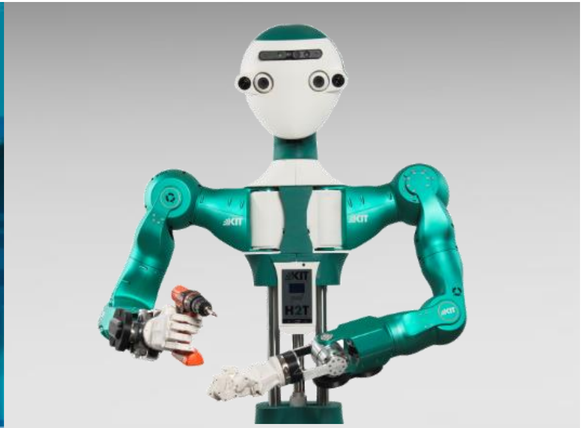
Robotics I: Introduction to Robotics

Chapter 0 – Introduction

Tamim Asfour

https://www.humanoids.kit.edu



Organization

Lecture Team

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Dr.-Ing.

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For questions and comments write to: **robotics-1@lists.kit.edu**

Lecture dates

- Lecture & Exercise
  - Monday, 14:00–15:30, **Gerthsen** Lecture Hall
  - Wednesday, 15:45–17:15, “**Hörsaal am Fasanengarten**” **(HS a.F.)**
  - Exercise: Upon announcement
- See ILIAS for current information

H²T – InformatiKOM 1

InformatiKOM 1

Adenauerring 12

Building 50.19

Office hours

- Tamim Asfour
  - Wednesday 14:00–16:00
  - InformatiKOM 1, 5th floor, Room 510
  - Appointment via email asfour@kit.edu

- Other office hours: See H^{2}T Website
  - https://www.humanoids.kit.edu
  - www.humanoids.de

ILIAS Course

- Access ILIAS course via https://ilias.studium.kit.edu
  - Login
  - Search course “2424152 – Robotik I - Einführung in die Robotik”
  - Password to join the course: **armar@kit**

- Content
  - Lecture slides, exercise sheets, lecture recordings (incl. previous semesters), previous exams
  - Announcements will be sent via email to members of this course
  - Two forums: “Organisation” and “Lecture Content”

Exam

- Credit points: 6 ECTS

- Exam in winter term 2024/2025
  - **Written exam in English (schriftlich)**
  - Date: **February 24, 2025, 08:00 – 10:00**
    - **Place will be announced in the lecture and in ILIAS**
  - Registration: **Campus-System,** https://campus.studium.kit.edu
  - Last registration date: **February 19, 2025**

- All information regarding lectures and exams will also be published on our homepage: https://www.humanoids.kit.edu

Exam – 120 minutes

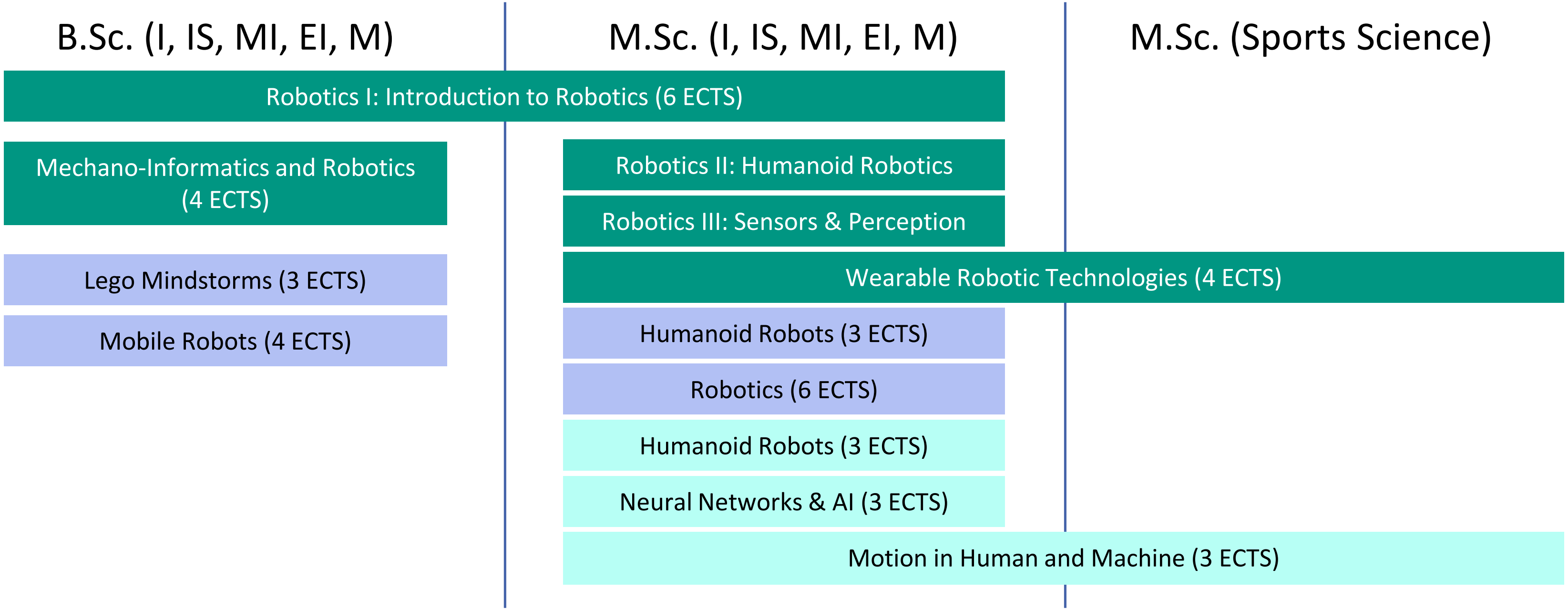
- Compared to previous semesters:
  More time for the exam, namely **120min** instead of 60min
- Expect, for example:
  - More **in-depth** tasks, requiring a **deeper understanding and to think more**
  - Longer tasks/calculations
  - More topics covered

Exam

Exam	Date	Time	Deadline for registration
Robotics II: Humanoid Robotics	February 6, 2025	17:30 - 18:30	January 31, 2025
Robotics III: Sensors and Perception in Robotics	February 13, 2025	17:30 - 18:30	February 7, 2025
Robotics I: Introduction to Robotics	February 24, 2025	08:00 - 10:00	February 19, 2025
Wearable Robotic Technologies	March 3, 2025	08:00 - 09:00	February 26, 2025
Mechano-Informatics and Robotics	March 12, 2025	14:45 - 15:45	March 7, 2025
Human Brain and Central Nervous System	March 19, 2025	08:00 - 09:00	March 14, 2025

Teaching @ H²T

🟩 Lecture
🟦 Seminar
🟪 Practical Course



B.Sc. (I, IS, MI, EI, M)

M.Sc. (I, IS, MI, EI, M)

M.Sc. (Sports Science)

Robotics I: Introduction to Robotics (6 ECTS)

Mechano-Informatics and Robotics (4 ECTS)

Lego Mindstorms (3 ECTS)

Mobile Robots (4 ECTS)

Robotics II: Humanoid Robotics

Robotics III: Sensors & Perception

Wearable Robotic Technologies (4 ECTS)

Humanoid Robots (3 ECTS)

Robotics (6 ECTS)

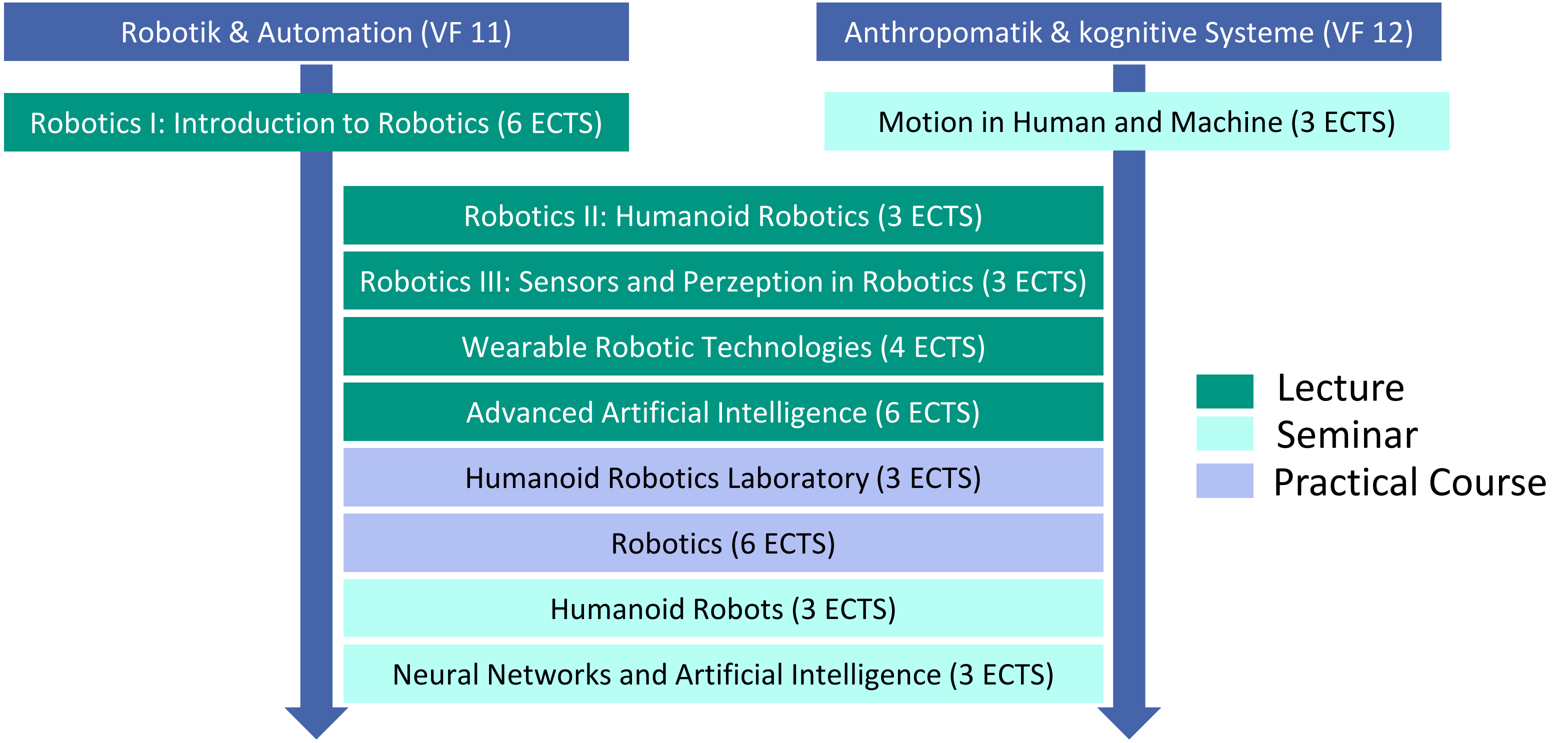
Humanoid Robots (3 ECTS)

Neural Networks & AI (3 ECTS)

Motion in Human and Machine (3 ECTS)

I = Informatics (* = applies **only** to informatics)
IS = Information Systems (Informationswirtschaft)
MI = Mechatronics & Information Technology
EI = Electrical Engineering & Information Technology
M = Mechanical Engineering

Teaching @ H²T – Specialization Subjects (Informatics)



Robotik & Automation (VF 11)

Anthropomatik & kognitive Systeme (VF 12)

Robotics I: Introduction to Robotics (6 ECTS)

Motion in Human and Machine (3 ECTS)

Robotics II: Humanoid Robotics (3 ECTS)

Robotics III: Sensors and Perzeption in Robotics (3 ECTS)

Wearable Robotic Technologies (4 ECTS)

Advanced Artificial Intelligence (6 ECTS)

Humanoid Robotics Laboratory (3 ECTS)

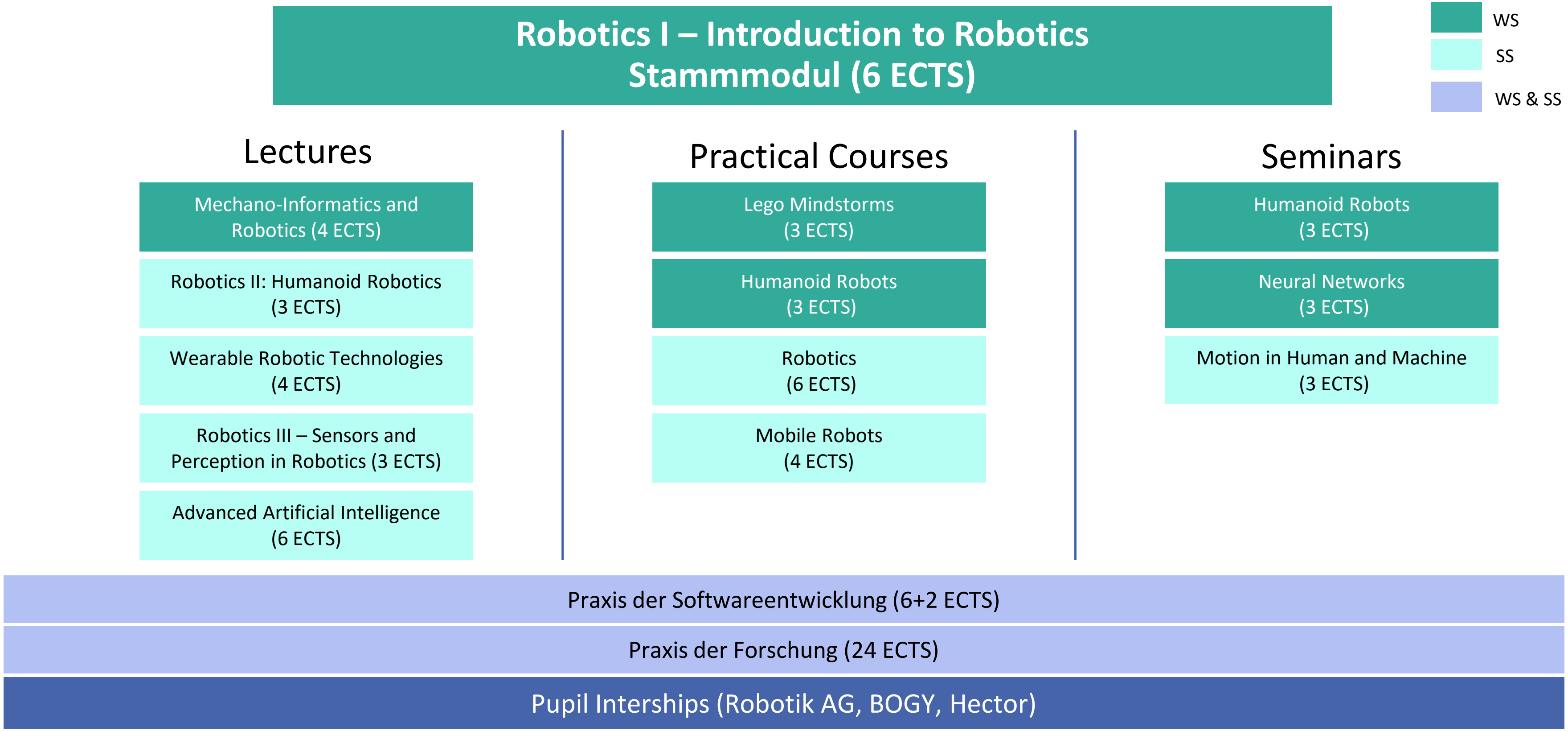
Robotics (6 ECTS)

Humanoid Robots (3 ECTS)

Neural Networks and Artificial Intelligence (3 ECTS)

- 🟩 Lecture
- ⬜ Seminar
- 🟦 Practical Course

Teaching @ H²T



🟩 WS

▭ SS

🟦 WS & SS

Robotics I – Introduction to Robotics
Stammmodul (6 ECTS)

Lectures

- Mechano-Informatics and Robotics (4 ECTS)
- Robotics II: Humanoid Robotics (3 ECTS)
- Wearable Robotic Technologies (4 ECTS)
- Robotics III – Sensors and Perception in Robotics (3 ECTS)
- Advanced Artificial Intelligence (6 ECTS)

Practical Courses

- Lego Mindstorms (3 ECTS)
- Humanoid Robots (3 ECTS)
- Robotics (6 ECTS)
- Mobile Robots (4 ECTS)

Seminars

- Humanoid Robots (3 ECTS)
- Neural Networks (3 ECTS)
- Motion in Human and Machine (3 ECTS)

Praxis der Softwareentwicklung (6+2 ECTS)

Praxis der Forschung (24 ECTS)

Pupil Interships (Robotik AG, BOGY, Hector)

Courses at H^{2}T in the Current Semester

- Lectures:
  - Robotics I
  - Mechano-Informatics

- Practical Courses:
  - Lego Mindstorms
  - Humanoid Robots

- Seminars:
  - Humanoid Robots

Lego Mindstorms – Laboratory

- Course for **Bachelor students (4 ECTS)**
  - Design and build a simple robot using Lego Mindstorms
  - Prerequisites:
    - Good knowledge of python and git
    - Basic algorithmic concepts (especially finate state machines)

- October 23, 2024 until February 12, 2025:
  Wednesday 13:00–17:30 Uhr, Seminar Room 1, InformatiKOM 1

- Registration via ILIAS:
  - https://ilias.studium.kit.edu/goto.php?target=crs_2473201&client_id=produktiv

Humanoid Robotics Laboratory

- Course for **Master students (6 ECTS)**
  - Mid-size project related to current research on humanoid robotics
  - Alone or in a small team
  - Prerequisite: very good programming skills

- Application deadline:
  - **Wednesday, October 23, 2024**

- Registration:
  - Join the ILIAS course to see the topics: https://ilias.studium.kit.edu/goto.php?target=crs_2476594&client_id=produktiv
  - Apply via e-mail to the supervisor(s)
  - Decisions will, at latest, be announced until October 30, 2024

Seminar Humanoid Robots

- Course for **Master students (3 ECTS)**
  - Get to know a selected topic of humanoid robotics
  - Written report and presentation at the end of the semester

- Registration:
  - Join the ILIAS course to see the topics: https://ilias.studium.kit.edu/goto.php?target=crs_2467706&client_id=produktiv
  - Assignment of topics via ILIAS

Institute for Anthropomatics and Robotics

Anthropomatics and Robotics

- **Anthropomatics: The science of the symbiosis between human and machine**

- Science and technology to improve the quality of life for humans

Institute for Anthropomatics and Robotics (IAR)

- 14 Chairs with approx. 150 employees

- High Performance Humanoid Technologies

Asfour

- Vision and Fusion

Beyerer

- Socially Assistive Robotics with Artificial Intelligence

Barbara Bruno

- Human-Computer Interaction for Accessibility

Gerling

- Intelligent-Sensor-Actuator Systems

Hanebeck

- Intuitive Robot Intelligence

Lioutikov

- Optimization and Biomechanics for Human Centered Robotics

Katja Mombaur

- Autonomous Learning Robots

Neumann

- AI for Language Technologies

Niehues

- Computer Vision for Human Computer Interaction

Stiefelhagen

- Inteligent Robot Perception

Rudolph Triebel

- Machine Learning

Stühmer

- Interactive Systems

Waibel

- Intelligent Process Control and Robotics

(Asfour)

- Medical Robotics

NN

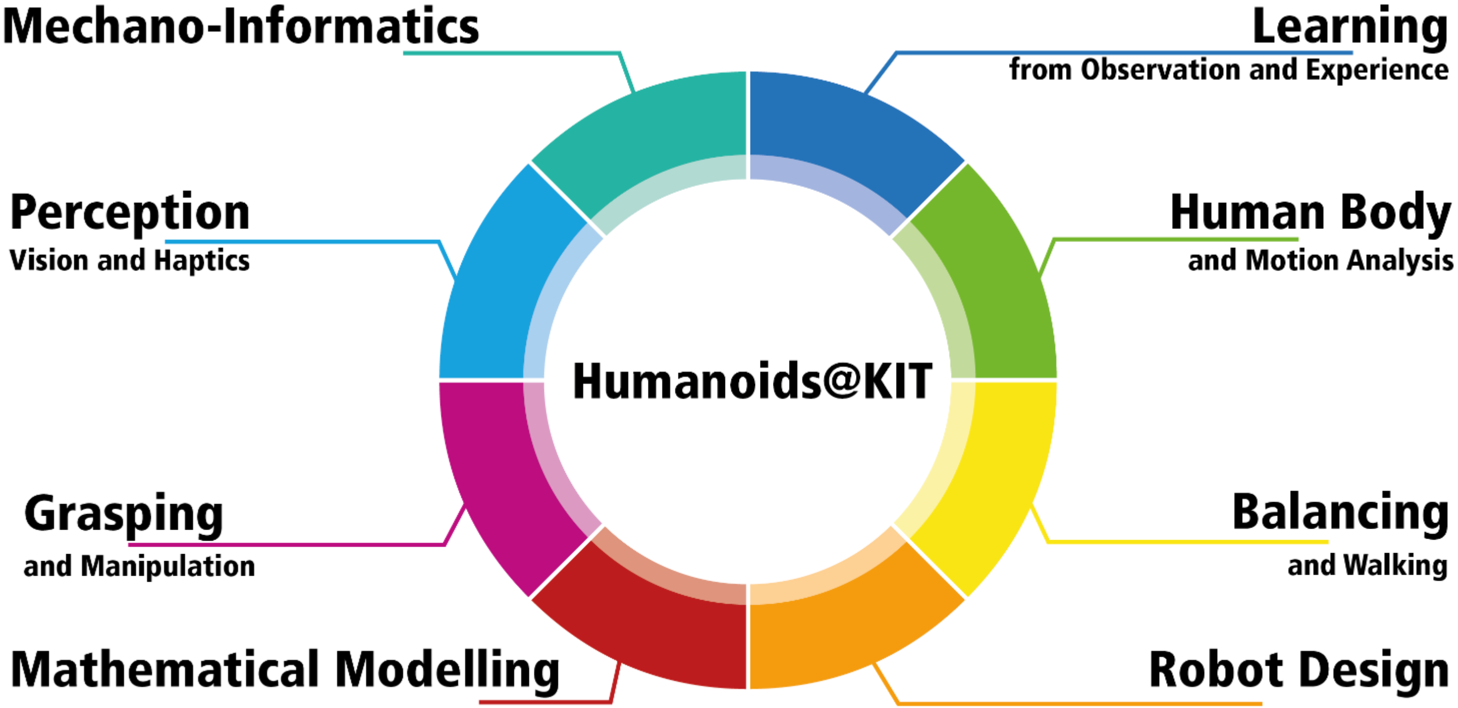
N.N.

Humanoids@KIT

H^{2}T Team

Humanoids@KIT

Research Topics at H²T



Mechano-Informatics

Perception
Vision and Haptics

Grasping
and Manipulation

Mathematical Modelling

Humanoids@KIT

Learning
from Observation and Experience

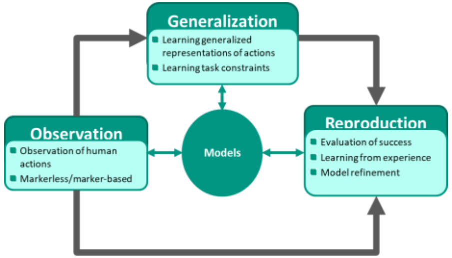
Human Body
and Motion Analysis

Balancing
and Walking

Robot Design

Humanoid Robotics @ KIT

Humanoid Assistance Robotics



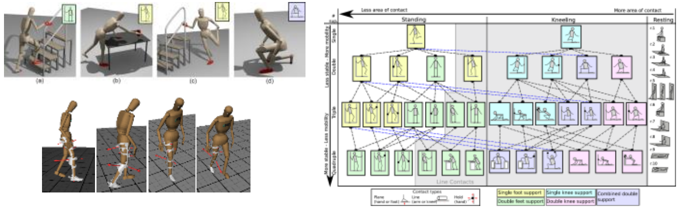
Generalization
- Learning generalized representations of actions
- Learning task constraints

Observation
- Observation of human actions
- Markerless/marker-based

Models

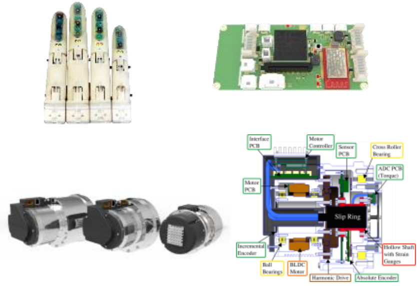
Reproduction
- Evaluation of success
- Learning from experience
- Model refinement

Learning from Human

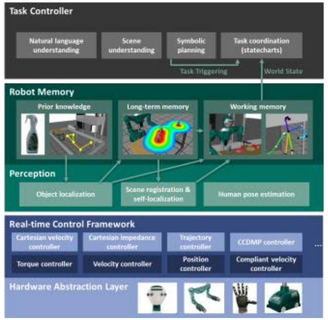


Human Motion Intelligence

Collaborative Robotics



Robotronics



Task Controller
- Natural language understanding
- Scene understanding
- Symbolic planning
- Task coordination (statecharts)

Task Triggering
World State

Robot Memory
- Prior knowledge
- Long-term memory
- Working memory

Perception
- Object localization
- Scene registration & self-localization
- Human pose estimation

Real-time Control Framework
- Cartesian velocity controller
- Cartesian impedance controller
- Trajectory controller
- CCDMP controller
- Torque controller
- Velocity controller
- Position controller
- Compliant velocity controller
- …

Hardware Abstraction Layer

Cognitive Architectures

Wearable Robotics

Our Goal: Humanoids in the Real World

- **Engineering** Humanoids
- **Grasping and manipulation**
- **Learning** for human observation and experience
- **Natural Interaction** and communication

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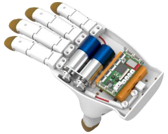
The ARMAR Robot Family





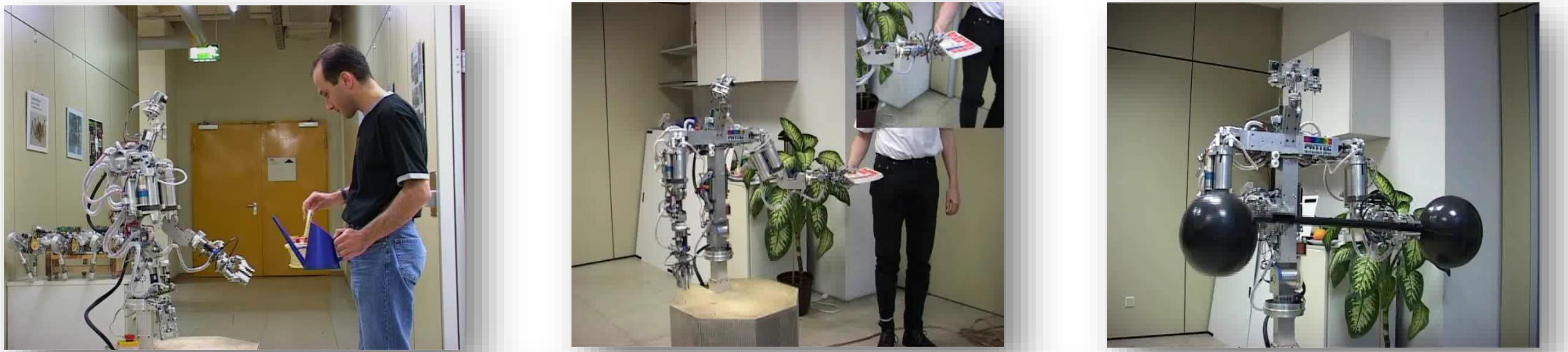





The ARMAR Family: Hands

ARMAR-I (1999) and ARMAR-II (2003)



First demonstrator of the SFB 588

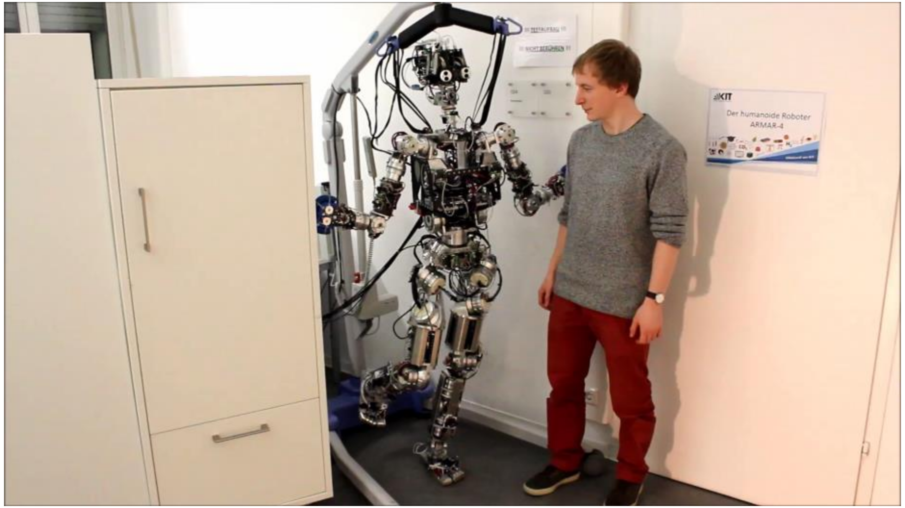
Demo at CEBIT 2006

ARMAR-III (2008)

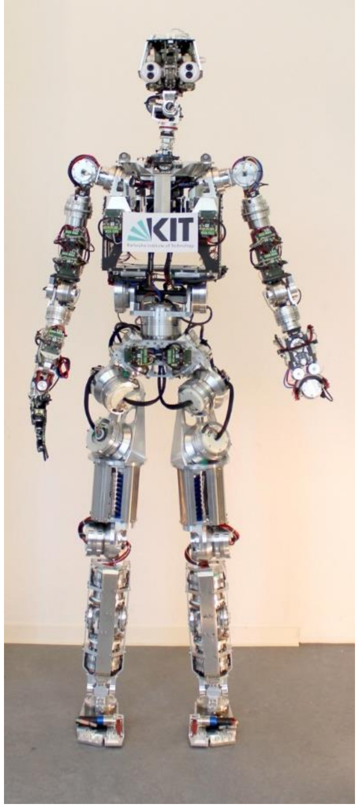
45 minutes household task, performed more than 4700 times since February 3, 2008

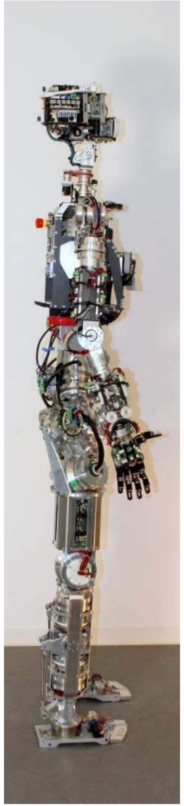
ARMAR-4 (2014)

- 63 DOF
- Torque-controlled!

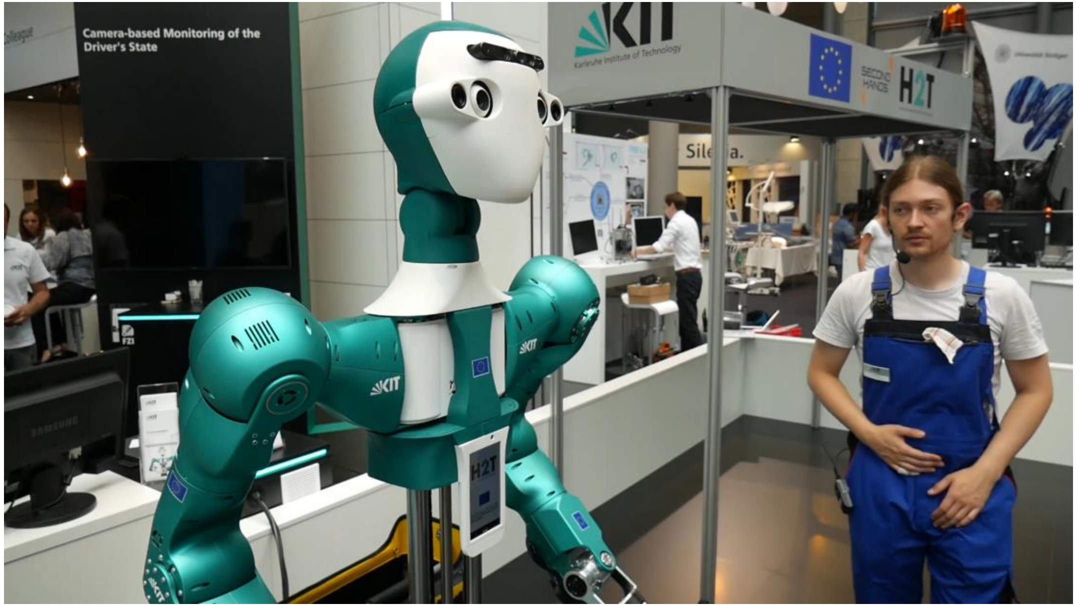


Multi-contact active compliance balancing controller





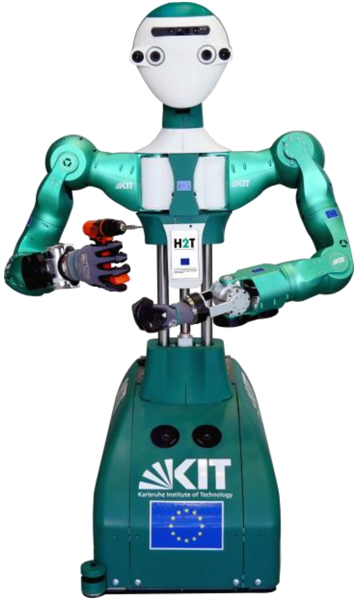
ARMAR-6 (2017)



Assistant of a human technician in maintenance and repair tasks in industrial environments

The Active ARMARs

ARMAR-3



ARMAR-6

ARMAR-DE

ARMAR-7

ARMAR-5: Humanoids for Human Augmentation

- Humanoid robots with **multiple functions** and for **multiple use**

Helper, Assistant and Companion

Wearable Humanoid „Body Suit“

ARMAR-5: Wearable Humanoid (since 2015)

Humanoids in the Real World

- **Engineering** Humanoids
- **Grasping and manipulation**
- **Learning** for human observation and experience
- **Natural Interaction** and communication

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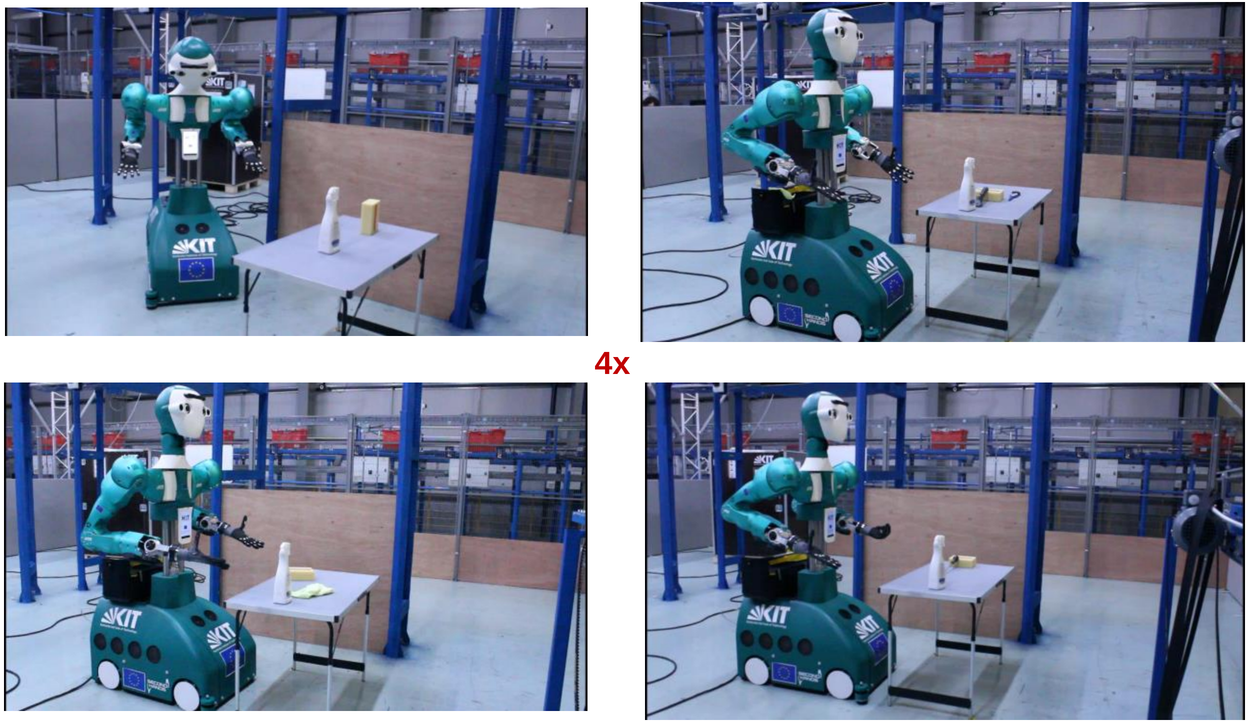
Grasping and Manipulation

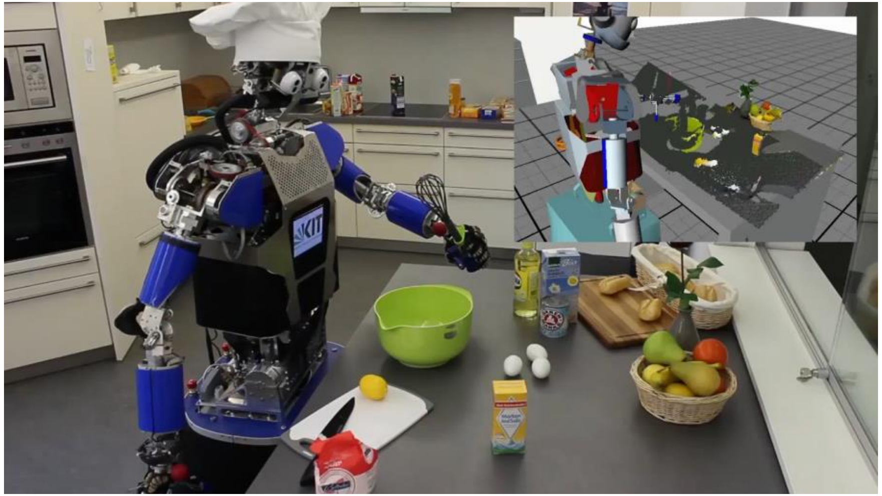
- **Known objects**
- Vision-based Object detection and pose estimation
- Vision-based grasping
- Vision-based self-localisation
- Grasp and motion planning
- Hybrid position/force control
- Collision-free navigation
- …

Grasping and Manipulation with ARMAR-6

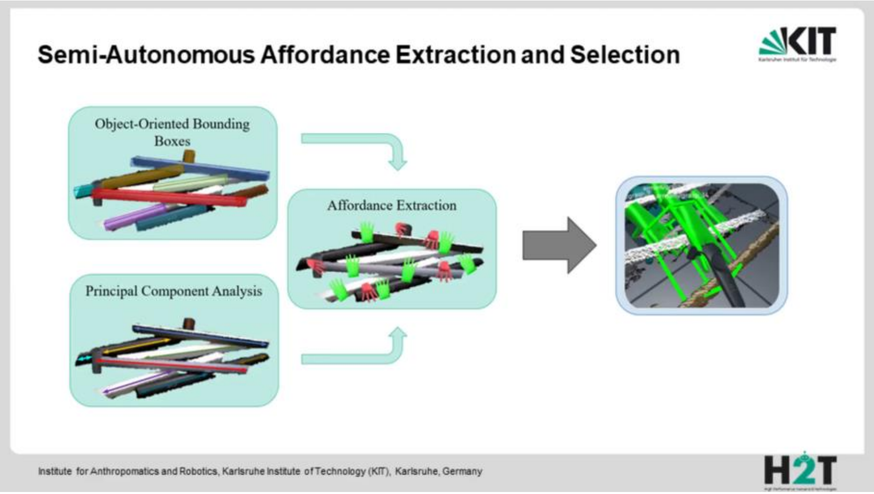


- **Known and unknown objects**
- Vision-based Object detection and pose estimation
- Vision-based grasping
- Grasp and motion planning
- Self-collision avoidance
- Collision-free navigation
- …

Grasping Unknown Objects



Deep CNN based grasping



Semi-Autonomous Affordance Extraction and Selection

Object-Oriented Bounding Boxes

Principal Component Analysis

Affordance Extraction

Institute for Anthropomatics and Robotics, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Affordance-based grasping

Humanoids in the Real World

- **Engineering** Humanoids
- **Grasping and manipulation**
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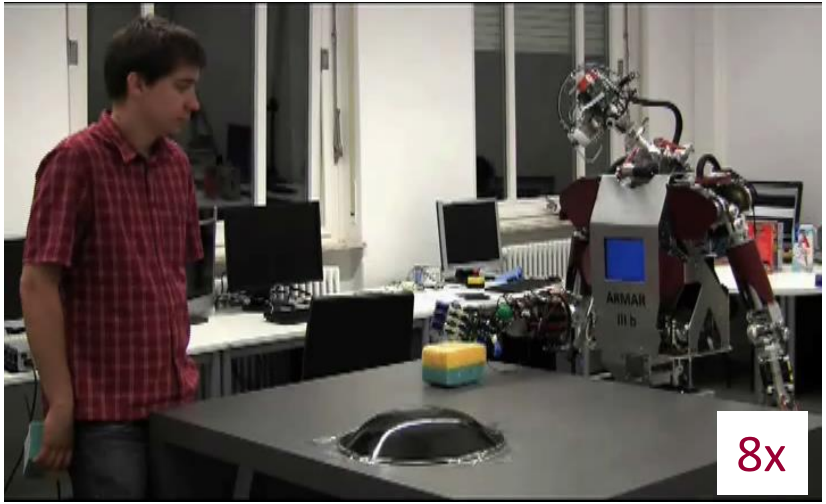
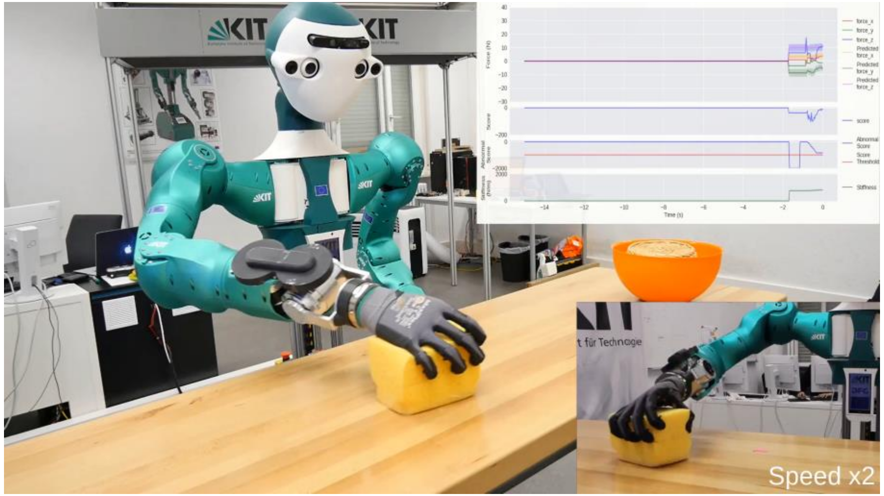
Imitation Learning

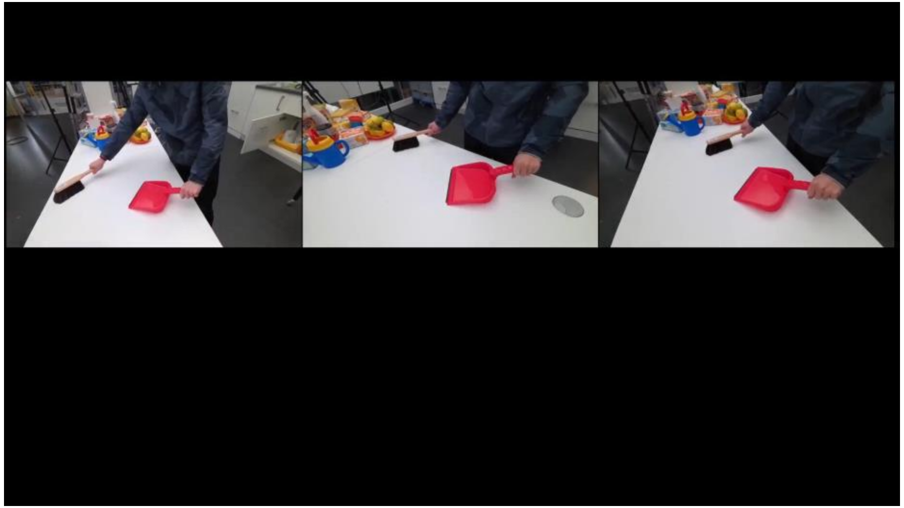
- Learning from Human Demonstration
- Library of motion primitives (motion alphabet)
- Tasks as sequences of motion primitives

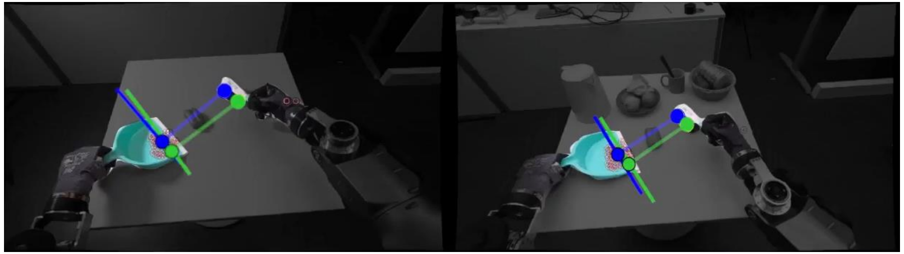




Imitation Learning

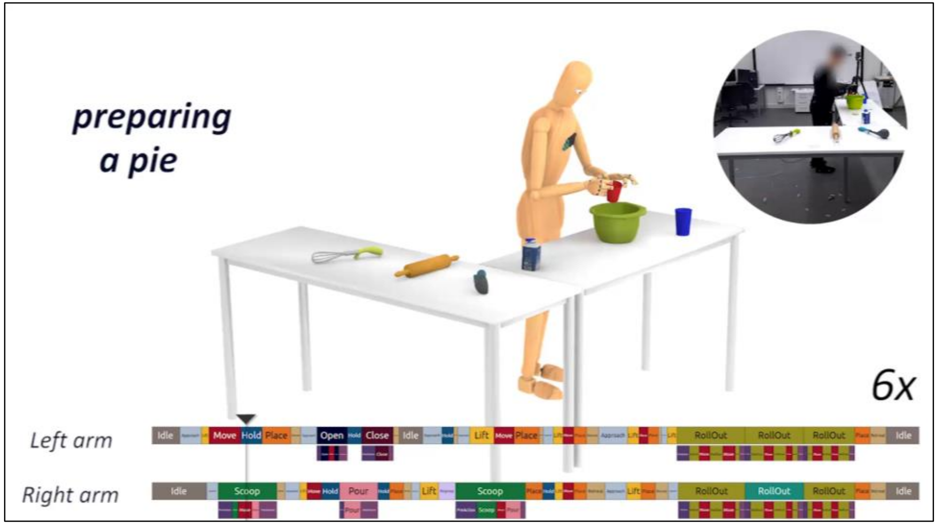
- Learning key-point based task models from human demonstration videos
- Generalization to novel scenes/objects
- Robot vision, machine learning and control





Creating a Robot Motion Alphabet

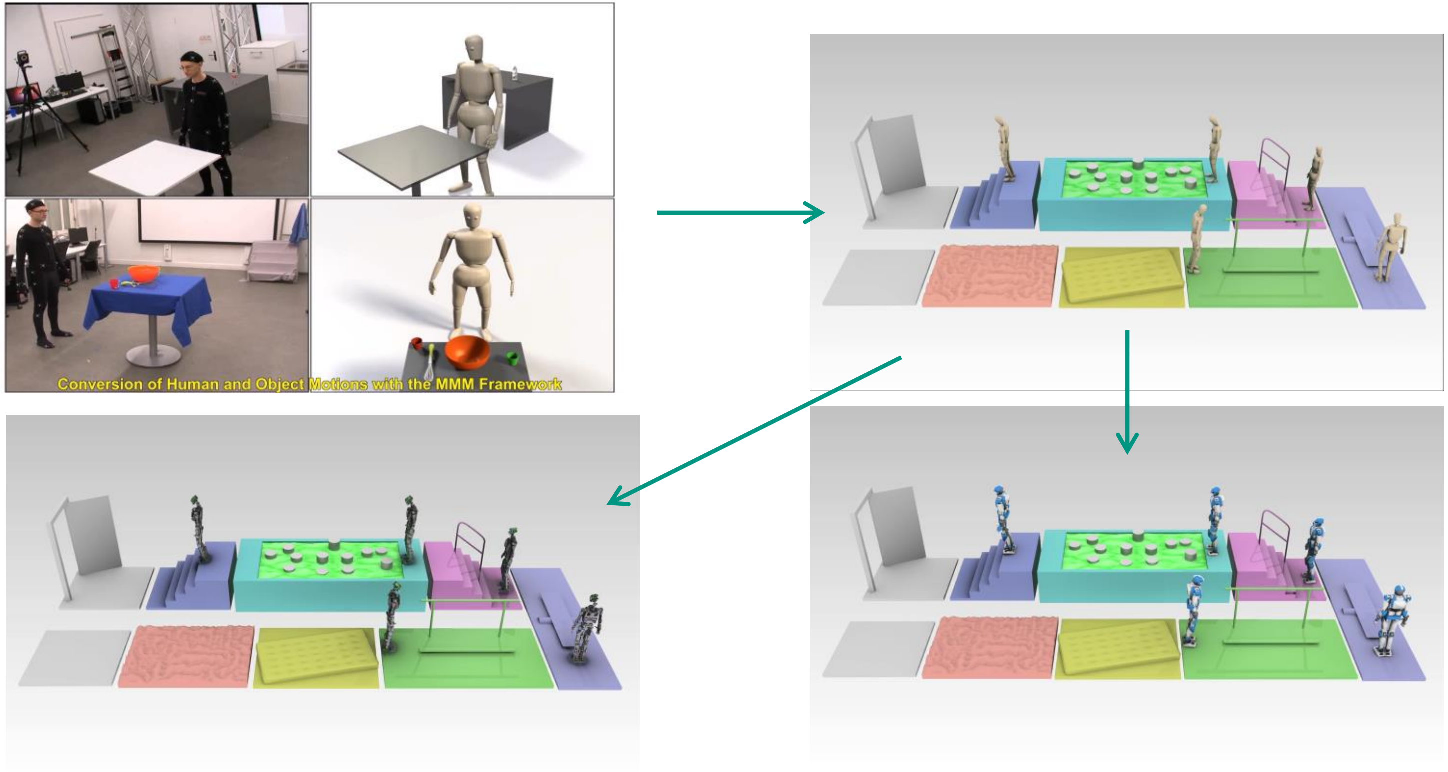
- KIT whole-body human motion database



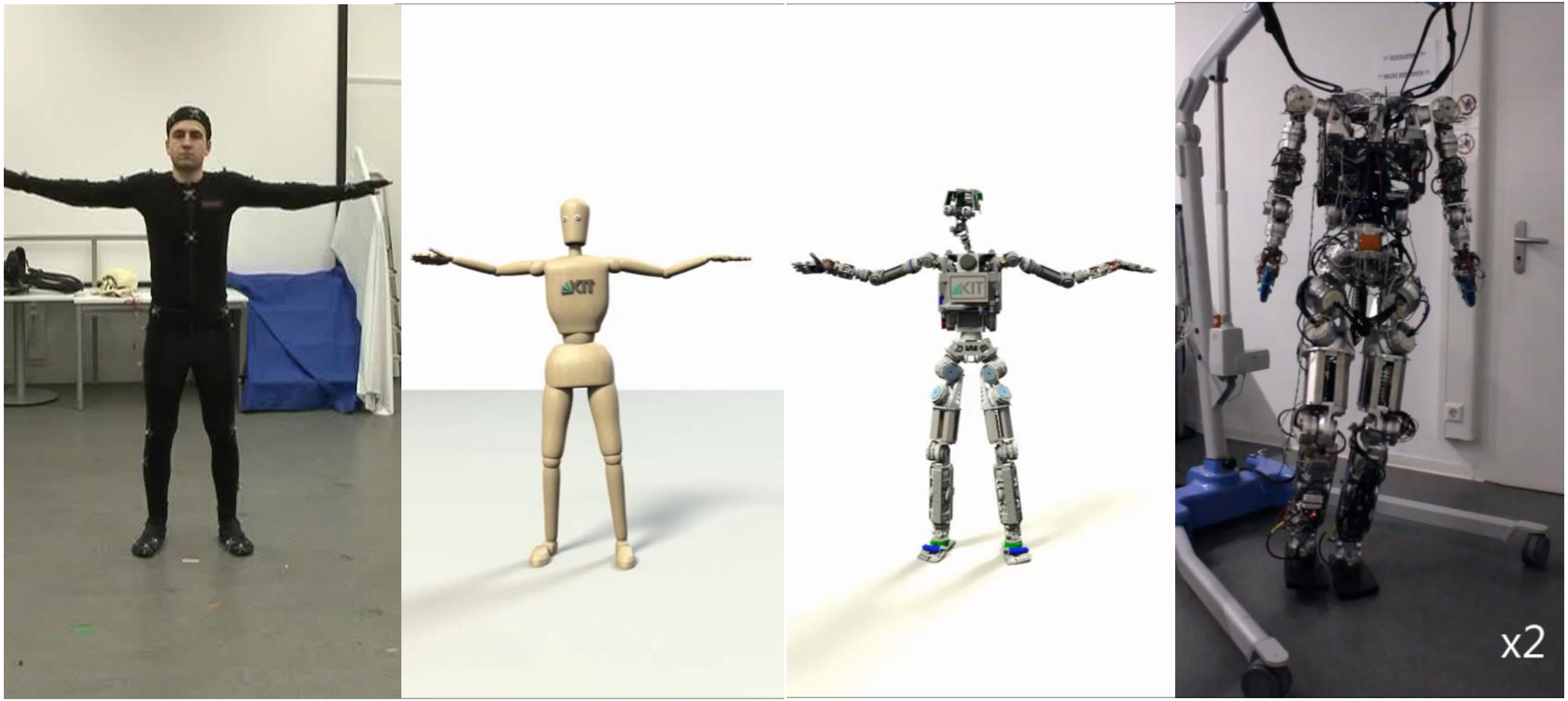
42 hours of manually labeled human motion data (including object information); 9375 motions; 234 (112/41) subjects and 158 objects.

motion-database.humanoids.kit.edu
https://gitlab.com/mastermotormp

The KIT whole-body human motion database



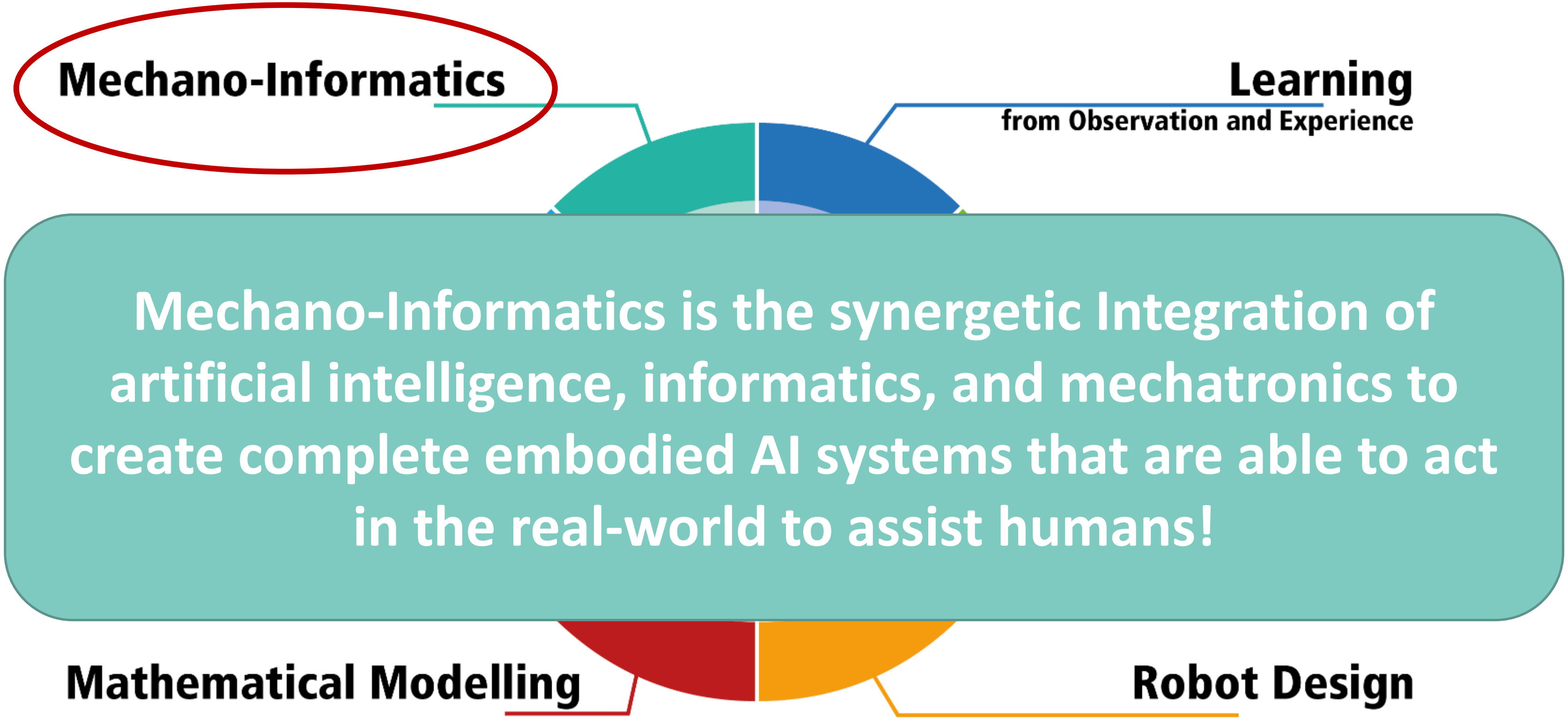
Learning to balance from human observation



Interactive learning for scene manipulation

- Manipulating the scene based on verbal instructions and spatial relations
- Generative models of spatial relations are learned incrementally and interactively from human demonstrations

Mechano-Informatics

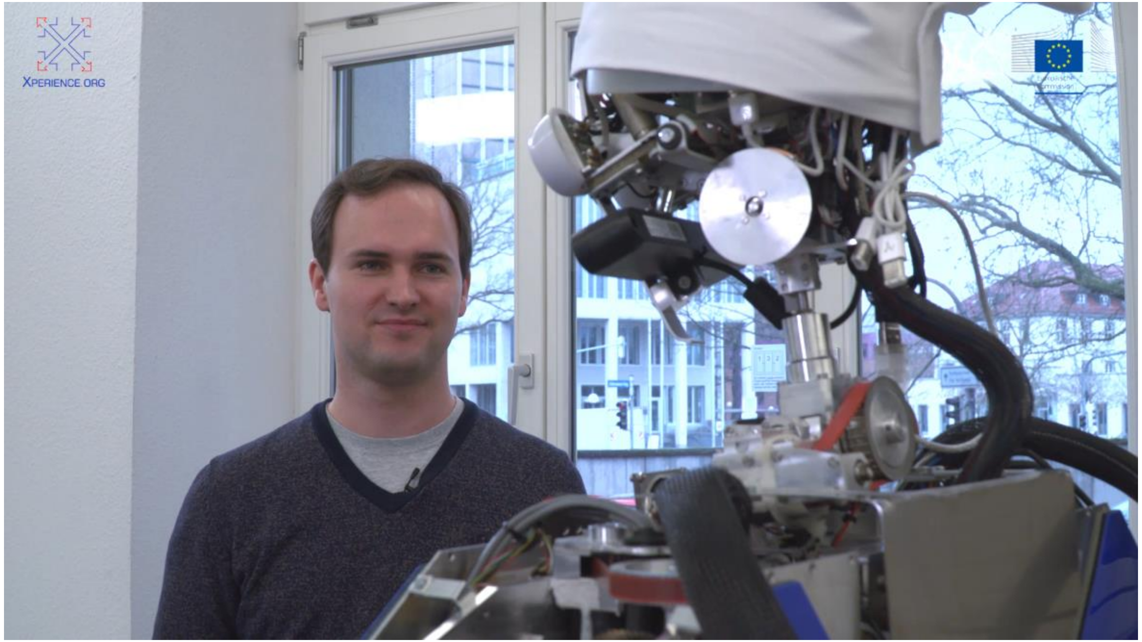


Mechano-Informatics is the synergetic Integration of artificial intelligence, informatics, and mechatronics to create complete embodied AI systems that are able to act in the real-world to assist humans!

Integration of AI, machine learning, vision and control

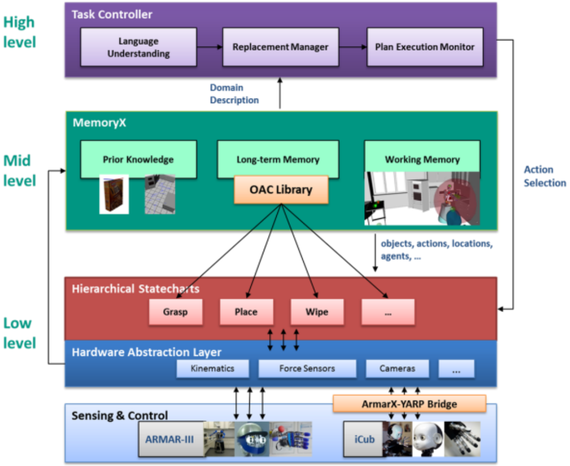
Karlsruhe Institute of Technology

- „ARMAR, please help me to prepare dinner for two people!“



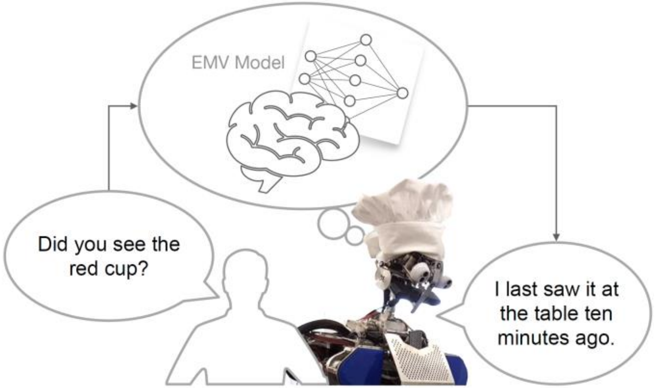
XPERIENCE.ORG

paco|plus
perception, action and cognition
through learning of object-action complexes



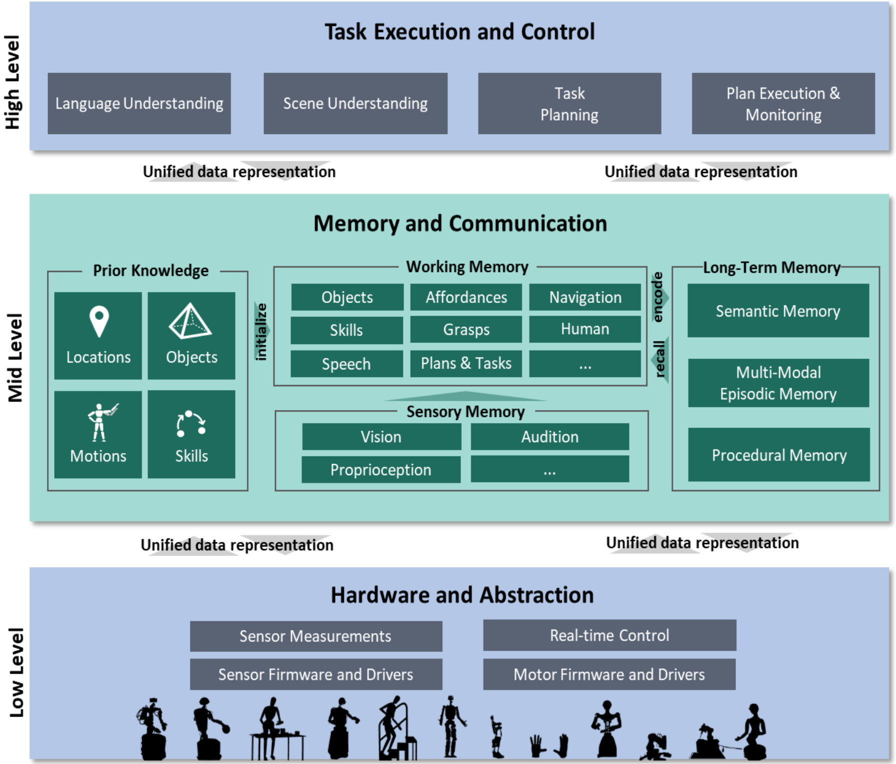
Verbalization of Robot Experience

- Deep Learning based Episodic Memory



Memory-Centric Robot Cognitive Architecture

Memory-centered, hybrid architecture that supports semantic and sensorimotor representations



Cognitive architecture implemented in ArmarX

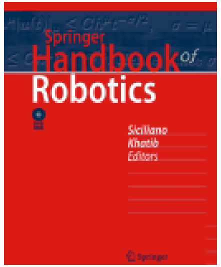
Robotics 1

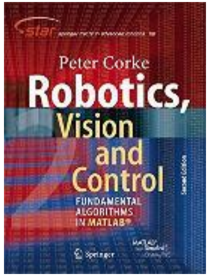
Lecture Content

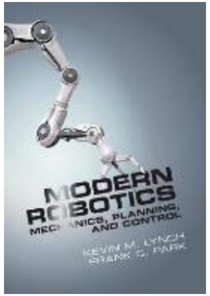
- What is Robotics?
- Mathematical Foundations
- Kinematics
- Inverse Kinematics
- Dynamics
- Control
- Continuous path control
- Motion Planning
- Grasping
- Robot Vision
- Ethics in Robotics
- Robot Programming and Robot Programming by Demonstration (PbD)
- Symbolic Planning

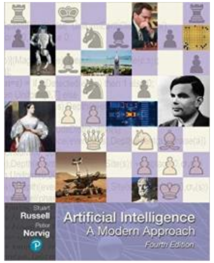
Literature

- **Handbook of Robotics:** Comprehensive overview (1600 pages)
  Bruno Siciliano and Oussama Khatib (PDF available inside the KIT network)
  http://link.springer.com/book/10.1007%2F978-3-319-32552-1
- **Robotics, Vision and Control: Fundamental Algorithms in Matlab**
  Peter Corke
  https://link.springer.com/book/10.1007/978-3-642-20144-8
- **Modern Robotics: Mechanics, Planning and Control**
  Kevin M. Lynch and Frank C. Park
  http://hades.mech.northwestern.edu/index.php/Modern_Robotics
- **Robotics: Control, Sensing, Vision, and Intelligence**
  K.S. Fu, R.C. Gonzalez, C.S.G. Lee
- **Artificial Intelligence – A Modern Approach**
  Stuart Russel and Peter Norvig
  http://aima.cs.berkeley.edu/
- **Selected Publications:** See ILIAS course









Software

In the excercises, we will get to know programms and libraries that are used in robotics.

- Python: https://docs.python.org/3/
- Matlab: https://www.scc.kit.edu/en/products/3841.php
- Robotics Toolbox (Matlab and Python): http://petercorke.com/wordpress/toolboxes/robotics-toolbox
- Simox: https://git.h2t.iar.kit.edu/sw/simox/simox/-/wikis/home
- OpenCV (Python): https://opencv-python-tutroals.readthedocs.io/en/latest/

Robotics Toolbox
for MATLAB
Peter Corke

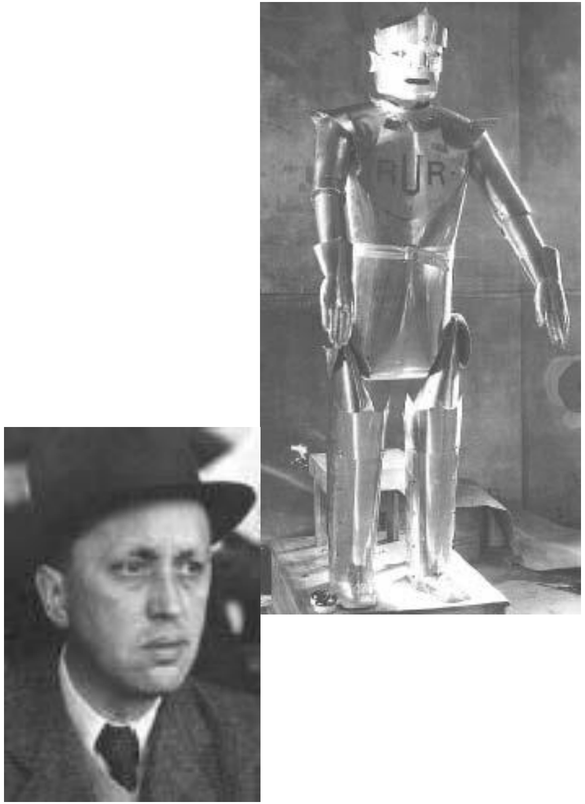
Introduction

- Terminology
- History
- Disciplines involved in Robotics
- Fields of Application

Terminology

Term “Robot”

- Karel Capek was a Czech writer
- He introduced the term „robota“ (west-Slavian: heavy work) in his play R.U.R (Rossum‘s Universal Robot)
- For Capek, a robot is (in contrast to humans) **restlessly working**



Asimov’s Three Laws of Robotics („Runaround“, 1942)

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

Isaac Asimov

Terminology

Industrial Context (VDI Guideline 2860, 1990)

A **Robot** is a **freely programmable, multifunctional manipulator** with at least 3 independent axes, to move materials, parts, tools or devices along programmed, variable trajectories to fulfil different tasks.

Scientific Context (Thomas Christaller, 2001)

Robots are **sensorimotor machines to extend human capacity to act**. They consist of mechatronic components, sensors and computer-based control functionalities. The complexity of a robot differs significantly from other machines due to the higher number of degrees of freedom, as well as the variety and extent of its actions.

Terminology

Term: Robotics (Wikipedia, 2024)

Robotics is the **interdisciplinary study and practice** of the design, construction, operation, and use of robots.

Within mechanical engineering, robotics is the **design and construction** of the physical structures of robots, while in computer science, robotics focuses on **robotic automation algorithms**. Other disciplines contributing to robotics include electrical, control, software, information, electronic, telecommunication, computer, mechatronic, and materials engineering.

The goal of most robotics is to design machines that can help and assist humans. Many robots are built to do jobs that are hazardous to people, such as finding survivors in unstable ruins, and exploring space, mines and shipwrecks. Others replace people in jobs that are boring, repetitive, or unpleasant, such as cleaning, monitoring, transporting, and assembling. Today, robotics is a rapidly growing field, as technological advances continue; researching, designing, and building new robots serve various practical purposes.

https://en.wikipedia.org/wiki/Robotics, accessed October 18, 2024

Terminology

Term: Robotics (My definition)

Robotics is the science of **engineering** technical systems with **intelligent behavior** for **real-world** usage, i.e., technical systems that generate **motions as the basis of intelligence**, perceive and evaluate **situations**, are able to predict and interprete **consequences of actions** and can **continually learn from interactions with the real world**, to broaden their cognitive horizon.

Robotics is artificial intelligence in the real world

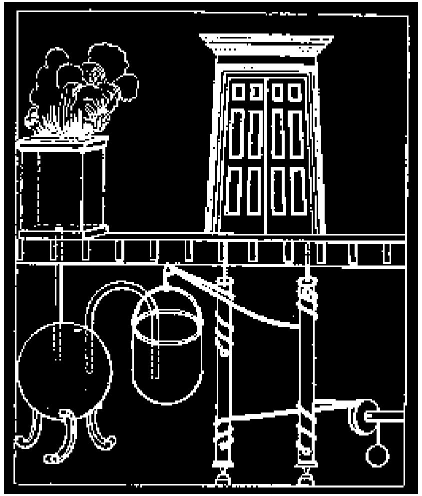
Robotics is an interdisciplinary field of research, that combines biology, neuroscience and cognitive science, psychology, material science and engineering, as well as computer science and artificial intelligence.

Robotics

- Terminology
- **History**
- Disciplines involved in Robotics
- Fields of Application

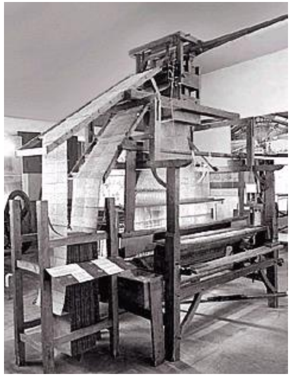
History of Robotics

- **1. Jh. AD,** Heron von Alexandria, automatic altar
- **3. Jh. AD,** four-legged walking machine, China, 200–250 kg payload at a speed of 10 km per day



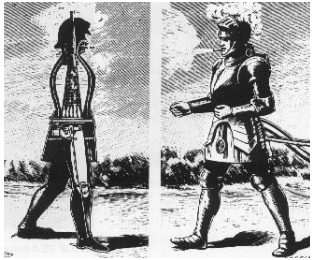
History of Robotics

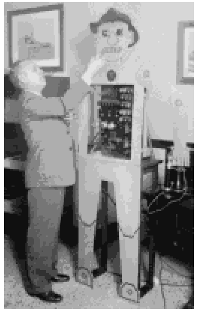
- **15. Jhd**, Leonardo Da Vinci, mechanical soldier
- **1738**, Jaques de Vaucanson, mechanical duck: flap the wings, quack, dring water, eat and digest seeds
- **1774**, Pierre Jaquet-Droz & Jean-Frédéric Leschot, mechanical writer
- **1805**, Joseph Maria Jacquard, programmable weaving loom (punch cards)



History of Robotics

- **1893**, George Moore, Steam Man
- **1927**, household robot Televox; control center for the household
- **1930**, Sabor II; for entertainment
- **1954**, Georg Devol, patent for programmable manipulators
- **1959/60**, **Georg Devol und Joesph Engelberger**, first industrial robot „**Unimate**“, hydraulic actuation, controlled by computer


Steam Man


Televox


Sabor IV

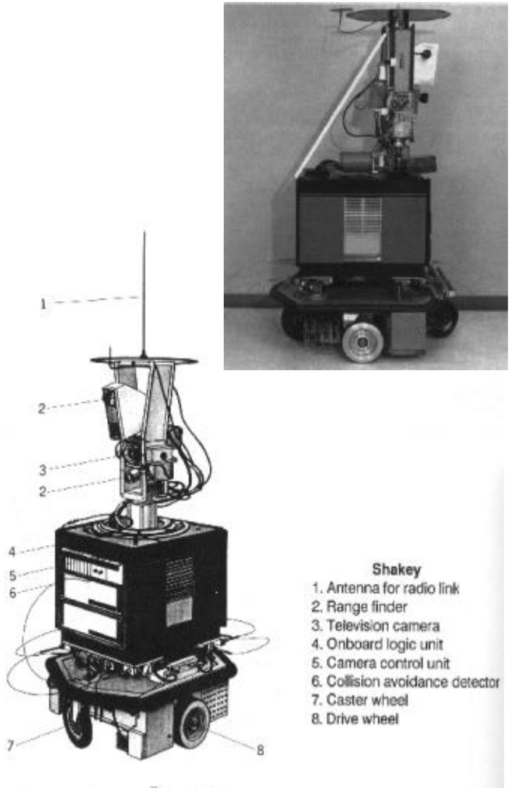

Unimate

History of Robotics

- **1959**, Planet Corp., first commercial robot (control via cams and limit switches)
- **1961**, Installation of a „Unimate“ robot at Ford
- **1968**, Charles Rosen, **Shakey**, Stanford Research Institute; first mobile robot (robotics, vision, speech processing)

See Celebration of the 50th Anniversary of Shakey at ICRA 2015

YouTube: https://www.youtube.com/watch?v=7bsEN8mwUB8



History of Robotics

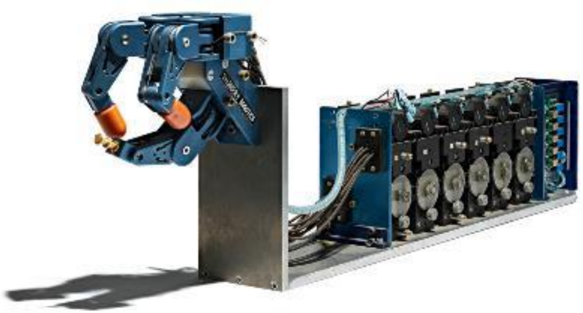
- **1970er**, Daimler-Benz, Sindelfingen, first industrial robots
- **1973**, Waseda University, Tokyo
  first humanoid robot: Wabot-1
- **1974**, Development of AL (Assembly language)
  - Carried forward by Unimation as programming language VAL
- **1978**, PUMA (Programmable Universal Machine for Assembly) by Unimation

Wabot-1

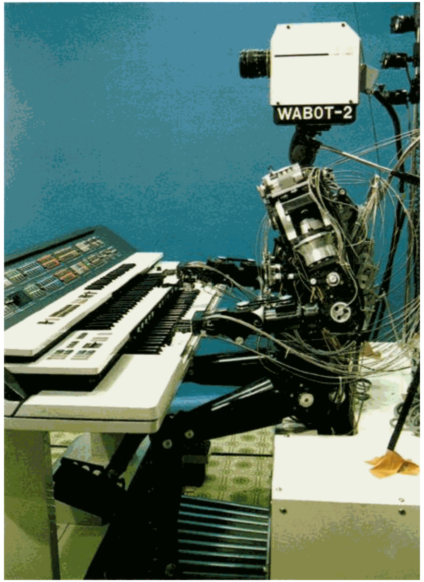
PUMA

History of Robotics

- **1984**, Wabot-2, Prof. Ichiro Kato, Waseda University, Tokyo
- **1985**, 3-Finger Salisbury Hand, Stanford/JPL



Salisbury Hand



Wabot-2

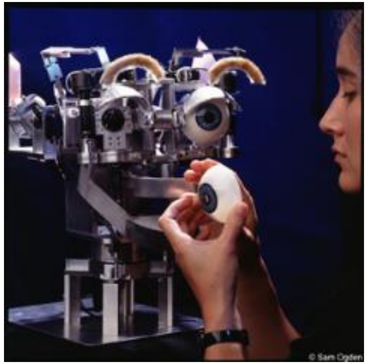
History of Robotics

- **1996**, Sojourner, Pathfinder MARS Mission
- **1998**, DLR Hand
- **1999**, The Sociable Machine Project, Kismet, MIT
- **2005**, Wakamaru, Mitsubishi

Sojourner

Wakamaru

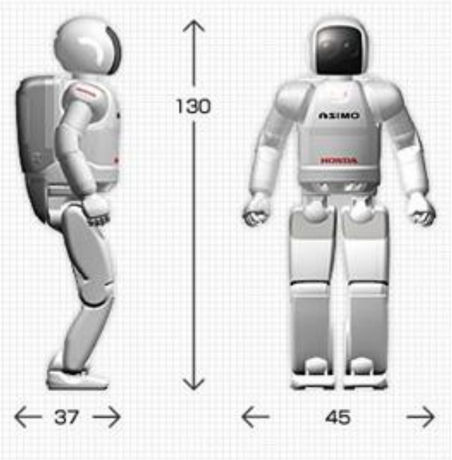
DLR hand



Kismet

History of Robotics

- **2005**, Humanoid Robot Asimo



Size
Height: 130cm
Width: 45cm
Depth: 37cm
Weight: 54Kg

Degrees of Freedom
Head: 3
Arm: 7 × 2
Hand: 2 × 2
Torso: 1
Leg: 6 × 2
TOTAL 34

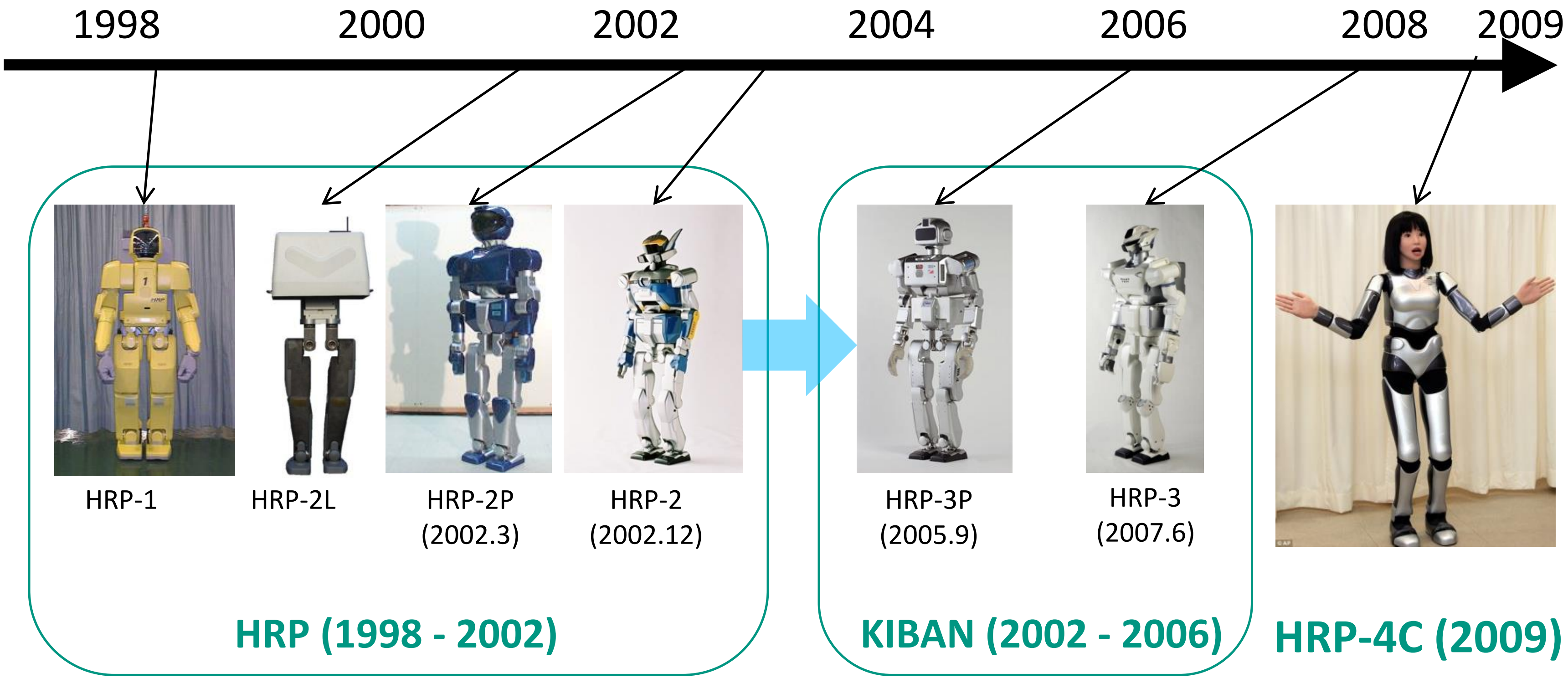
Performance
Running speed: 6km/h
Operational Time:(Walking) 40minutes

http://asimo.honda.com

ASIMO, Nov. 2011

http://asimo.honda.com

HRP Series: From HRP-1 to HRP-4C



HRP-1

HRP-2L

HRP-2P
(2002.3)

HRP-2
(2002.12)

HRP-3P
(2005.9)

HRP-3
(2007.6)

HRP (1998 - 2002)

KIBAN (2002 - 2006)

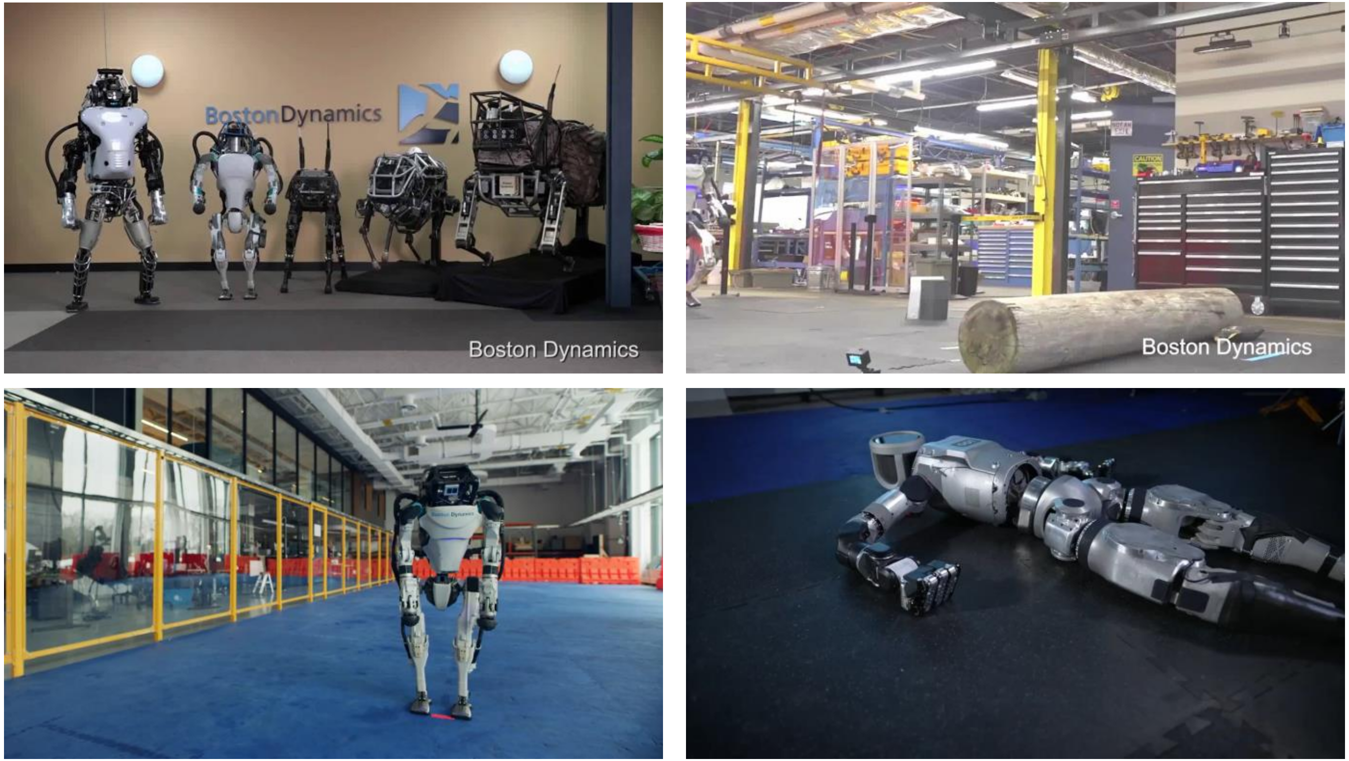
HRP-4C (2009)

AIST: http://www.is.aist.go.jp/humanoid

HRP = Humanoid Robotics Project

Thanks to Eiichi Yoshida for this slide!

Boston Dynamics Atlas (2006–today)



https://www.youtube.com/user/BostonDynamics

Autonomous Driving

- **1986:** Ernst Dickmanns, University of the German Federal Armed Forces, Munich
  - Robotic car VaMoRs, up to 96 km/h
- **2004:** Grand Challenge
  - Ghostrider, Berkeley
- **2005:** Grand Challenge
  - Stanford Racing Team
- **2007:** Urban Challenge
  - Team Annieway, Karlsruhe
- **2011:** Road Approval
  - Google Autonomous Vehicle

Stanford Racing Team

Team Annieway

Google Autonomous Vehicle

Lightweight Robotic Arms

- **2003: DLR LWR III** (Lightweight Robot)
  - 1:1 ratio of payload to weight (14 kg each)
  - 7 Degrees of Freedom with torque control
  - Integrated electronics, internal wiring
  - 2013: industry transfer as KUKA LBR iiwa product
- **2008: Universal Robots:**
  - UR5 (5kg payload)
  - Later: robots with other payloads
- **2017: Franka Emika Panda**
  - German “Zukunftspreis”
  - Original price: starting from approx. 10.000 €
  - 7 Degrees of Freedom with torque control

DLR LWR III

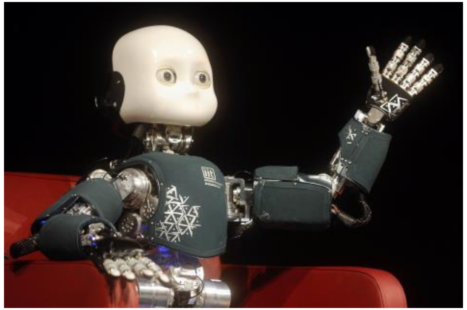
KUKA LBR iiwa

UR5

Panda

Humanoid Research Robots as a Product

- **2009:** iCub
  - Humanoid roboter at the size of a child
  - Developed by IIT (Italian Institute of Technology) and the RobotCub Consortium
  - Facilitates research at several universities worldwide



- PAL Robotics
  - **2013**: REEM-C
  - **2015**: TIAGo
  - **2017**: TALOS
  - **2019**: ARI
  - **2021**: KANGAROO (biped research platform)

REEM-C

TIAGo

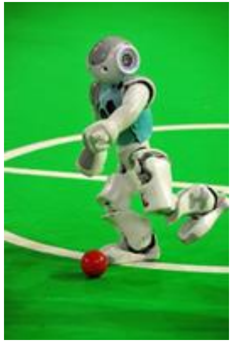
TALOS

ARI

KANGAROO

Commercial Humanoid Robots

- **2008**: NAO
  - 57 cm tall
  - Developed by Aldebaran Robotics (France)
    Now: SoftBank Robotics
  - Research, Education, Entertainment



NAO

- **2014**: Pepper
  - 120 cm tall
  - Developed by Aldebaran Robotics (France)
    Jetzt: SoftBank Robotics
  - Social interactions: customer service, guided tours, …
  - Payload of hands: 0.5 kg

Pepper

Robotic Challenges

- **1993–today: “RoboCup” Robot World Cup Initiative**
  - RoboCupSoccer, RoboCupRescue, RoboCup@Home, FoboCupIndustrial

- **2012–2015**: DARPA Robotics Challenge (DRC)
  - Robotic challenge to foster technological development for rescue scenarios
  - Semi-autonomous robots shall perform complex tasks in environments of disaster scenarios

- **2014 – 2017**: Amazon Picking Challenge
  - Autonomous identification and picking of objects from warehouse shelfs
  - Quickly learn new objects

Generations of Robots

- **1. Generation**
  (programmable manipulators, since 1960)
  - Low calculation capacity
  - Only fixed waypoints (Point-to-Point programming)
  - Little sensory abilities (Pick-and-Place actions)

- **2. Generation**
  (adaptive robots, since 1980-ies)
  - More sensors (e.g., cameras)
  - Adaptation to environment
  - Specialised programming languages (e.g., VAL)
  - Low level of robot intelligence (adaptive execution of tasks)

Generations of Robots

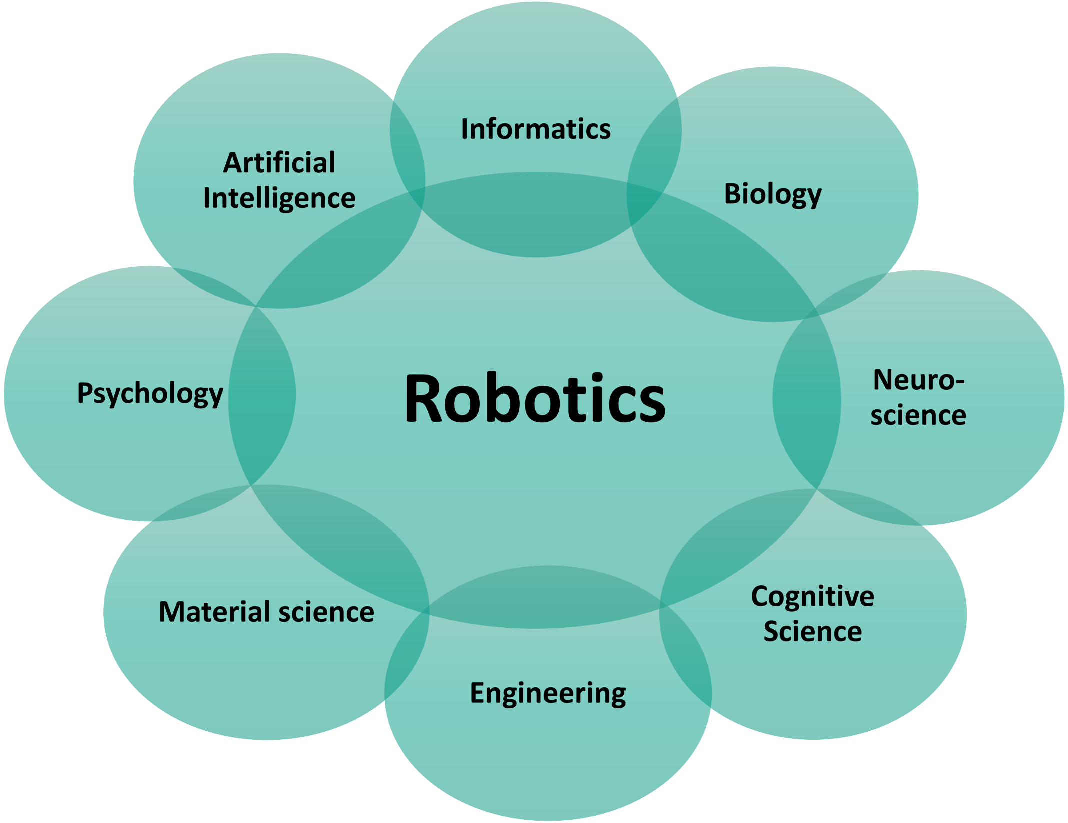
- **3. Generation**
  (autonomous robots, starting nowadays)
  - High computational capacity (multiprocessor systems)
  - Task-oriented programming
  - Depand for (machine) autonomy

- **4. Generation**
  (humanoid AI robots, current research)
  - High flexibility regarding environment and task
  - Ability to learn and adapt
  - Social interaction
  - Self-reflection

Robotics

- Terminology
- History
- **Disciplines involved in Robotics**
- Fields of Application

Disciplines Involved in Modern Robotics



Informatics

Artificial Intelligence

Biology

Psychology

Robotics

Neuro-science

Material science

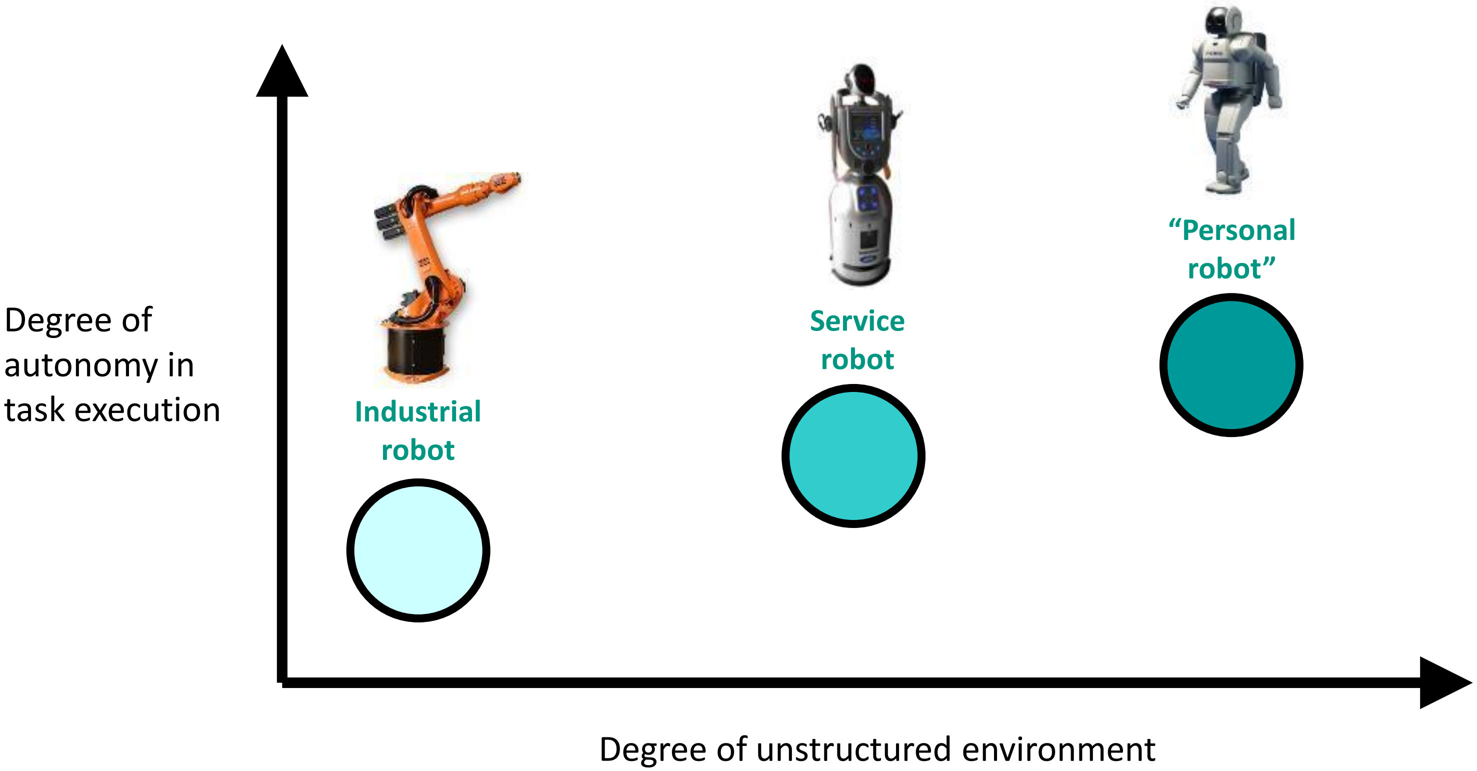
Cognitive Science

Engineering

Robotics

- Terminology
- History
- Disciplines involved in Robotics
- **Fields of Application**

Fields of Application



Degree of autonomy in task execution

Industrial robot

Service robot

"Personal robot"

Degree of unstructured environment

Industrial Robots

ISO 8373 (Manipulating industrial robots, 1994)

- 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

- Categorized according to
  - Number of axes (3, 4, 5, ...)
  - Type of control (PTP, continuous path, adaptive, teleoperation)
  - Kinematic structure (SCARA, parallel, ...)

Industrial Robots

Example: Paint shop and body shop

- Characteristics:
  - Usually stationary
  - Few degrees of freedom
  - Easy programming
  - High degree of specialization
  - More effective than humans (costs and labor)

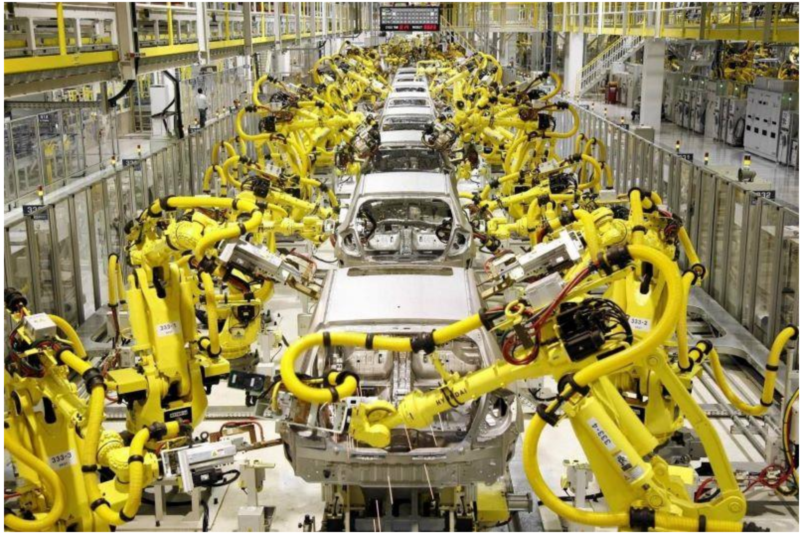
- Application areas:
  - Assembly line work
  - Welding
  - Painting
  - Pick-and-Place
  - Handling of dangerous goods

Industrial Robots

https://www.youtube.com/watch?v=fH4VwTgfyrQ

Industrial Robots

- Robotics is at the core of modern factories



- 3.5 million industrial robotcs in factories around the world (October 2022)
  https://ifr.org/downloads/press2018/2022_WR_extended_version.pdf

Service Robots

- A robot that works half- or fully autonomous, aiming to perform useful tasks to benefit humans and institutions. Industrial production tasks are excempted from that.

- Categories
  - For private households („domestic service robots“)
  - For institutions and craftwork („professional service robots“)
  - Others (e.g., for research, etc.)

Service Robots (From Europe)

ARMAR, KIT

Justin, DLR

Care-O-Bot; IPA

Reem, PAL Robotics

Ice cream robot, FZI

Robotic lawn mower

Professional Service Robotics

By Steve Crowe | August 5, 2022

Amazon buying iRobot for $1.7B

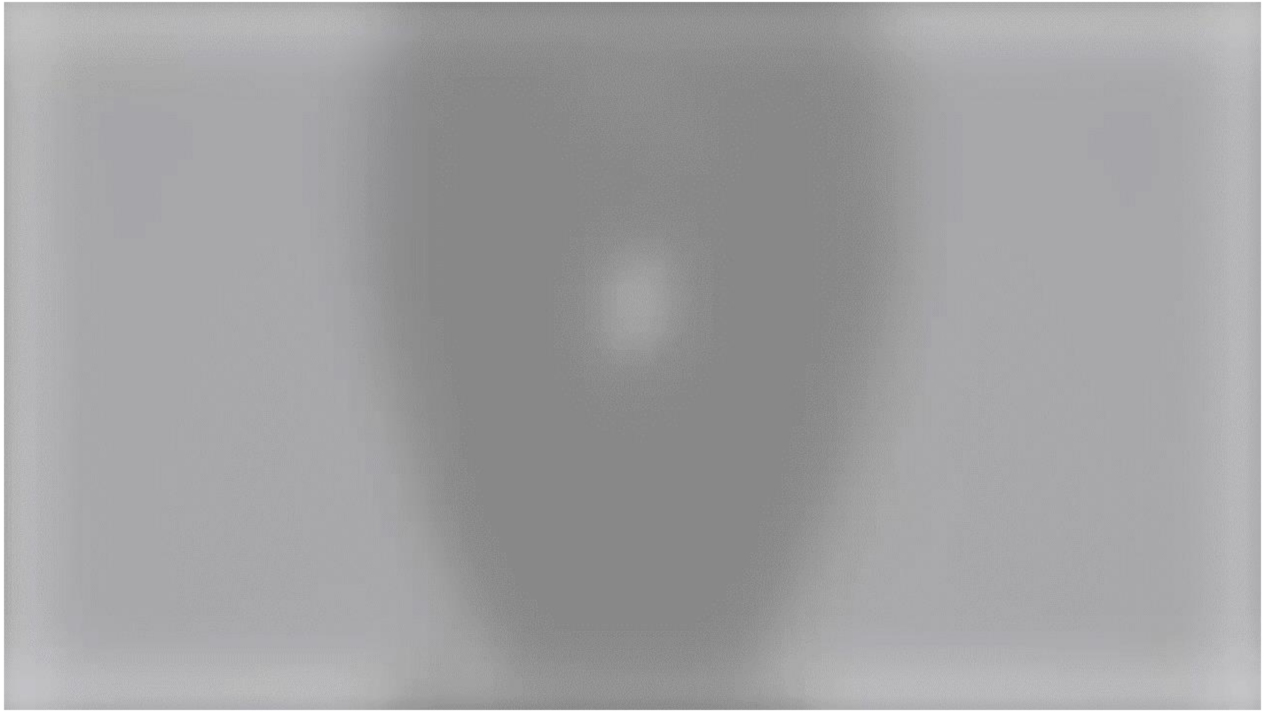
If this deal goes through, iRobot would be Amazon’s fourth most-expensive acquisition ever.

„Personal Robot“

A Robot that resembles human behavior regarding motion, intelligence, and communication. *(T. Fukuda, 2001, How Far Away Is Artificial Man?)*

Honda‘s Asimo

Generative AI and Robotics – OpenAI and Figure



Ready for Robotics ?

Next lecture: **Math!**