Karlsruher Institut für Technologie

Hochperformante Humanoide Technologien

Robotics III: Sensors and Perception in Robotics
Chapter 01: Introduction

Tamim Asfour

http://www.humanoids.kit.edu

Organization

Lecture Team

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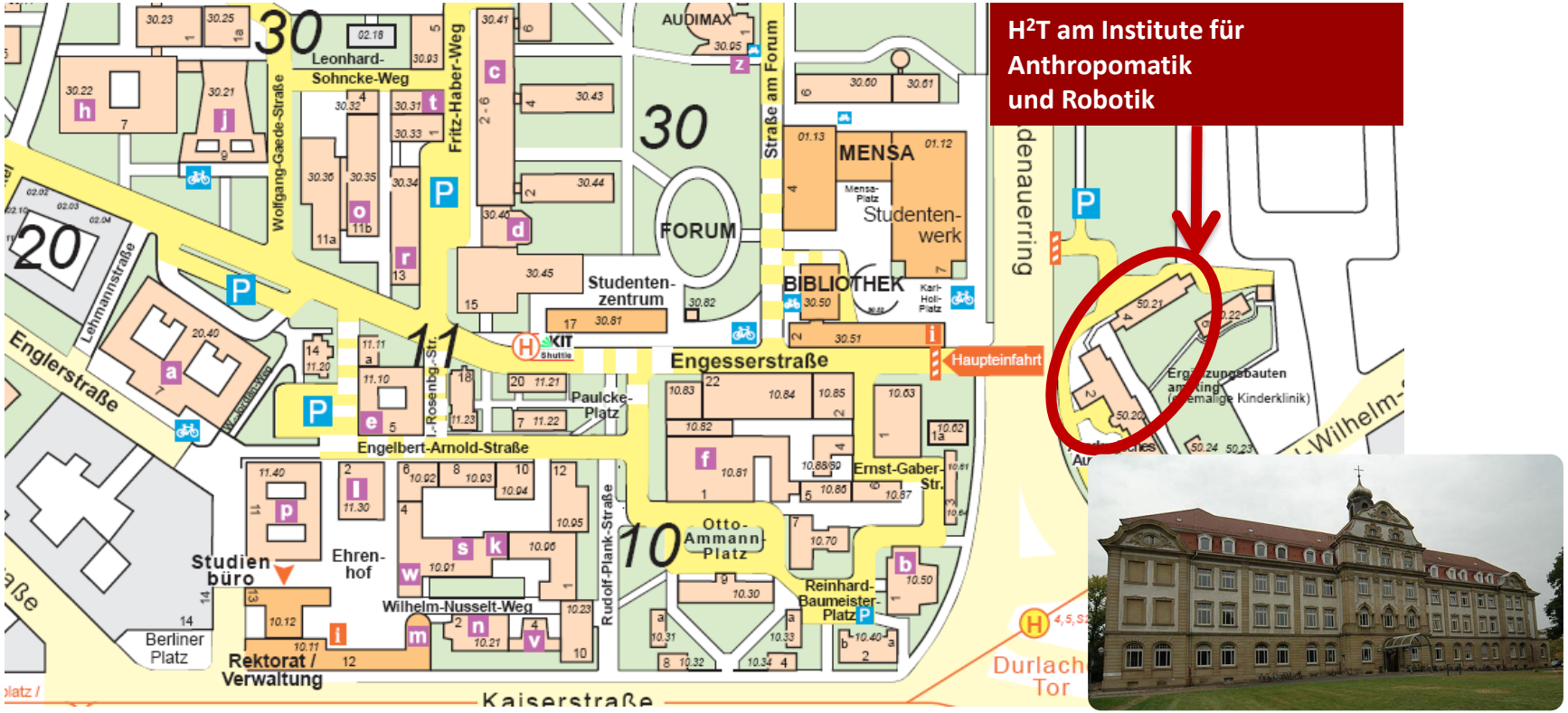
H²T: Geb. 50.20


H²T am Institute für Anthropomatik und Robotik
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FORUM
MENSA
Studenten-werk
BIBLIOTHEK
AUDIMAX
Studenten-zentrum
Leonhard-Sohncke-Weg
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Haupteinfahrt
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Ehren-hof
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Berliner Platz
Durlach Tor
Kaiserstraße
Karl-Holl-Platz
Mensa-Platz
KIT Shuttle

Office hours

- Tamim Asfour
  - Wednesday 14:00 – 16:00
    appointment via email asfour@kit.edu

- Other office hours: See H²T Website
  - www.humanoids.kit.edu
  - www.humanoids.de

Lecture-Related Information (I)

- KIT **ILIAS-Portal:** https://ilias.studium.kit.edu
  - Password for ILIAS: **armar@kit**
  - Lecture slides will be available after each lecture
  - Announcements will be sent via email to participants of this course

- Access ILIAS:
  - Login
  - Search course: „Robotik III – Sensoren und Perzeption in der Robotik“
  - Join the course using the password
  - Now you can access the slides and additional material

Lecture-Related Information (II)

- Previous recordings of the lecture are available:
  - SS 2020
    - YouTube Channel: https://youtube.com/c/HumanoidRobots
    - YouTube Playlist: https://www.youtube.com/watch?v=L8QjmuF7rVk&list=PLLfZgQJNfLgPGONv_BwSZBQGqe9tzwhK5

- Check the following link for a complete list of all KIT public lectures http://www.zml.kit.edu/veroeffentlichte_vorlesungen.php
- and for the KIT-Department of Informatics https://www.informatik.kit.edu/920.php

Dates of the Exams at H²T – SS 2023

Exam	Date	Time	Deadline for registration
Robotics I: Introduction to Robotics	July 12, 2023	17:30 – 18:30	July 5, 2023
Mechano-Informatics and Robotics	July 19, 2023	17:30 – 18:30	July 12, 2023
Human Brain and Central Nervous System	August 9, 2023	13:00 – 14:00	August 2, 2023
Robotics II: Humanoid Robotics	September 1, 2023	15:00 – 16:00	August 25, 2023
Wearable Robotic Technologies	September 7, 2023	15:00 – 16:00	August 31, 2023
Robotics III: Sensors and Perception in Robotics	September 19, 2023	14:30 – 15:30	September 12, 2023

Lecture-Related Information (III)

- Credit points: 3 ECTS

- Exam in SS 2023
  - **Written exam in English (schriftlich)**
  - Date: **September 19th, 2023, 14:30 – 15:30**
    - **Place will be announced in the lecture and in ILIAS**
  - Registration: **Campus-System,** https://campus.studium.kit.edu
  - Last registration date: **September 12th, 2023**

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

Teaching @ H2T

Karlsruher Institut für Technologie

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)

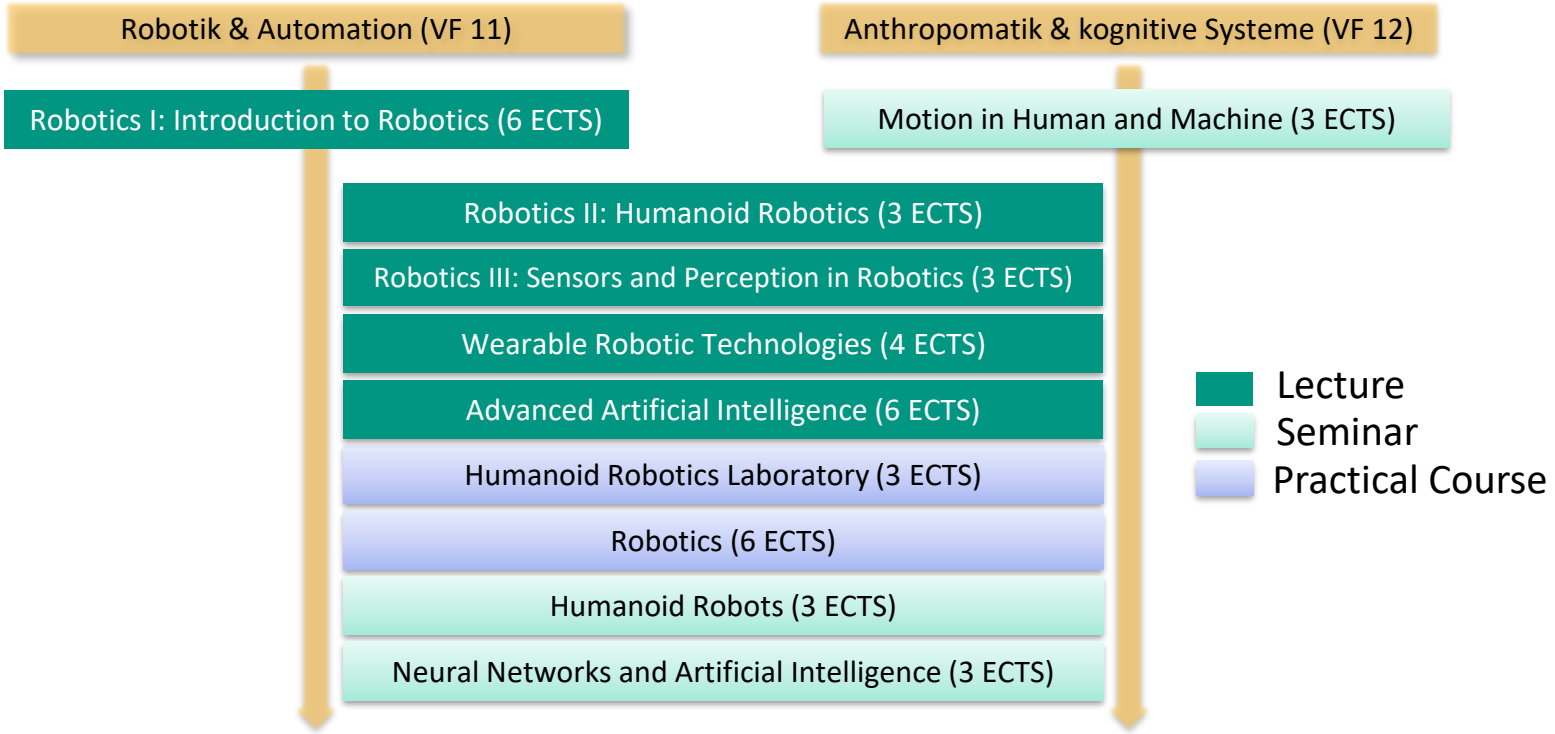
Praxis der Softwareentwicklung (6+2 ECTS)

Praxis der Forschung (24 ECTS)

Pupil (Robotik AG, BOGY, Hector Seminar)

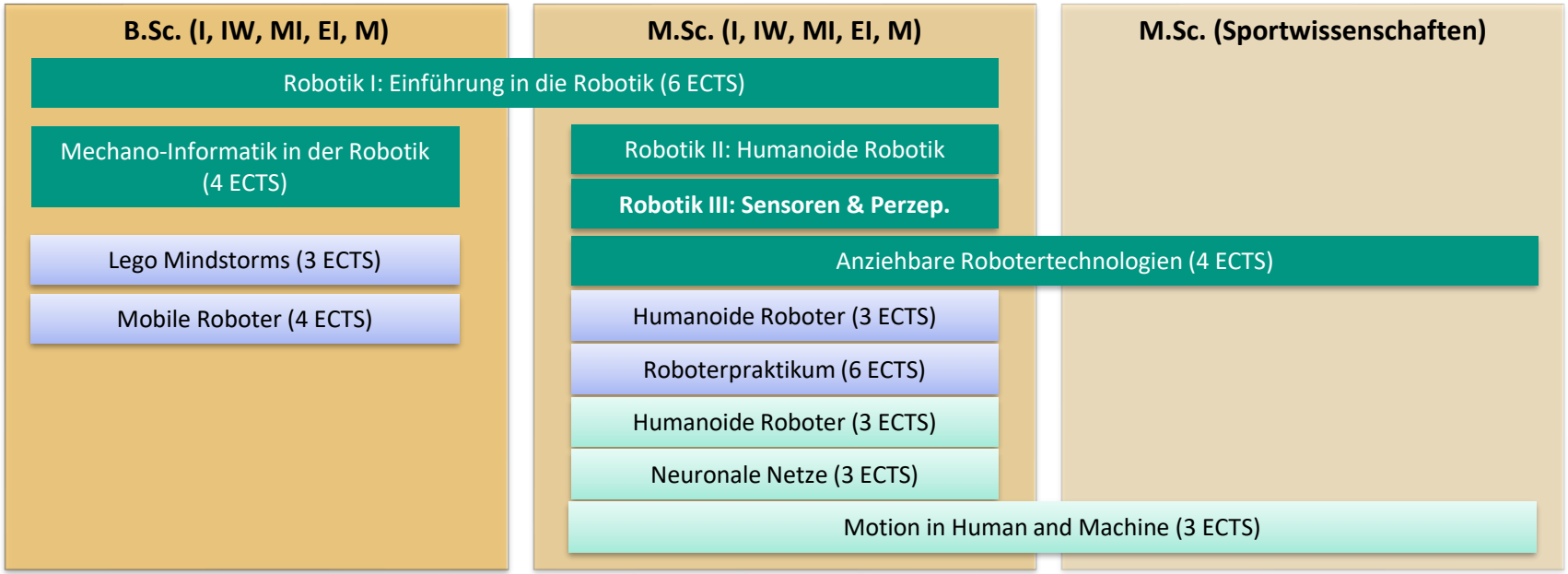
H2T

Teaching @ H2T – Specialization Subjects (Informatics)



Teaching @ H2T

Vorlesung
Seminar
Praktikum



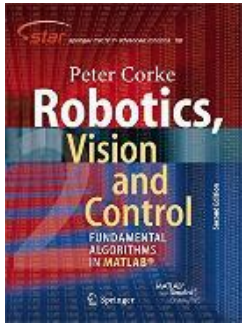
I = Informatik (* = gilt **nur** für Informatik)
IW = Informationswirtschaft
MI = Mechatronik & Informationstechnik
EI = Elektrotechnik & Informationstechnik
M = Maschinenbau

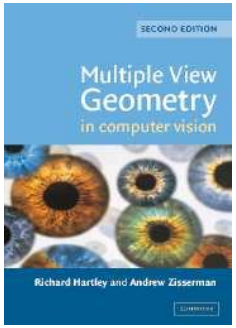
This lecture: Robotics III

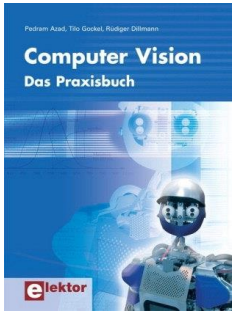
- Interactive lecture
- Selected topics related to **sensors and perception in robotics** will be discussed to extend the theoretical and practical knowledge in the area.
- Current state of the art of research
- **Material: Slides and selected publications**

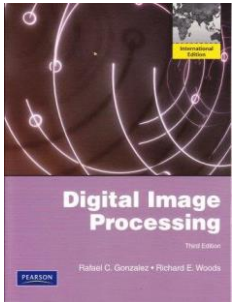
Literatur – Computer Vision

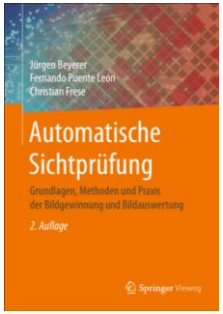
- **Robotics, Vision and Control: Fundamental Algorithms in Matlab**, Peter Corke
- **Multiple View Geometry in Computer Vision**, R. Hartley und A. Zisserman
- **Digital Image Processing**, Rafael C. Gonzalez and Richard E. Woods
- **Automatische Sichtprüfung**, J. Beyerer, F. Puente León und C. Frese
- **Computer Vision – Das Praxisbuch**, Pedram Azad, Tilo Gockel und Rüdiger Dillmann











Literatur

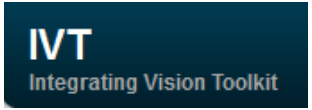
- References to other topic will be provided in the chapters

Outline of Table of Content

- **Introduction**
- **Internal sensors**
  - position, velocity, IMUs, force, torque sensors, …
- **External sensors**
  - proximity, distance, visual and position sensors
- **Tactile sensing and exploration**
  - Skin, tactile sensors and tactile exploration
- **Feature Extraction**
  - Correlation methods
  - Corner & feature detection
  - Pose estimation
- **Scene understanding**
  - Scene representation
  - Extraction of scene semantics
  - Object relations
- **Active Vision**
  - Visual perception in humans
  - Gaze selection and stabilization
  - Active visual search
- **SLAM**
  - Localization
  - EKF SLAM, Graph SLAM, FastSLAM

Computer Vision Software

- OpenCV
  - http://opencv.org
  - Face detection, Optical Flow, GPU Computing, …
- Point Cloud library (PCL)
  - http://pointclouds.org
  - Pointcloud processing, RANSAC primitive fitting, ICP, …
- Integrating Vision Toolkit (IVT)
  - http://ivt.sourceforge.net
  - Firewire, image formats, visualization, image processing



Outline

- Humanoids@KIT

- Introduction Robotics III

Humanoids at KIT – Introduction to H²T

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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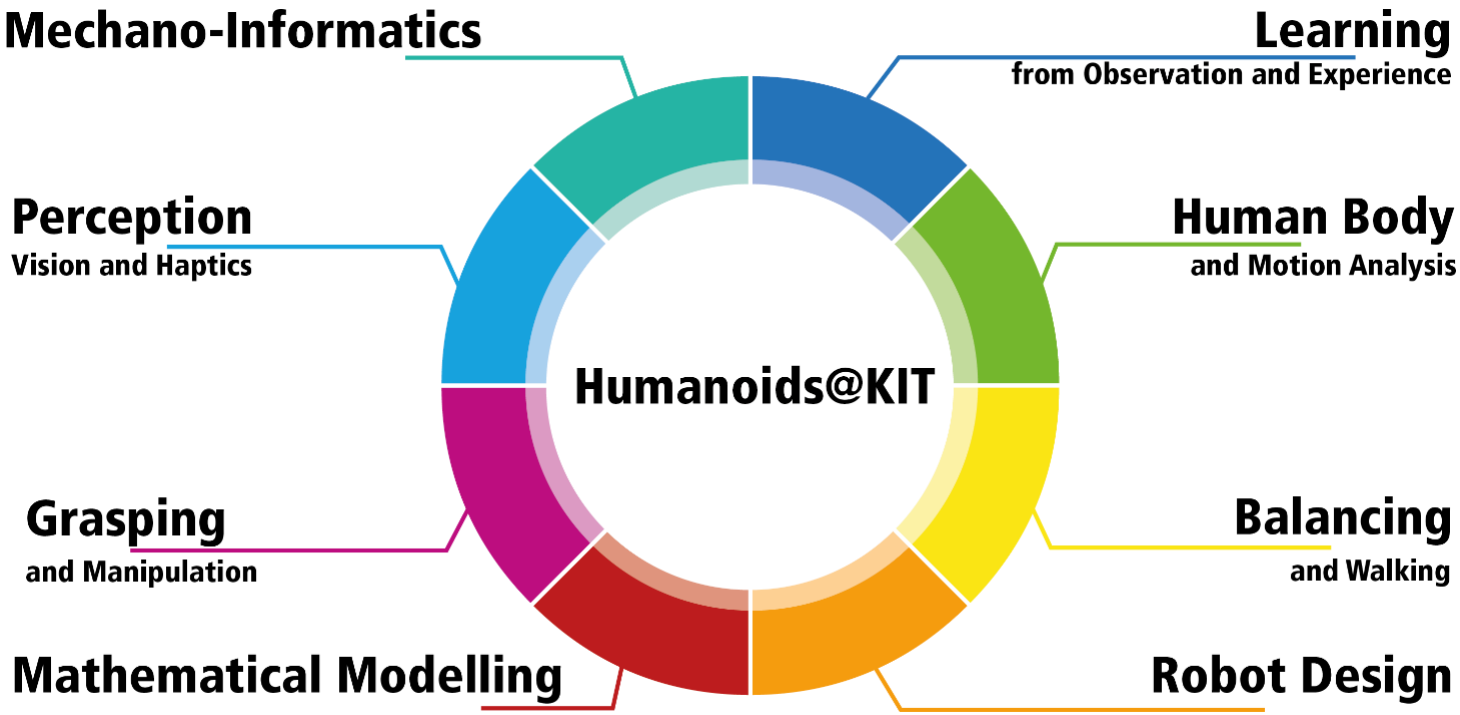
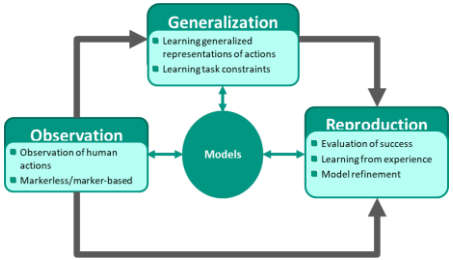
Research Topics at H²T

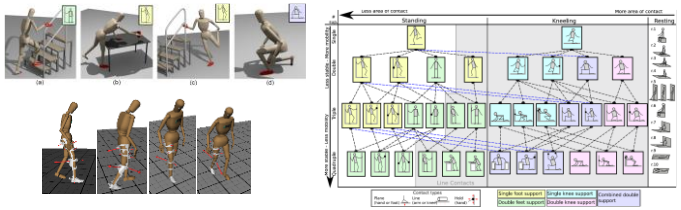


Humanoid Robotics @ KIT

Humanoid Assistance Robotics

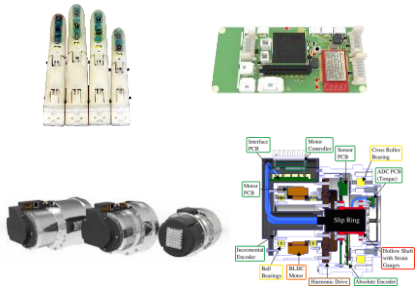


Learning from Human



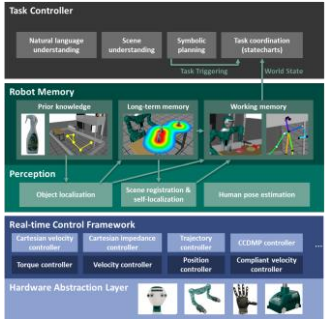
Human Motion Intelligence

Collaborative Robotics



Robotronics

Wearable Robotics



Mechano-Informatics

Our Goal: Humanoids in the Real World

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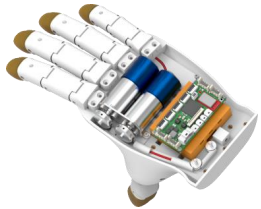
The ARMAR robot family





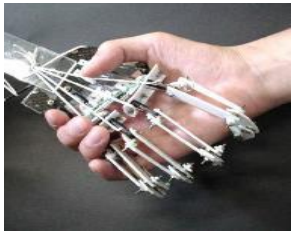


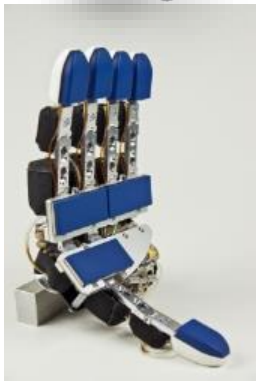


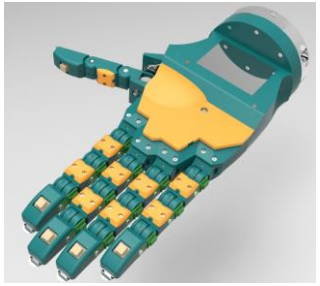

The ARMAR Family: Hands



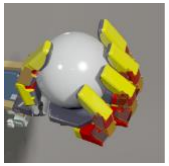
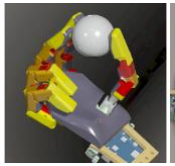
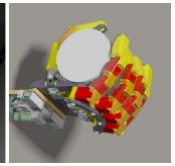



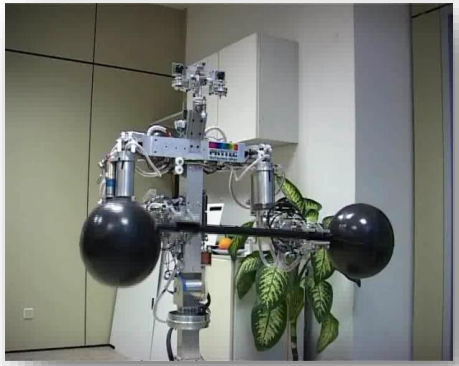





ARMAR-I (1999) and ARMAR-II (2003)



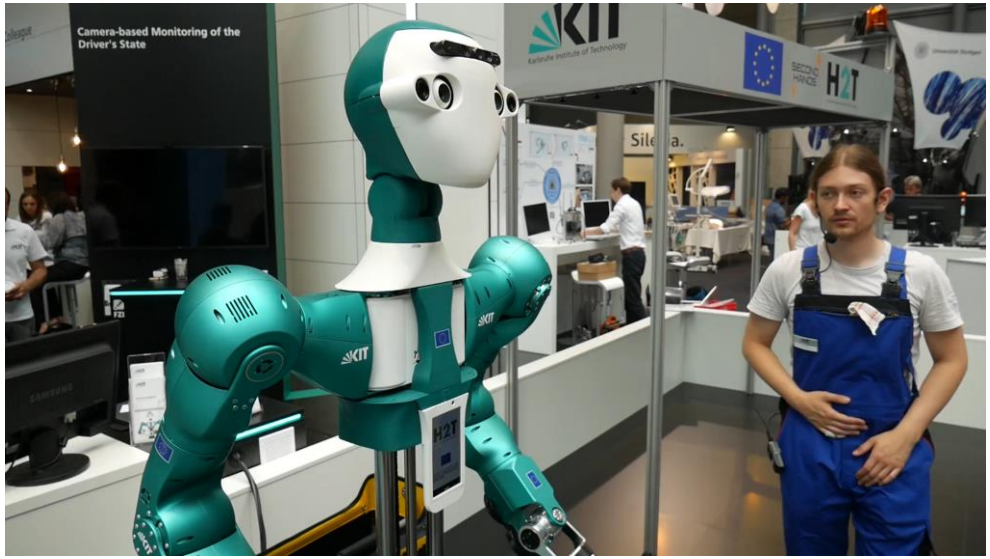
First demonstrator of the SFB 588

Demo at CEBIT 2006

ARMAR-III (2008)

45 minutes household task, performed more than 4000 times since February 3, 2008

ARMAR-6 (2017)



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

Humanoids in the Real World

- **Engineering** Humanoids
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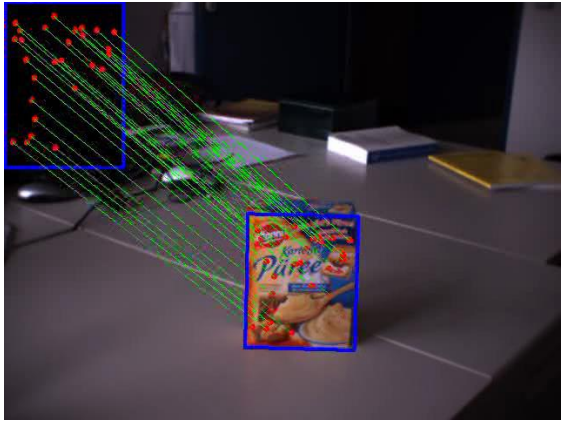
Object Recognition and Localization for Grasping

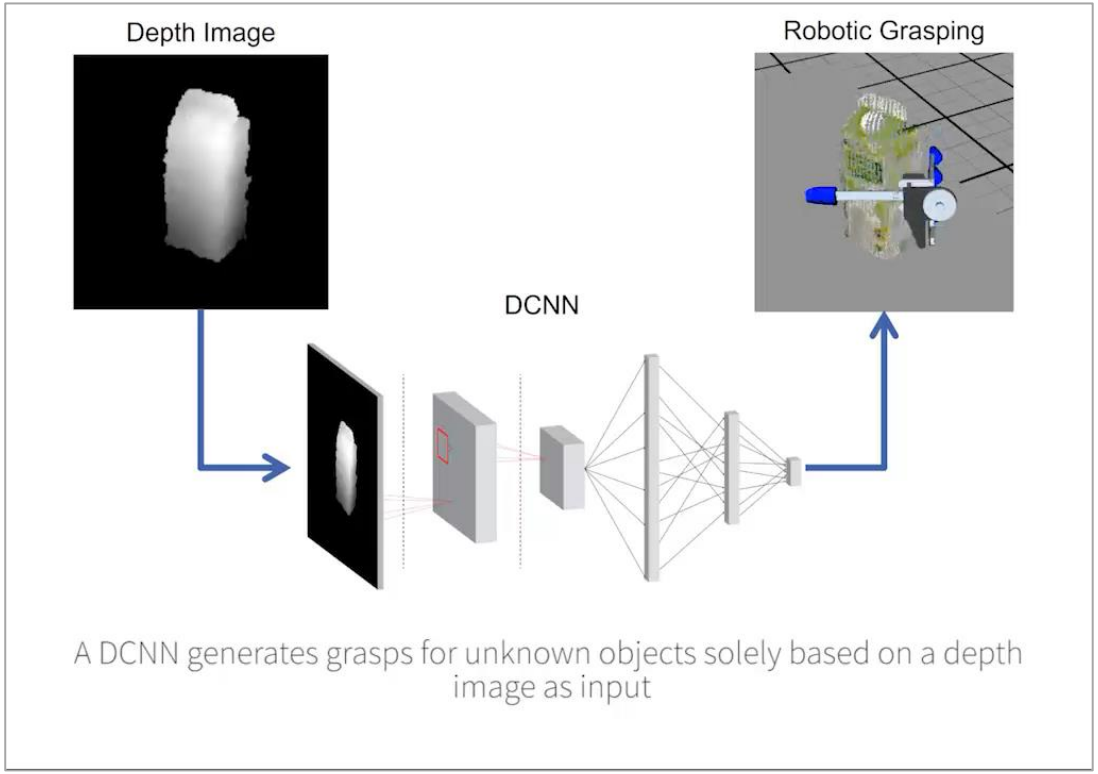
- Feature Detectors
- Descriptors
- Example: SIFT, SURF, MSER
- Matching, Verification, Localization



ARMAR-III (2008)

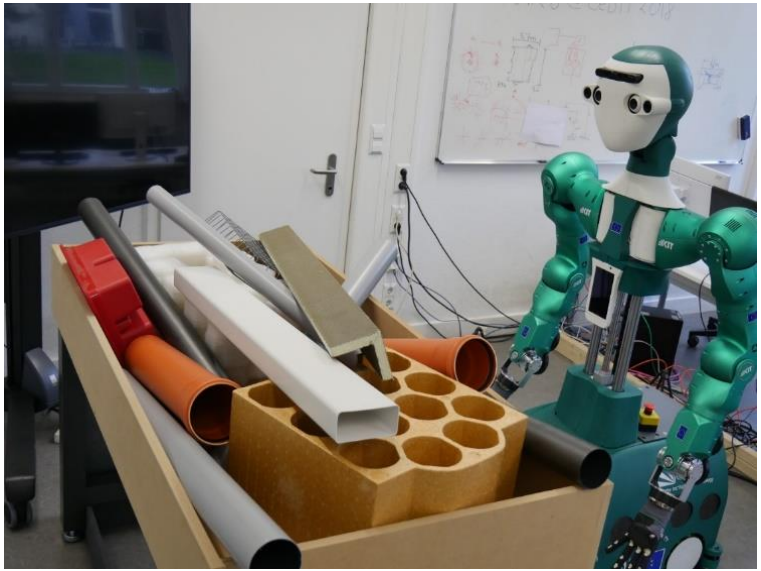
45 minutes household task, performed more than 4000 times since February 3, 2008

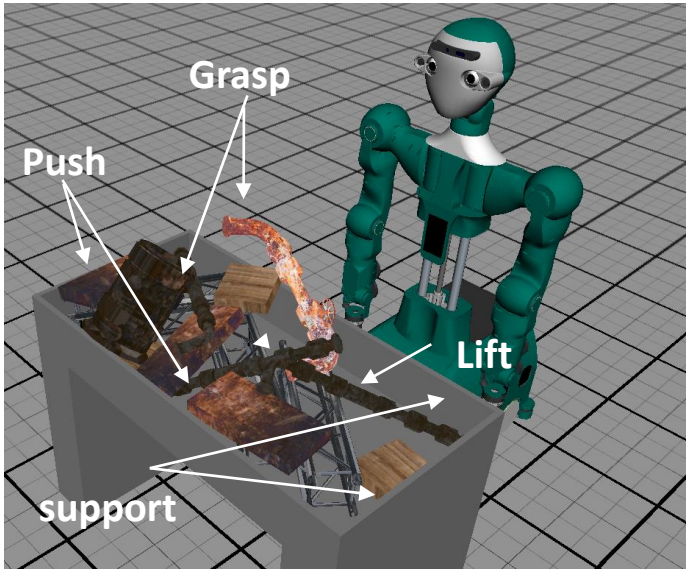
Grasping of Unkown Objects with CNN



Understanding Perception-Action Relations

- **Affordance-based manipulation:** Robots have to understand action/interaction possibilities (affordances) in unknown environments





Understanding Perception-Action Relations

- **Affordance-based manipulation:** Robots have to understand action/interaction possibilities (affordances) in unknown environments

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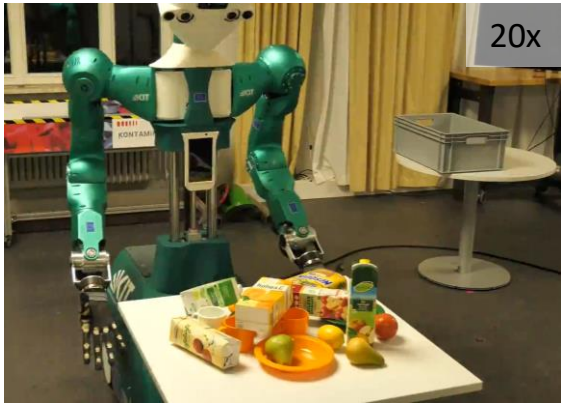
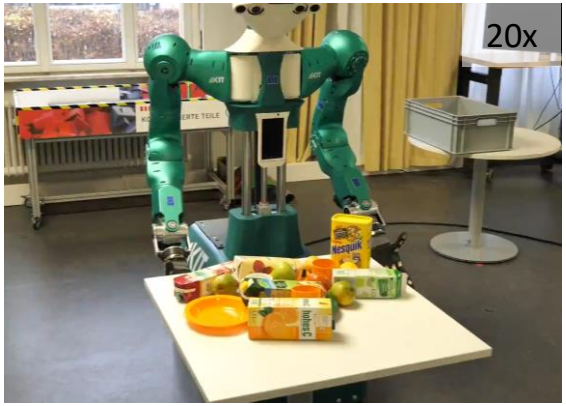
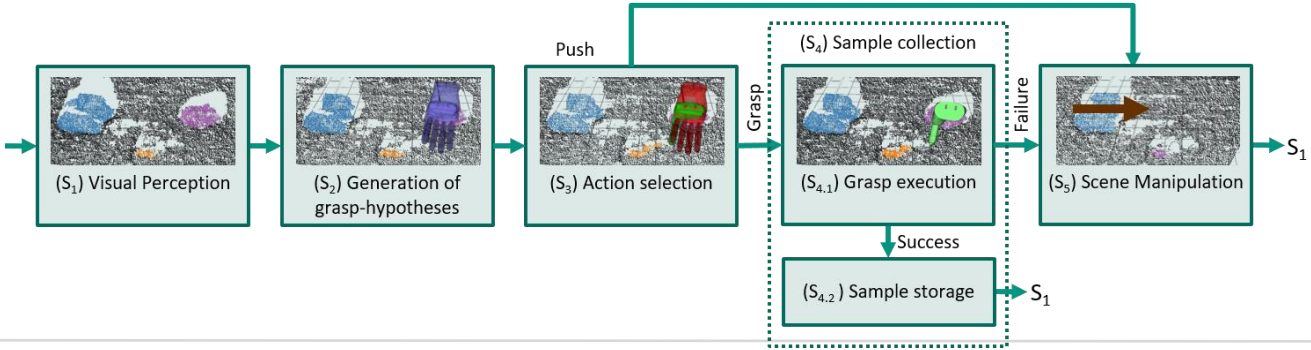




Vision-based Grasping for Stone Sample Collection

- **Goal:** Fast algorithms for systems with limited computing resources (e.g. space rover)
- Approach:
  - Generate grasp hypotheses based on shape approximation (from point clouds)
  - Pushing actions to enable grasping

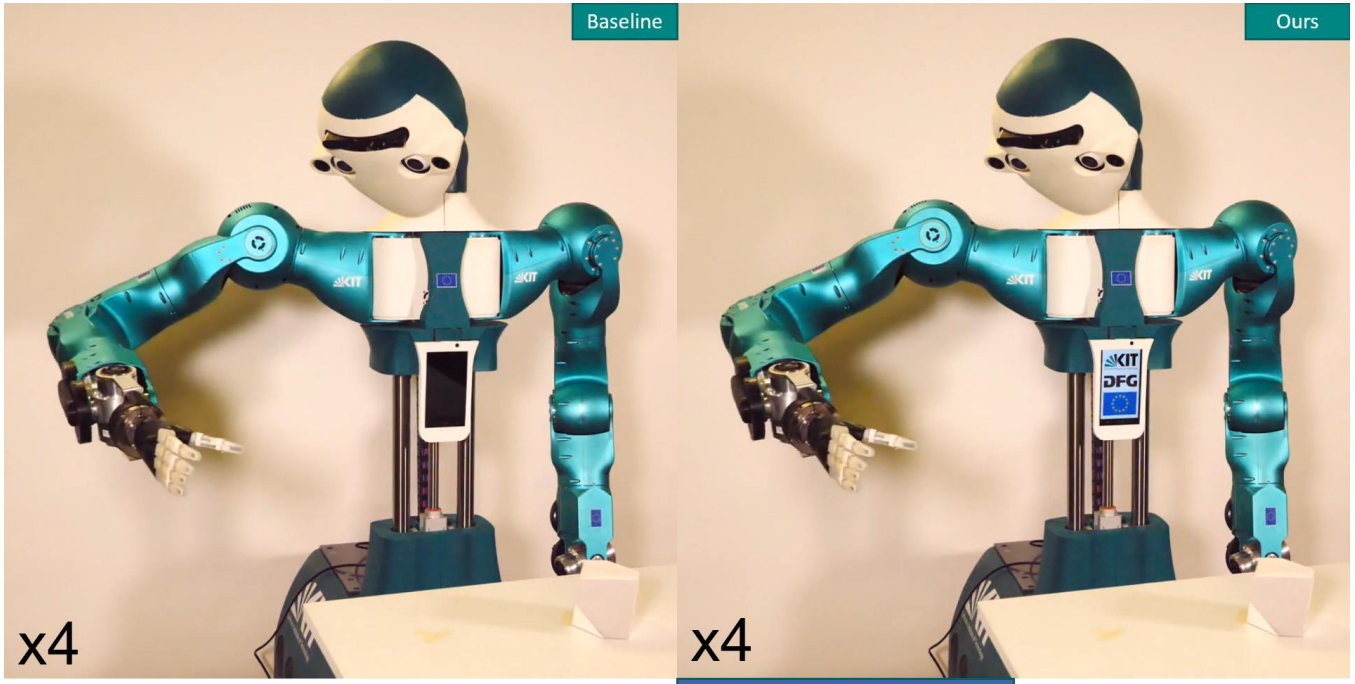


Vision-based Grasping for Stone Sample Collection

Grasping based on generated grasp hypotheses

Pushing to separate stones

Grasping with Soft Hands and Tactile Feedback



Grasp Phase of the proposed Controller: Reach & Close

Humanoids in the Real World

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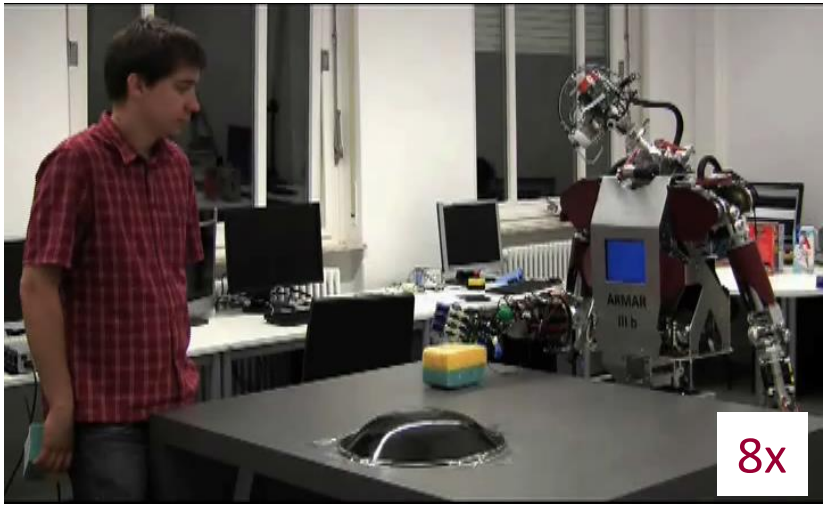
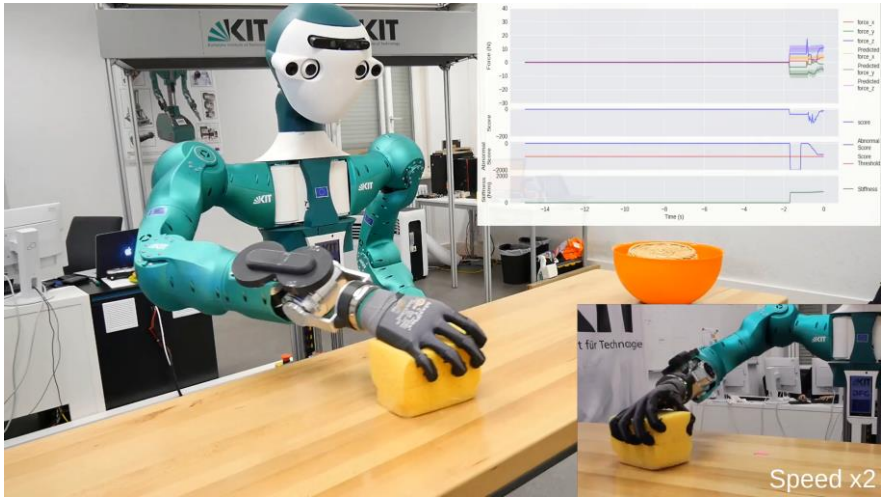
Imitation Learning

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





Visual Imitation Learning

- Learning key-point based task models from human demonstration videos

Robot Internet of Skills

- KIT whole-body human motion database: **A Robot Motion Alphabet**

42 hours of manually labeled human motion data (including object information); 9375 motions; 229 (108/40) subjects and 158 objects.

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

Outline

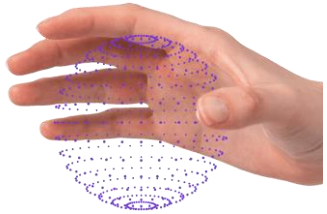
- Humanoids@KIT

- Introduction Robotics III

Robotics III: Sensors and Perception in Robotics

Sensor Types – In Humans

Sense	Sensor
Vision	Eyes
Audition	Ears
Gustation	Tongue
Olfaction	Nose
Tactition	Skin



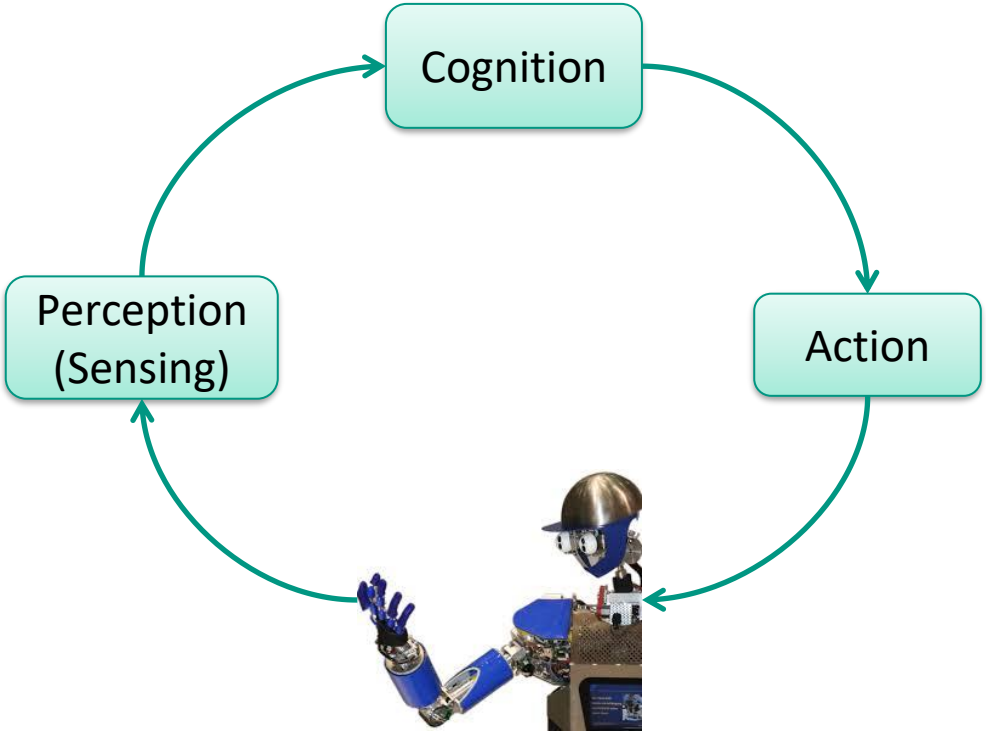
Perception vs. Sensation

- **Perception** (from the Latin *perceptio*) is the organization, identification, and interpretation of sensory information in order to represent and understand the presented information, or the environment.

- **Sensation** is the body's detection of external or internal stimulation (e.g., eyes detecting light waves, ears detecting sound waves). Perception utilizes the brain to make sense of the stimulation (e.g., seeing a chair, hearing a guitar).

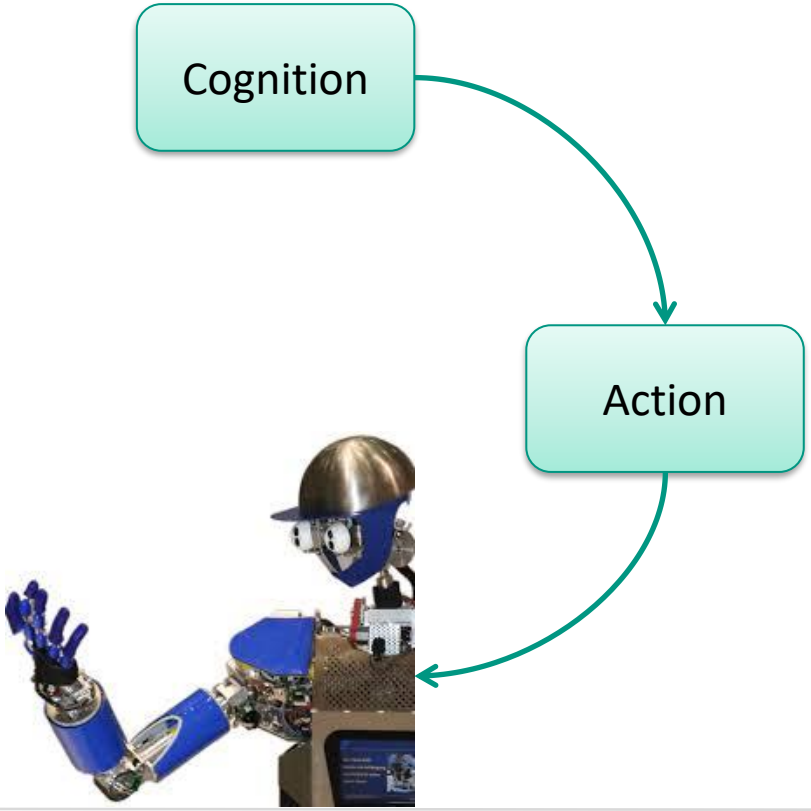
Wikipedia contributors. (2019). Sense. In *Wikipedia, The Free Encyclopedia*. from https://en.wikipedia.org/w/index.php?title=Sense&oldid=952103763

Perception-Cognition-Action Cycle



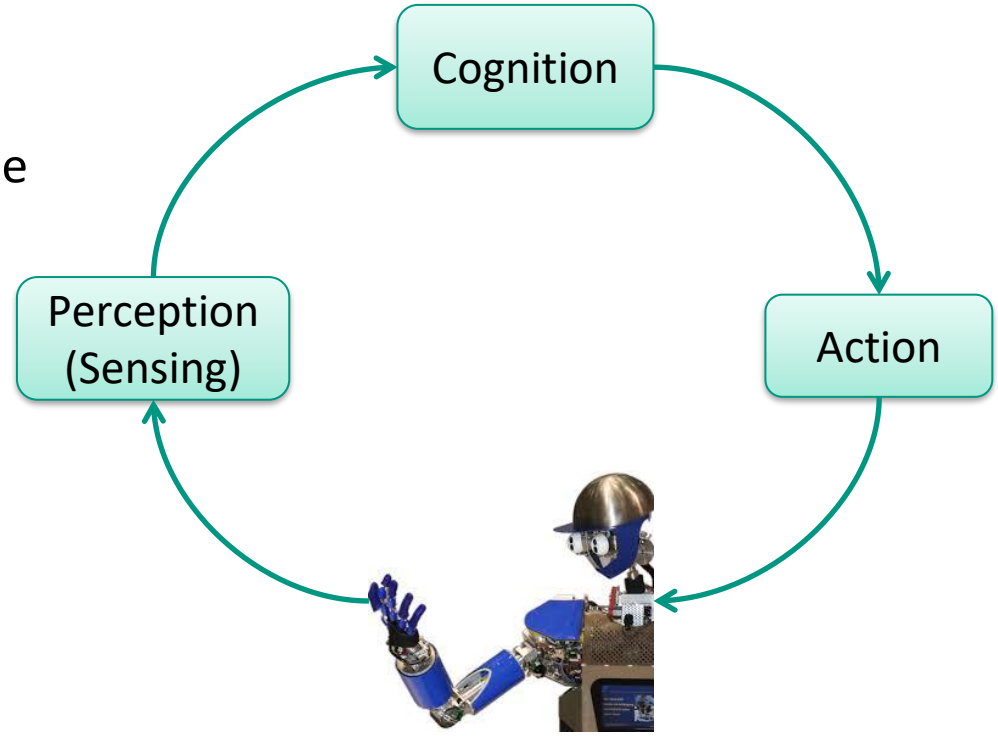
Open Loop Systems

- No sensing input
- Open loop control suffers from
  - Uncertainty, changes in the world
  - Error detection and correlation



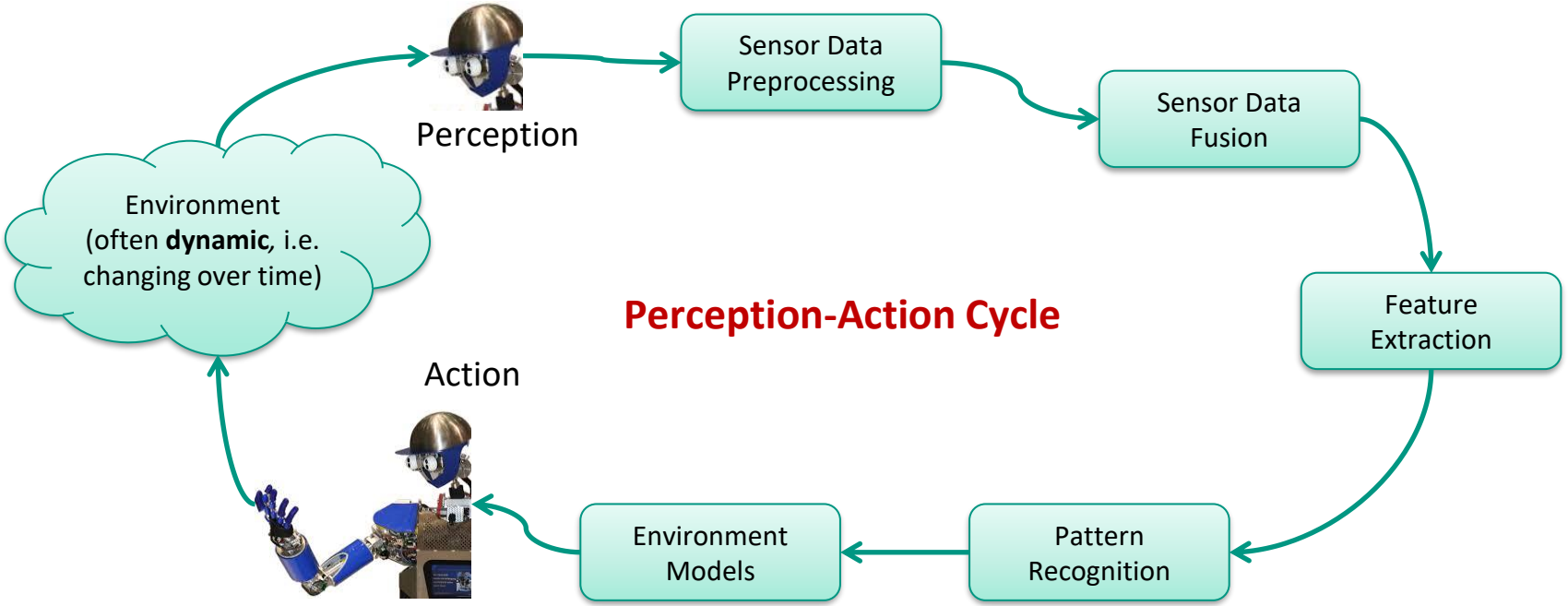
Closed Loop Systems

- Feedback control
- Perception-Cognition-Action Cycle
- Sensors are required to acquire information about the environment and oneself

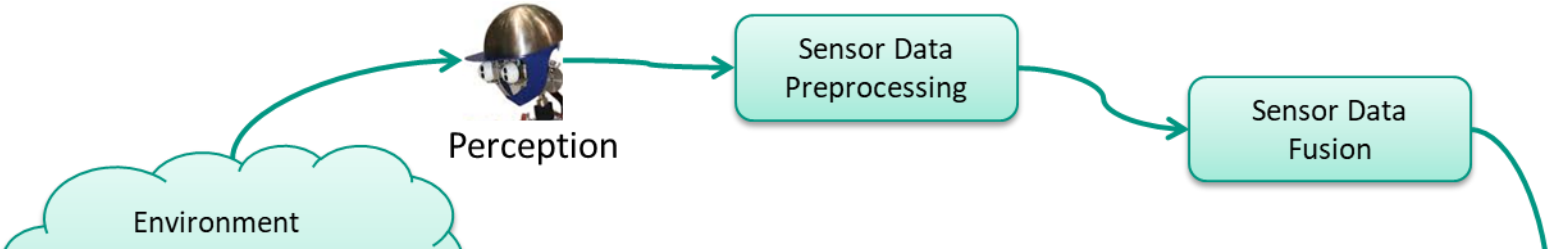


The Perception-Action Cycle

- The Perception-Action Cycle is crucial to the implementation of interactive, adaptive and situation-based behavior.

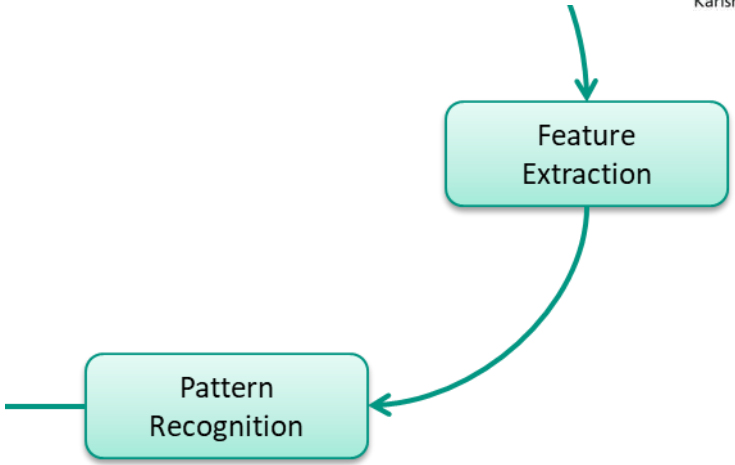


The Perception-Action Cycle (II)



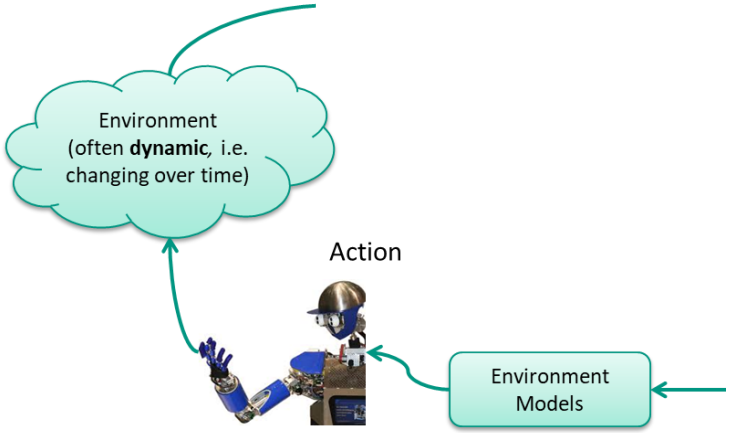
- **Sensation**: Data acquisition, i.e. sampling of analog/digital signals output from various sensor devices
- **Data Preprocessing**: Filtering, normalization, and/or scaling, etc., of acquired sensory data
- **Data Fusion**: Combination/fusion of multi-model sensory data leading to robust measurements, reduced uncertainty and information gain

The Perception-Action Cycle (III)



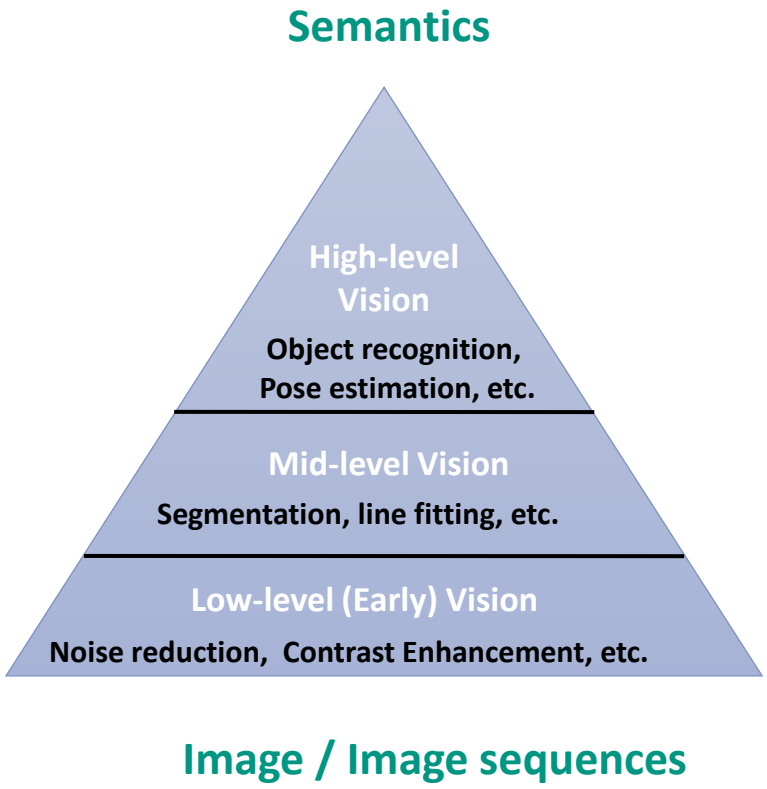
- **Feature Extraction**: Extraction of features representing a mathematical model of the sensed environment
- **Pattern Recognition**: Extracted features are searched for patterns in order to classify the data

The Perception-Action Cycle (IV)

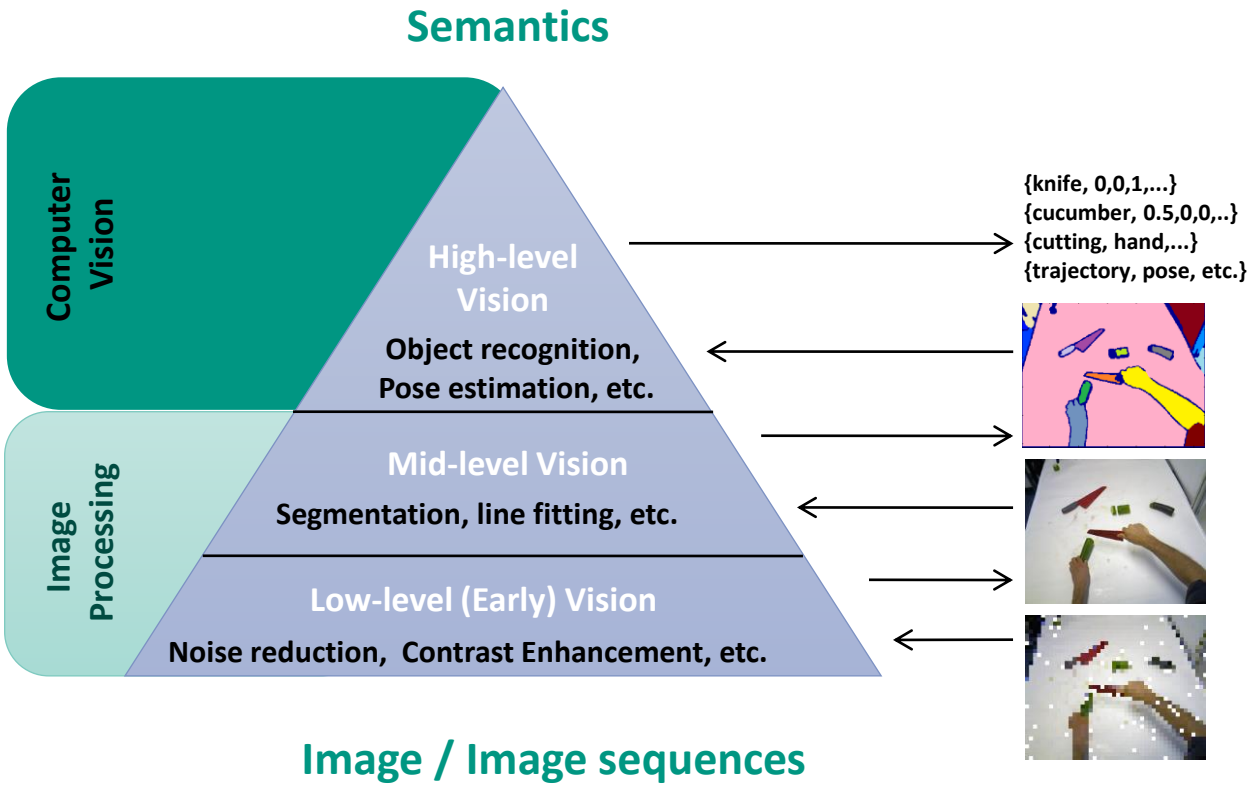


- **Environmental Modeling**: classified patterns are used to build models of the environment
- **Action**: Execution of the goal-oriented tasks, i.e., manipulating the environment using robotic arms, grippers, wheels, etc.

Was ist Computer Vision?



Was ist Computer Vision?



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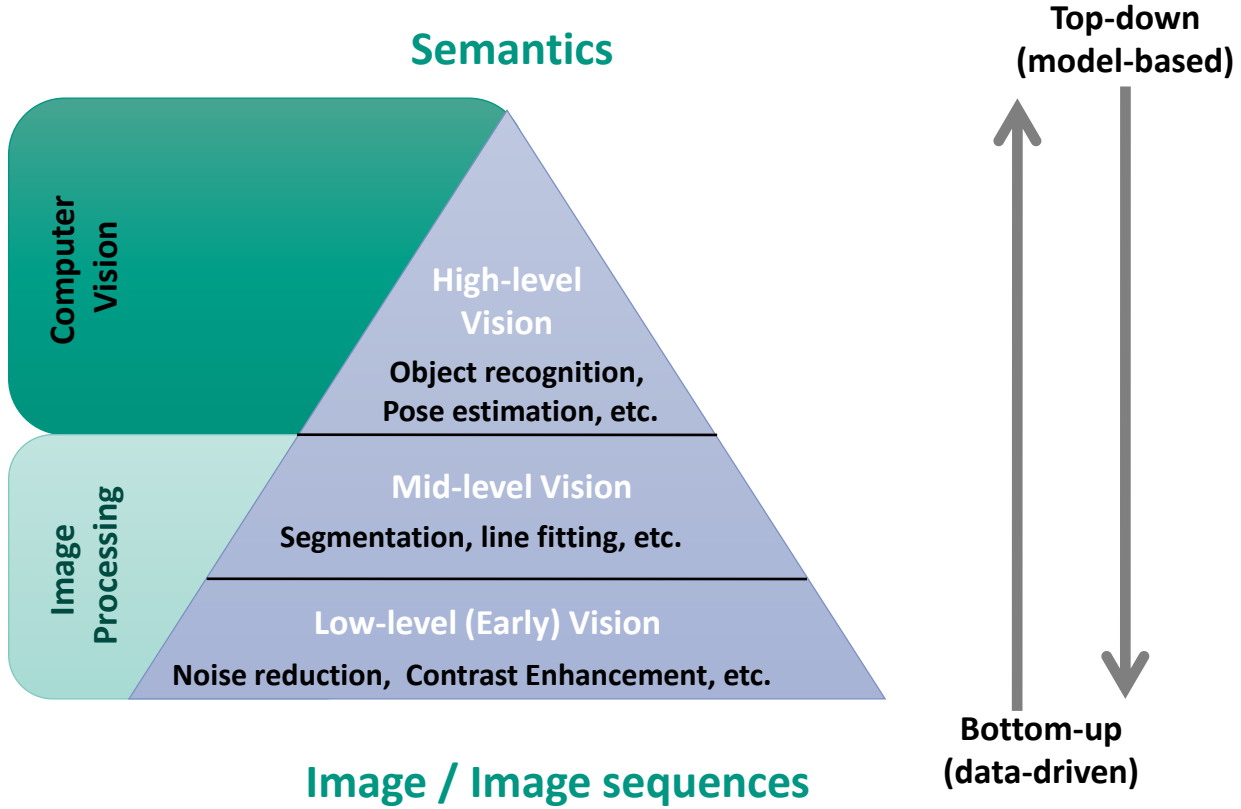
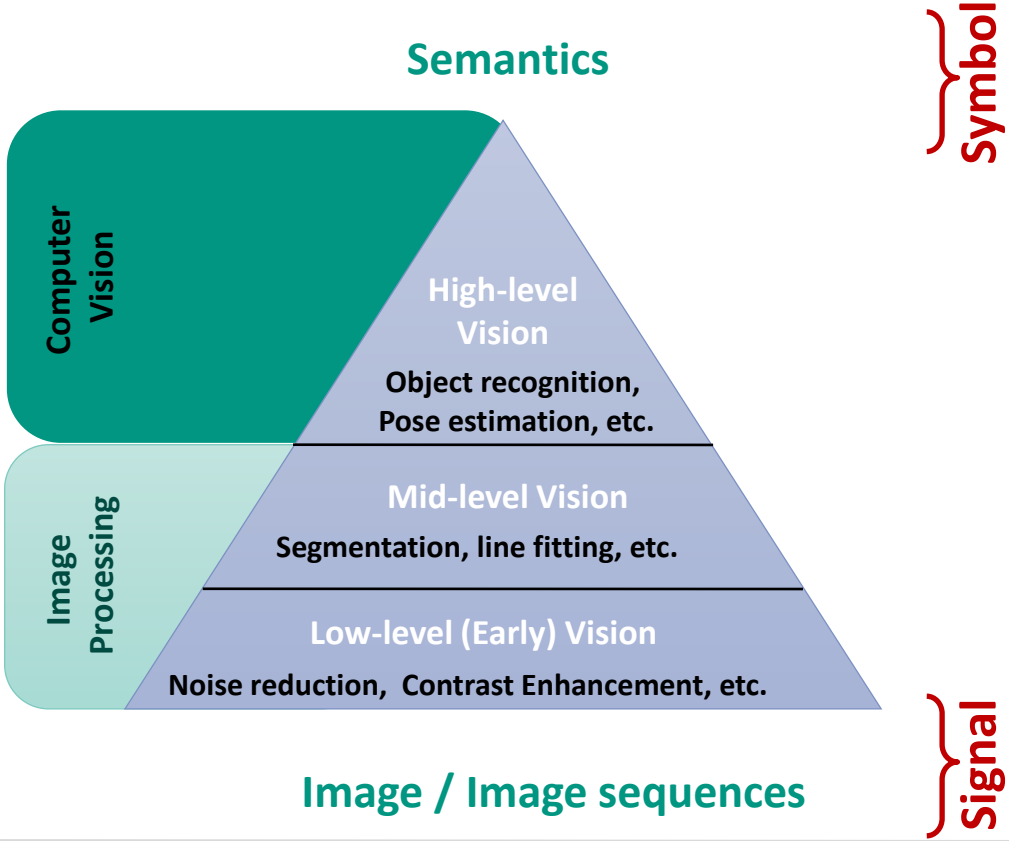
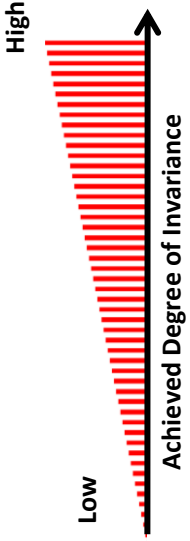
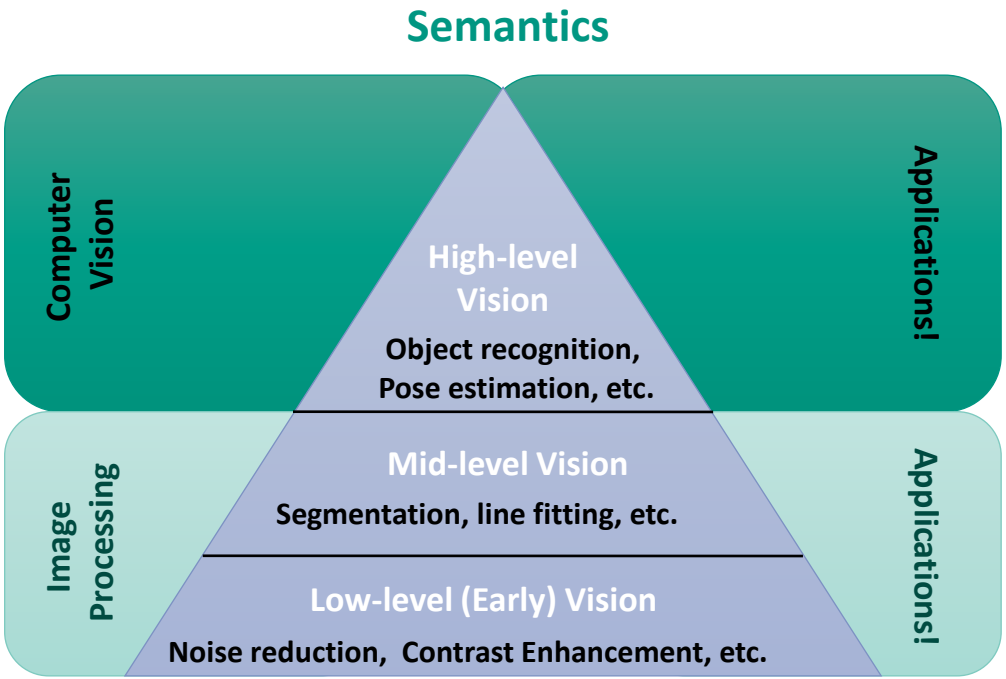


Was ist Computer Vision?

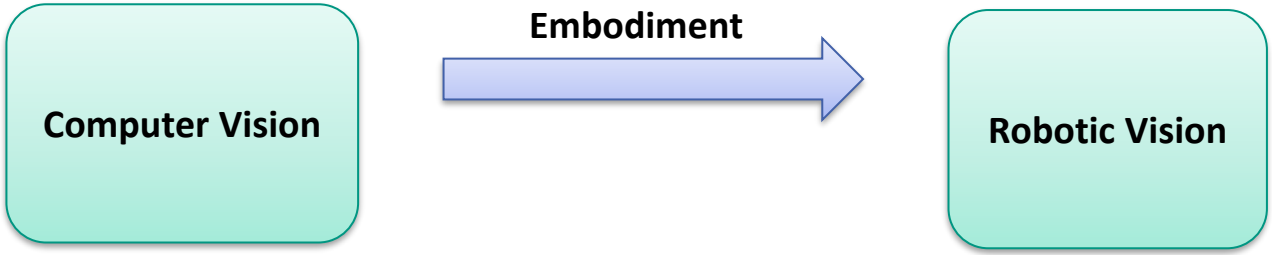




Was ist Computer Vision?



Robotic Vision vs. Computer Vision



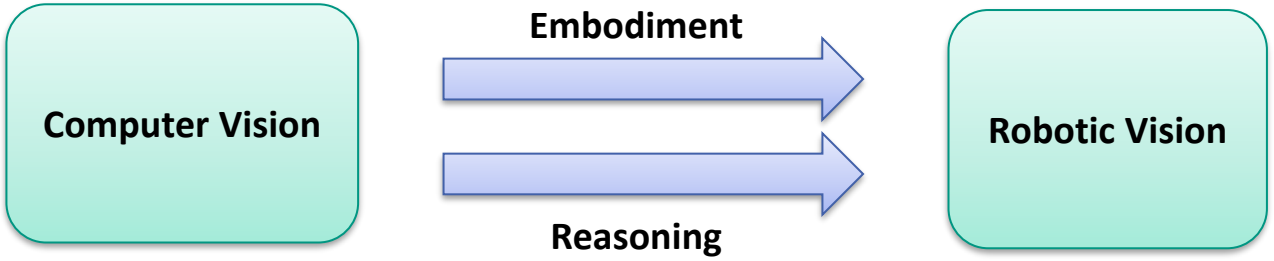
Robotic Vision is about …

… **Embodiment**

- Active Vision → change viewpoint of the camera
- Manipulation → change the scene for better understanding
- Temporal → strong correlation between consecutive images
- Spatial → coherency between objects in the scene

Sünderhauf, N., Brock, O., Scheirer, W., Hadsell, R., Fox, D., Leitner, J., Upcroft, B., Abbeel, P., Burgard, W., Milford, M., Corke, P., The Limits and Potentials of Deep Learning for Robotics, *Computing Research Repository (CoRR), 2018*

Robotic Vision vs. Computer Vision (II)

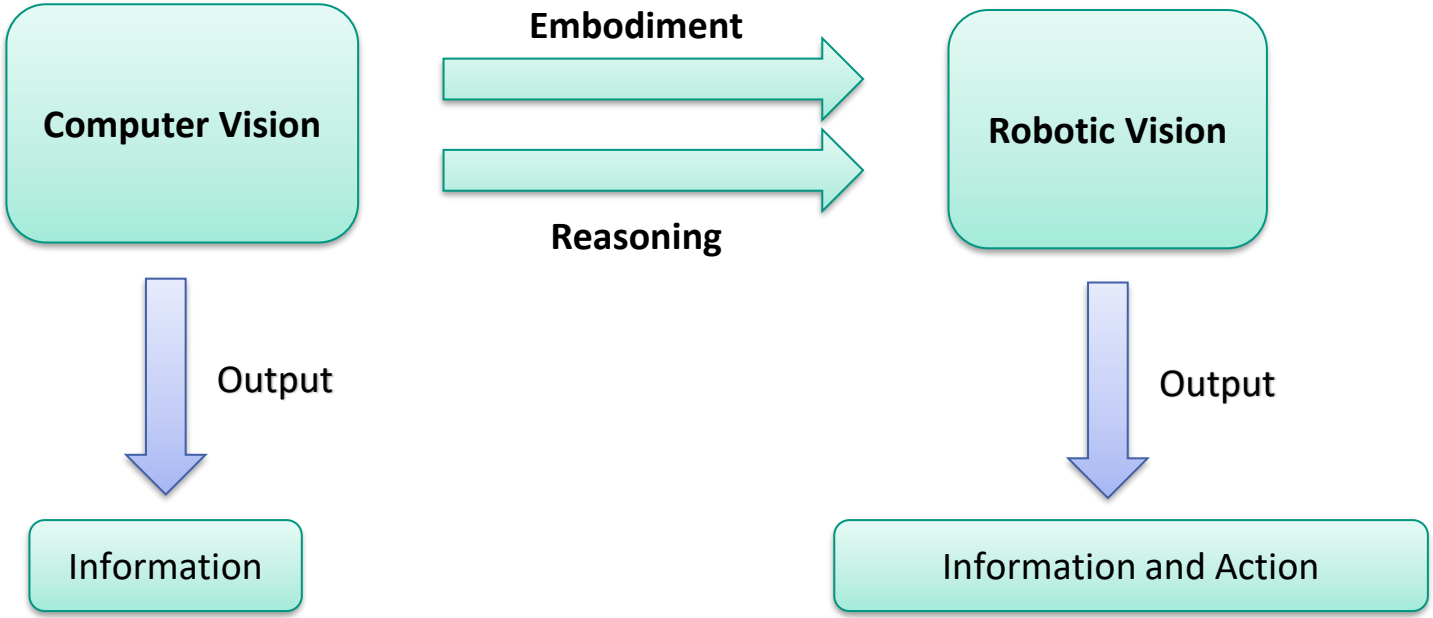


Robotic Vision is about …

… Embodiment & **Reasoning**

- Semantics → use prior contextual knowledge about the scene and objects
- Geometry → use prior geometrical knowledge about the scene and objects

Robotic Vision vs. Computer Vision (III)



Thanks for your attention

- See you next week