



64-424 Intelligent Robotics

[https://tams.informatik.uni-hamburg.de/
lectures/2018ws/vorlesung/ir](https://tams.informatik.uni-hamburg.de/lectures/2018ws/vorlesung/ir)

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University of Hamburg
Faculty of Mathematics, Informatics and Natural Sciences
Department of Informatics
Technical Aspects of Multimodal Systems

Winterterm 2019/2020



Outline

1. Organization

2. Motivation



64-424 Lecture

Lecture	Monday 14:15 - 15:45 (s.t.)
Room	G-021/G-022
Web	https://tams.informatik.uni-hamburg.de/lectures/2018ws/vorlesung/ir
Organizers	Marc Bestmann
Room	F-308 / F-315
Phone	+49 40 42883-2431 / -2432
E-mail	bestmann@informatik.uni-hamburg.de
Lecturers	Marc Bestmann Michael Görner



64-425 Seminar

Seminar	Monday 16:15 - 17:45 (s.t.)
Room	G-021/G-022, G-203
Web	https://tams.informatik.uni-hamburg.de/lectures/2018ws/seminar/ir/
Organizers	Yannick Jonetzko, Marc Bestmann
Room	F-324 / F-313
Phone	+49 40 42883-2504 / -2398
E-mail	jonetzko, bestmann@informatik.uni-hamburg.de

Today, the seminar takes place in G-021/22 only.



Expected background knowledge

- ▶ Basic knowledge of physics
 - ▶ concepts of gravity, acceleration, force. . .
- ▶ Linear algebra
 - ▶ vector and matrix operations, systems of linear equation, basic differential calculus. . .
- ▶ Probability calculus
 - ▶ conditional probability, conditional independence, . . .
- ▶ General understanding of electrical engineering concepts
- ▶ **No background in robotics is required**



Purpose of this course

A cross section of fields required for intelligent robotics:

- ▶ Fundamental sensor/actuator technology
 - ▶ rotation, motion, force/torque, tactile, distance, vision ...
- ▶ Established data processing algorithms
 - ▶ sequence filters, camera calibration, ...
- ▶ Model estimation methods
 - ▶ Probabilistic State Estimation, ICP registration, ...
- ▶ Task-Level Robot Control
 - ▶ Reasoning Methods, Fuzzy Logic ...
- ▶ Machine Learning in Robotics

This course should provide you with a broad basis
for understanding current intelligent autonomous robots



- ▶ 1 - Organization/Motivation
- ▶ Sensors
 - ▶ 2 - Sensor Fundamentals
 - ▶ 3 - Vision
 - ▶ 4 - Rotation / Motion
 - ▶ 5 - Force / Torque
 - ▶ 6 - Tactile Sensing / Distance Sensing
- ▶ Filtering
 - ▶ 7 - Scan Processing / State Estimation
 - ▶ 8 - Bayes Filter / Kalman Filter
 - ▶ 9 - Particle Filter / (Fuzzy Logic)
- ▶ Decision Making
 - ▶ 10 - Symbolic Reasoning
 - ▶ 11 - Control Architectures
- ▶ Machine Learning in Robotics
 - ▶ 12 - Supervised / Unsupervised Learning
 - ▶ 13 - Reinforcement Learning / Reality Gap
- ▶ 14 - Ethics
- ▶ 15 - Summary (during seminar slot)



Exams

- ▶ Oral exam
- ▶ 2 possible times: during first and last 3 weeks of semester break
- ▶ Only content of lecture (not seminar)
- ▶ Exam structure is (theoretically) building a robot for a task
 - ▶ What sensors do I need ?
 - ▶ How do I filter my data ?
 - ▶ What is my state estimation ?
 - ▶ How do I take decisions ?
 - ▶ Maybe additional questions



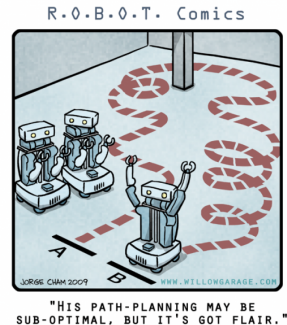
Outline

1. Organization

2. Motivation

Robotics is fun!

- ▶ Robots can act in mundane environments
- ▶ Autonomous robotics is an interdisciplinary field
 - ▶ Mechatronics
 - ▶ Architecture- and system design
 - ▶ Control theory
 - ▶ Data science / Machine Learning
 - ▶ Reasoning Methods
 - ▶ Psychology
 - ▶ Cognitive Science
 - ▶ ...
- ▶ Lots of problems wait for your solution!





Heider and Simmel

Video Heider and Simmel

<https://www.youtube.com/watch?v=VTNmLt7QX8E>



What is "Intelligent"?



1. <http://usportt.com/wp-content/uploads/2017/09/Chess.jpg>

2. https://c2.staticflickr.com/8/7290/12314247113_0b71480233_b.jpg

3. <https://i.pining.com/736x/31/3d/b4/313db492ab9da909013eb99e3f8f2232-candy-colors-dog-activities.jpg>

4. <https://www.bbc.com/news/av/science-environment-37364938/clever-crow-naturally-uses-tools>



What is an "Intelligent Robot"?

- ▶ There is no general definition
- ▶ Intelligence is often associated with
 - ▶ Interpretation of percepts
 - ▶ Mental world models
 - ▶ Goal-directed actions
 - ▶ The Total Turing test
- ▶ These are hard to define or model when programming robots
- ▶ We *can* talk about
 - ▶ Scene / Object recognition
 - ▶ Tracking
 - ▶ Pick&Place
 - ▶ Path planning
 - ▶ Localization
 - ▶ ...

The old problem with AI

"Robots can do it [already], so it's not Intelligence"



Definitions Intelligence

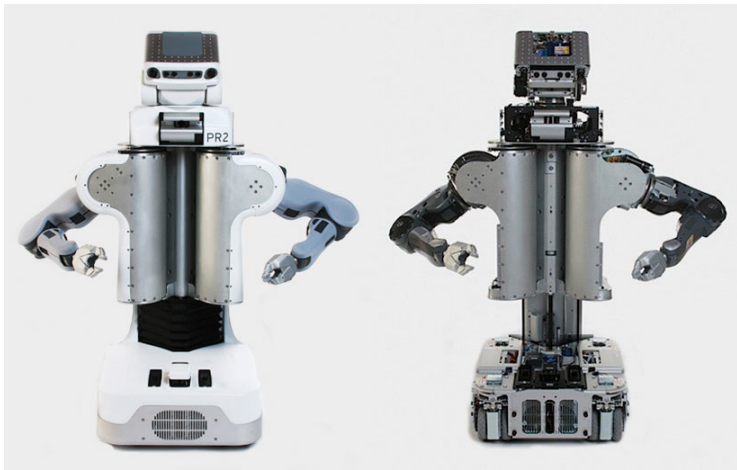
- ▶ "Intelligence is the computational part of the ability to achieve goals in the world" John McCarthy
- ▶ "Judgment, otherwise called good sense, practical sense, initiative, the faculty of adapting one's self to circumstances ... auto-critique." Alfred Binet
- ▶ "A very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings—"catching on," "making sense" of things, or "figuring out" what to do." Mainstream Science on Intelligence



What is an Intelligent Robot Made of?

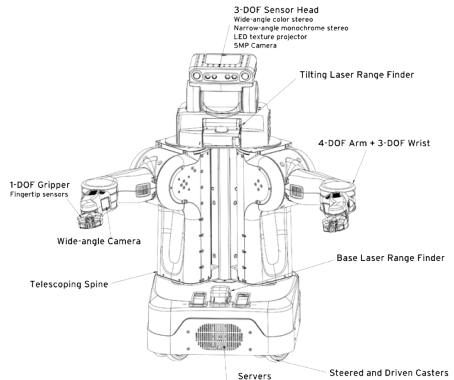
- ▶ Sensors
 - ▶ Camera
 - ▶ Microphone
 - ▶ Button/Bumper
 - ▶ ...
- ▶ Processing Unit
 - ▶ Classic desktop system
 - ▶ Microcontroller
 - ▶ FPGA
 - ▶ ...
- ▶ Actuators
 - ▶ Wheels
 - ▶ Gripper
 - ▶ ...

Example: Personal Robot 2 (PR2)



Personal Robot 2 (PR2): Platform

- ▶ Mobile base
 - ▶ 4-wheel omnidirectional drive
 - ▶ 1kHz motor control loop
 - ▶ Fixed laser range finder
- ▶ Two compliant arms
 - ▶ Passive counterbalance
 - ▶ 4 degree of freedom arms
 - ▶ 3 degree of freedom wrists
 - ▶ Payload: $\approx 1.8\text{kg}$





Personal Robot 2 (PR2): Sensor head

- ▶ 2 degrees of freedom (pan/tilt)
- ▶ 5MP RGB camera
- ▶ Kinect RGB-D camera (not shown)
- ▶ Environment (wide) stereo cameras
- ▶ Manipulation (narrow) stereo cameras
- ▶ LED texture projector
- ▶ Inertial measurement unit
- ▶ Tilting laser range finder





Personal Robot 2 (PR2): Grippers

- ▶ 1 degree of freedom
- ▶ 90mm range of motion
- ▶ 3-axis accelerometers
- ▶ Fingertip pressure sensor arrays
- ▶ Grip force: 80N (\approx 8kg)
- ▶ Gripper cameras in forearm





Personal Robot 2 (PR2): Processing and control

- ▶ Dual Quad-Core i7 Xeon CPUs
- ▶ 24 GB main memory
- ▶ 1.5 TB storage
- ▶ Multi-gigabit interconnections
- ▶ Synchronized network cameras
- ▶ EtherCAT communication bus



Trixi video



It's your turn!

- ▶ The field and community of robotics is growing fast
- ▶ Lots of innovative research work
- ▶ Many amazing interdisciplinary applications
- ▶ Lots of grant money and high demand for specialists
- ▶ Many problems are yet to be solved
- ▶ Existing literature provides a good foundation to build upon





The Lecture in an Application

- ▶ We want to build a vacuum robot
- ▶ What does the robot need to do?
- ▶ What hardware do we need?
- ▶ How do we do "intelligent" decisions?
- ▶ What are the limitations for this robot?



Videos



Lab Visit

Let's visit the labs and have a look at some robots.