position, velocity, acceleration
- Temperature, electrical voltage
- Distance measurement
- Shape, color, size and motion detection
- Texture, smell
- Detection of sound waves and voices

# History of Robotics

- 33 BC: Heron of Alexandria
  - automatic altar
- 3 AD: Four-legged walking machine, China
- 1738: Jacques de Vaucanson
  - Flute player and tambourine player, musical doll in human size (see picture)
  - Blowing in flute, change of lip shape and tongue, finger movement

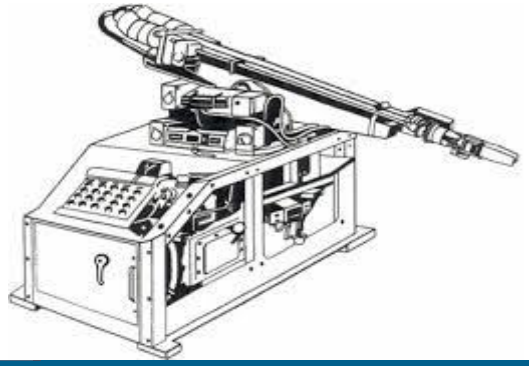


# History of Robotics

- 1774: Pierre Jaquet-Droz & Jean-Frédéric Leschot
  - Painter, writer and musician (see picture)
- 1805: Joseph Maria Jacquard
  - Weaving loom (punched cards)
- 1810: Johann Gottfried and Friedrich Kaufmann
  - Trumpeter
- 1830: Christopher Spencer
  - Cam controlled turning lathe
- 1938: Williard Pollard and Harold Rosel
  - Programmable spraying machine

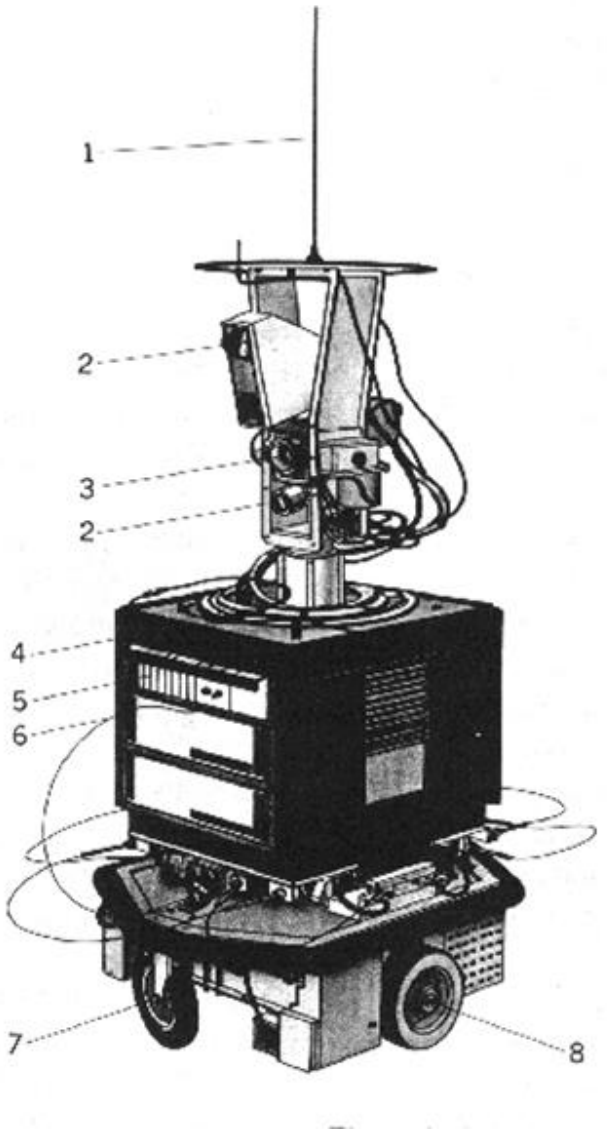
# History of Robotics

- 1954: Georg C. Devol
  - Patent for a programmable manipulator
- 1959: Planet Corp.
  - First commercial robot
- 1959/60: Devol u. J. F. Engelberger
  - First industrial robot „Unimate“ (powered hydraulic, controlled by a computer)
- 1961: Ford installs robot of type „Unimation“



# History of Robotics

- 1968 Charles A. Ross, Stanford, USA
  - Robot Shakey (see picture)
- 70er: Daimler-Benz, Sindelfingen
  - first industrial robot Daimler
- 1974: Development of language AL
- 1974: Further development of Unimation to the programming language VAL
- 1975: first fully electrical powered robot

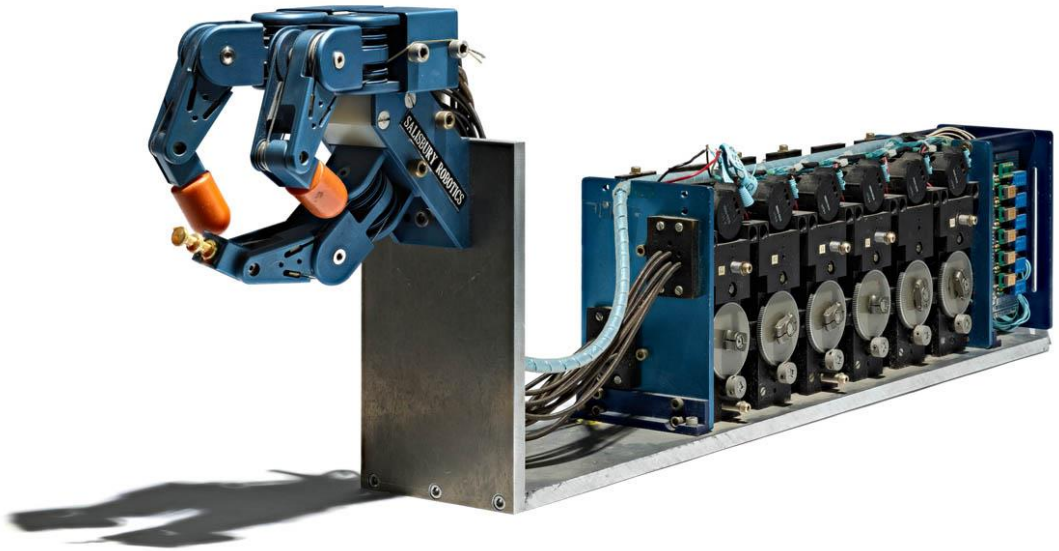


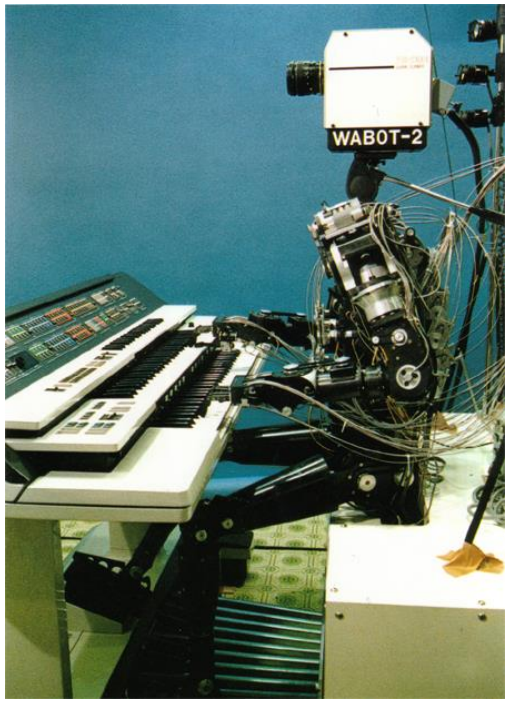

**Shakey**

1. Antenna for radio link
2. Range finder
3. Television camera
4. Onboard logic unit
5. Camera control unit
6. Collision avoidance detector
7. Caster wheel
8. Drive wheel

# History of Robotics

- 1978: Unimation
  - PUMA (Programmable Universal Machine for Assembly)
- 1984: Ichiro Kato, Waseda University Tokio
  - Wabot-2 (see picture)
- 1985: Massachusetts Institute of Technology
  - 3-Finger Salisbury-Hand



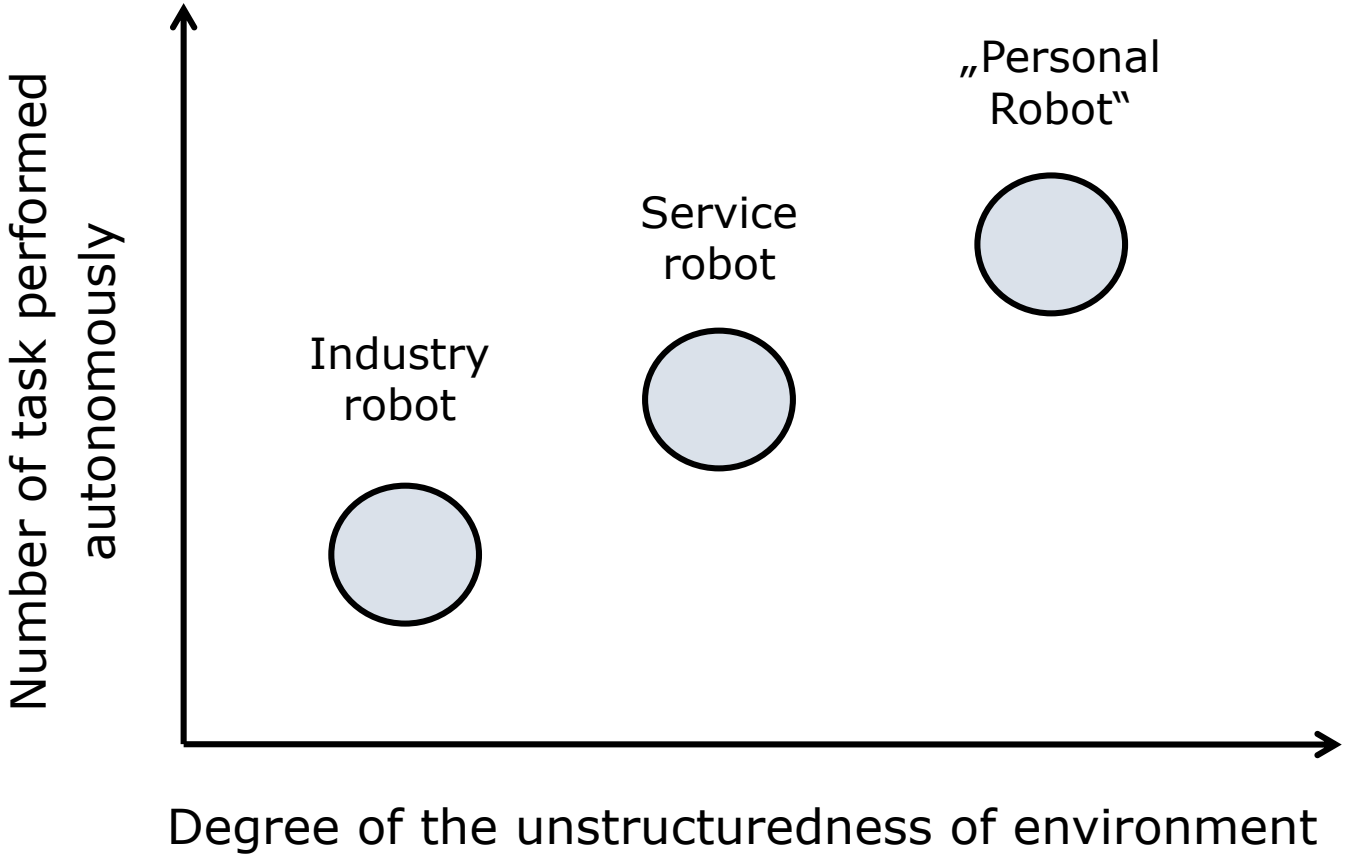
# Phases in the Development of Robots

- 1. Programmable manipulators (1960 – 75)
  - Low computing power
  - Only fixed breakpoints (point-to-point programming)
  - Nearly no sensors involved (only pick-and-place)
- 2. Adaptive robots (1976 – 1982)
  - More sensors (e.g. cameras)
  - Adaptation to the environment
  - Use of high level programming languages (e.g. VAL)
  - Low robot-intelligence (adaptive task performance)

# Steps in Robot Development

- 3. Autonomous robots (since 1983)
  - High computing power (multi-processor systems)
  - Task-oriented programming
  - Demand for (machine) autonomy
- 4. Humanoid robots (since 1995)
  - High flexibility regarding environment and task
  - Learning ability and adaptability
  - Self reflection
  - Interaction based on emotional expressions
- 5. Service robot as products (since 2000)
  - E.g. vacuum cleaner, mover, inspection machines
  - Cheap and reliable

# Application Areas



# Definition: Industrial Robot

- Manipulating industrial robot
  - An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications [*World Robotics 2003*]
- Classification based on …
  - number of axes (3, 4, 5, …)
  - type of control (PTP, cont. path, adaptive, tele-operative)
  - mechanical structure (SCARA, parallel, …)
- [*World Robotics 2003*]
  International Federation of Robotics,
  United Nation, New York and Geneva, 2003

# Industrial Robots

Application areas:

- Electronic board
- Welding
- Spraying
- Autonomous transport systems
- Handling of hazardous materials
- …….

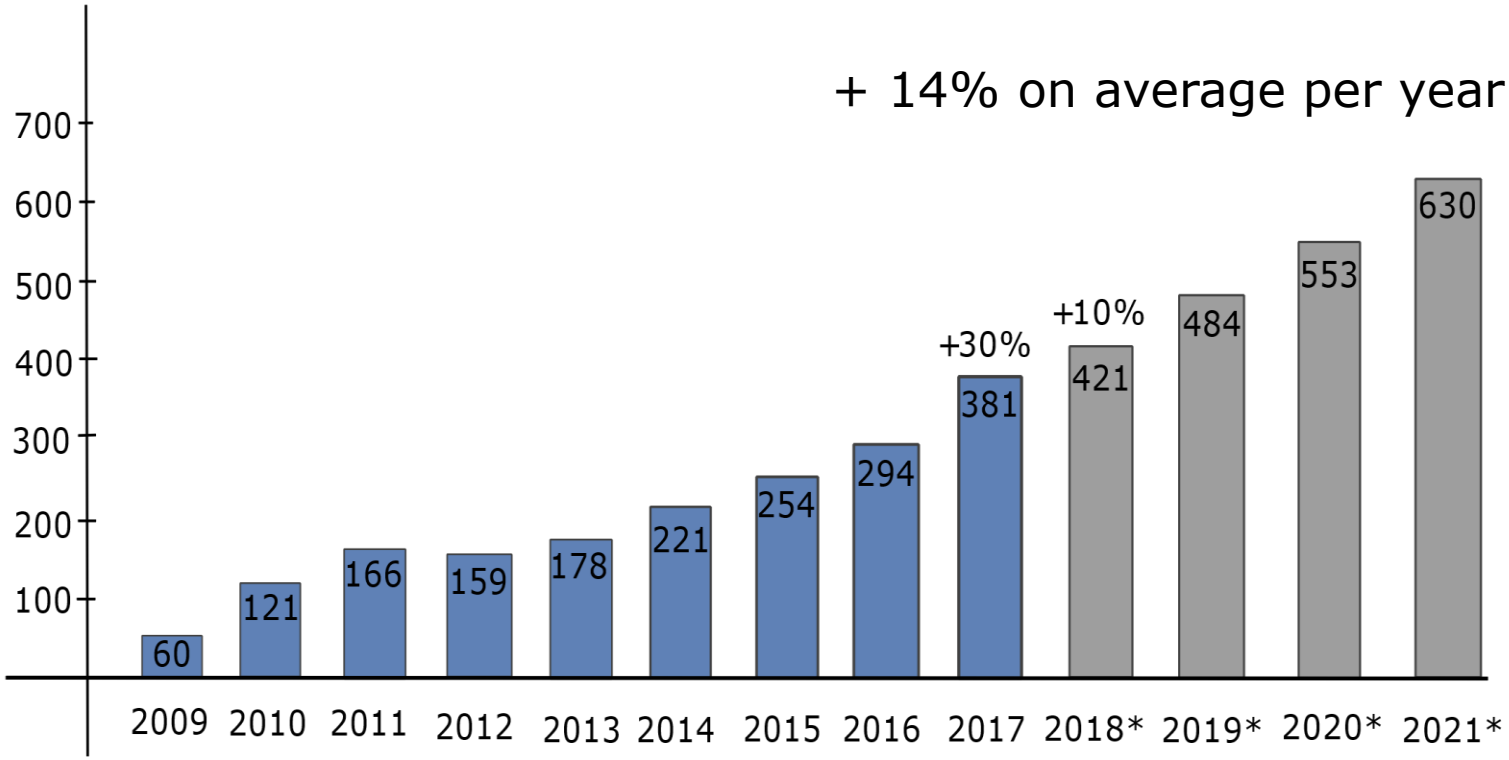
Properties:

- Usually stationary
- Less degree of freedom
- Easily programmable
- No perception of the environment
- Highly specialized
- Higher efficiency in cost and time compare to humans

Spraying of Chassis
(Daimler Sindelfingen)

# Statistics of Industrial Robots

## Estimated annual worldwide supply of industrial robots 2009-2017 and 2018*-2021*




* forecast

Source: IFR world Robotic 2018

# Chassis Construction BMW 3 Series

# Definition: Service Robot / Personal Robot

- A robot which operates semi- or fully autonomously to perform services useful to the well-being of humans and equipment, excluding manufacturing operations [*World Robotics 2003*]
- Classification based on
  - servicing humans
  - servicing equipment
  - others

# Humanoid Robot ARMAR III

# Application Areas

- Industrial robots
- Underwater robots
- Robots in construction and mining
- Robots in agriculture and forestry
- Computer based robotics assistance systems
- Personal robots in private environments
- Robots in operations
- Garbage collection
- Pipe inspection and maintenance
- Entertainment
- Elderly Care

# References

- Text Books
  - Craig, J. (2005). Introduction to Robotics – Mechanics and Control. Pearson Prentice Hall
  - Tsai, L.-W. (1999). Robot Analysis – The Mechanics of Serial an Parallel Manipulators, John Wiley & Sons
  - Siegert, H.-J. und Bocionek, S. (1996). Robotik: Programmierung intelligenter Roboter. Springer Verlag.
  - Stark, G. (2009). Robotik mit MATLAB. Hanser Fachbuchverlag

# Coming up next …

## *Subsystems of Robots – Mechatronics and Control*