Introduction to Mobile Robotics

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Today

- Course organization
- Robotics in the past and today

Organization

- Format: on-site live lecture. No online connection, no recordings.
- Tue 14:15 – 16:00 Lecture 101 00 026
- Thu 14:15 – 16:00 Lecture + exercises 101 01 009/13
- Exercises: please solve beforehand to benefit from the discussion
- Webpage: http://ais.informatik.uni-freiburg.de/teaching/ss23/robotics/
  - Contains general information, slides, exercise sheets, solutions
  - For recordings of earlier lecture check SS21
- Getting in touch: talk to us. Or mobilerobotics@cs.uni-freiburg.de
- Exam: written. More information at the end of the semester

Goal of this Course

- Provide an overview of problems and approaches in mobile robotics
- Probabilistic reasoning: Dealing with noisy data
- Hands-on experience

Content of this Course

1. Linear Algebra
2. Wheeled Locomotion
3. Sensors
4. Probabilities and Bayes
5. Probabilistic Motion Models
6. Probabilistic Sensor Models
7. Mapping with Known Poses
8. The Kalman Filter
9. The Extended Kalman Filter
10. Discrete Filters
11. The Particle Filter, MCL
12. SLAM: Simultaneous Localization and Mapping
13. SLAM: Landmark-based FastSLAM
14. SLAM: Grid-based FastSLAM
15. SLAM: Graph-based SLAM
16. Techniques for 3D Mapping
17. Iterative Closest Points Algorithm
18. Path Planning and Collision Avoidance
19. Multi-Robot Exploration
20. Information-Driven Exploration
21. Summary

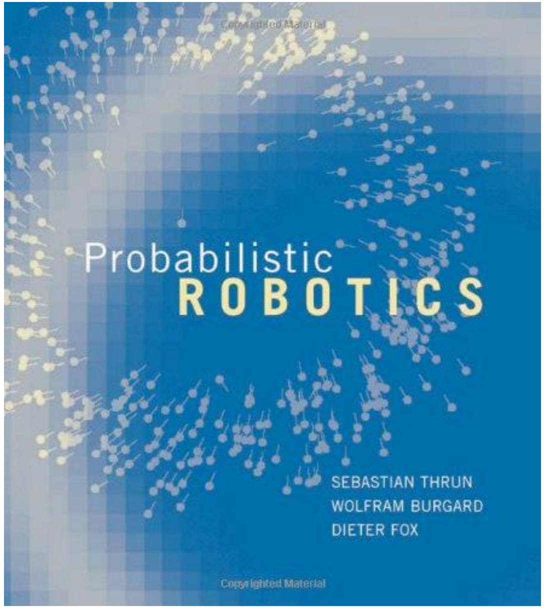
Relevant other Courses

- Foundations of Artificial Intelligence
- Deep Learning
- Computer Vision
- Machine Learning

…and many others from the area of cognitive technical systems

Reference Book

Thrun, Burgard, and Fox:
"Probabilistic Robotics"



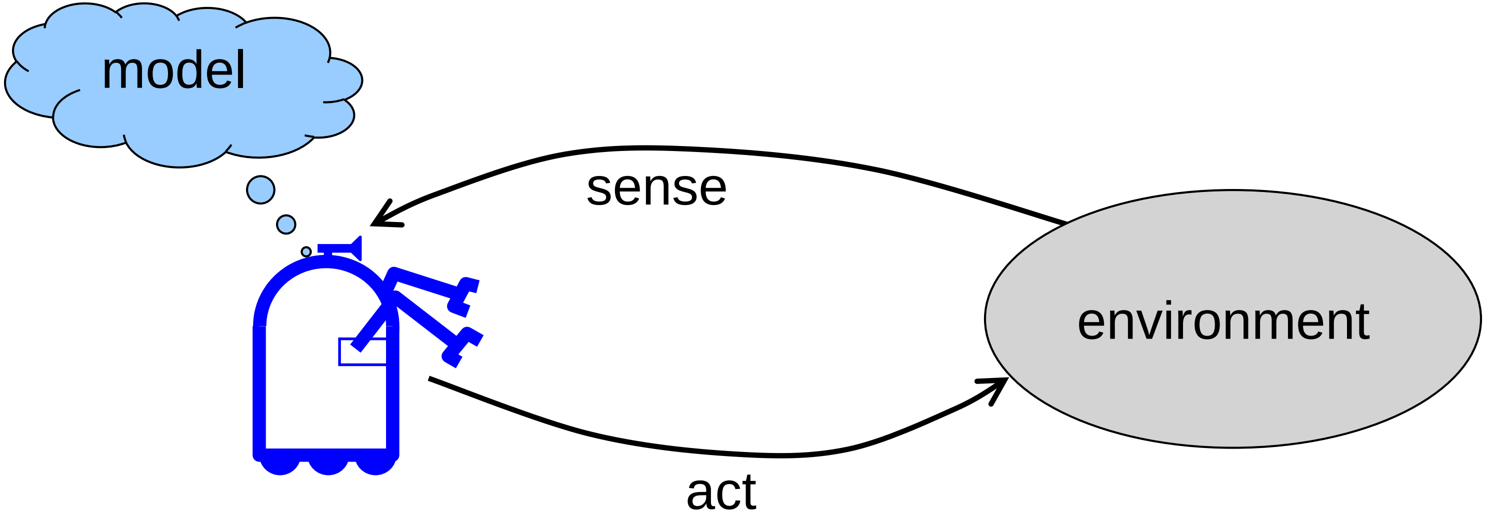
Opportunities

- Projects
- Practical courses
- Seminars
- Thesis

…your future!

Autonomous Robotic Systems

- Perceive their environment and
- Generate actions to achieve their goals.



Tasks that Need to be Solved by Robots

- Navigation
- Perception
- Learning
- Cooperation
- Acting
- Interaction
- Robot development
- Manipulation
- Grasping
- Planning
- Reasoning

…

Robotics Yesterday

- Highly repeatable tasks
- Robots bolted to the ground, often caged
- Limited to no perception
- Very little “AI”

Picture: Bachmann, Kuka Roboter GmbH

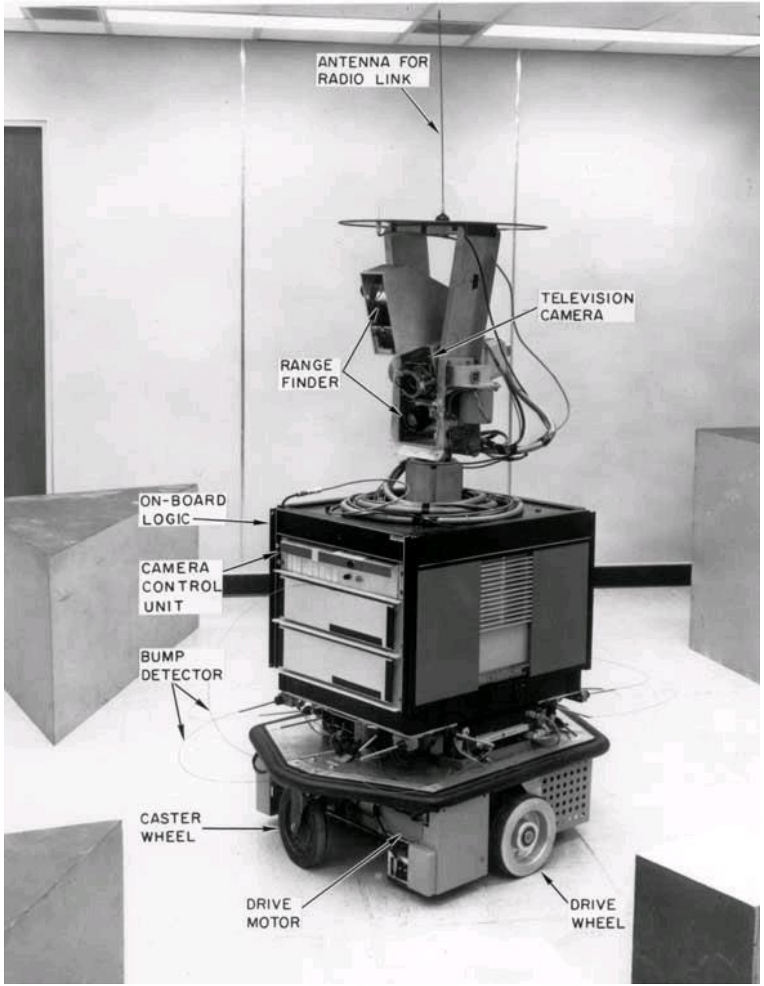
Current Trends in Robotics

Robots are (partly) moving away from factory floors …

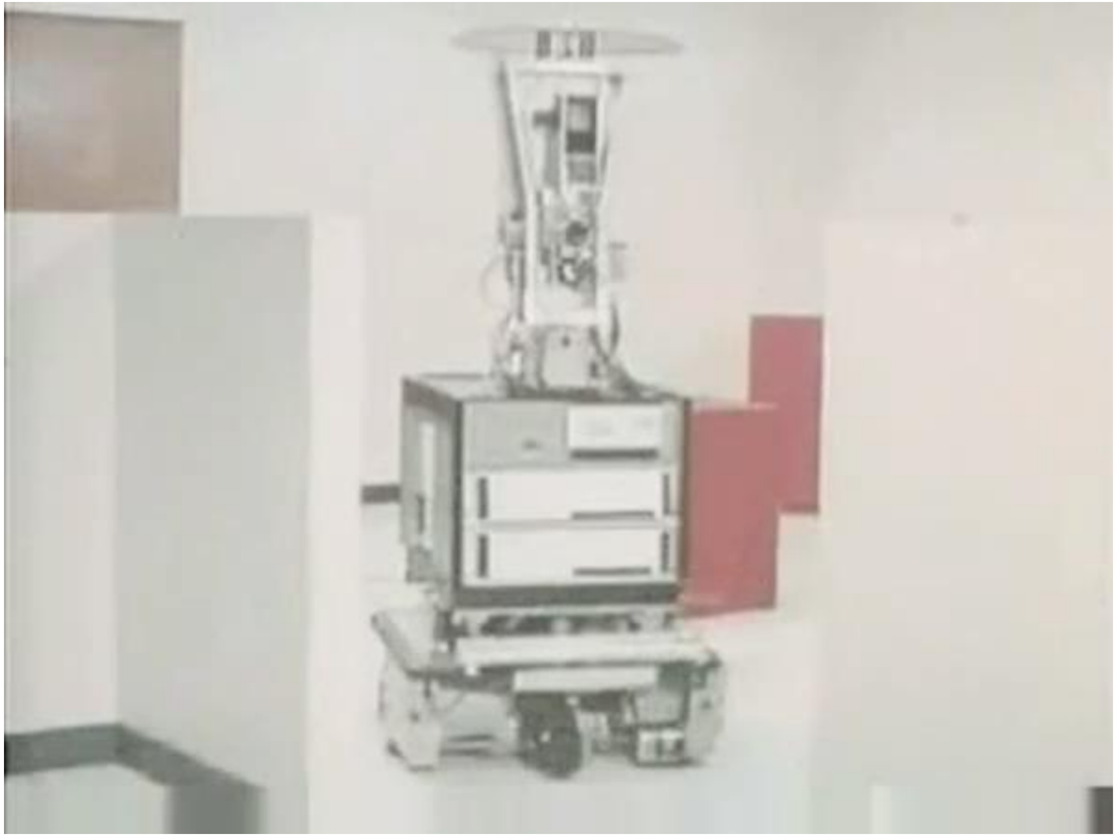
- Entertainment, toys
- Personal services
- Medical, surgery
- Industrial automation
- Hazardous environments
  (mining, harvesting, space, underwater)
- Self-driving cars
- …

Shakey the robot

- The first general-purpose mobile robot (1966)
- Developed in Stanford (SRI)
- Many components the same as today



Shakey the Robot (1966)

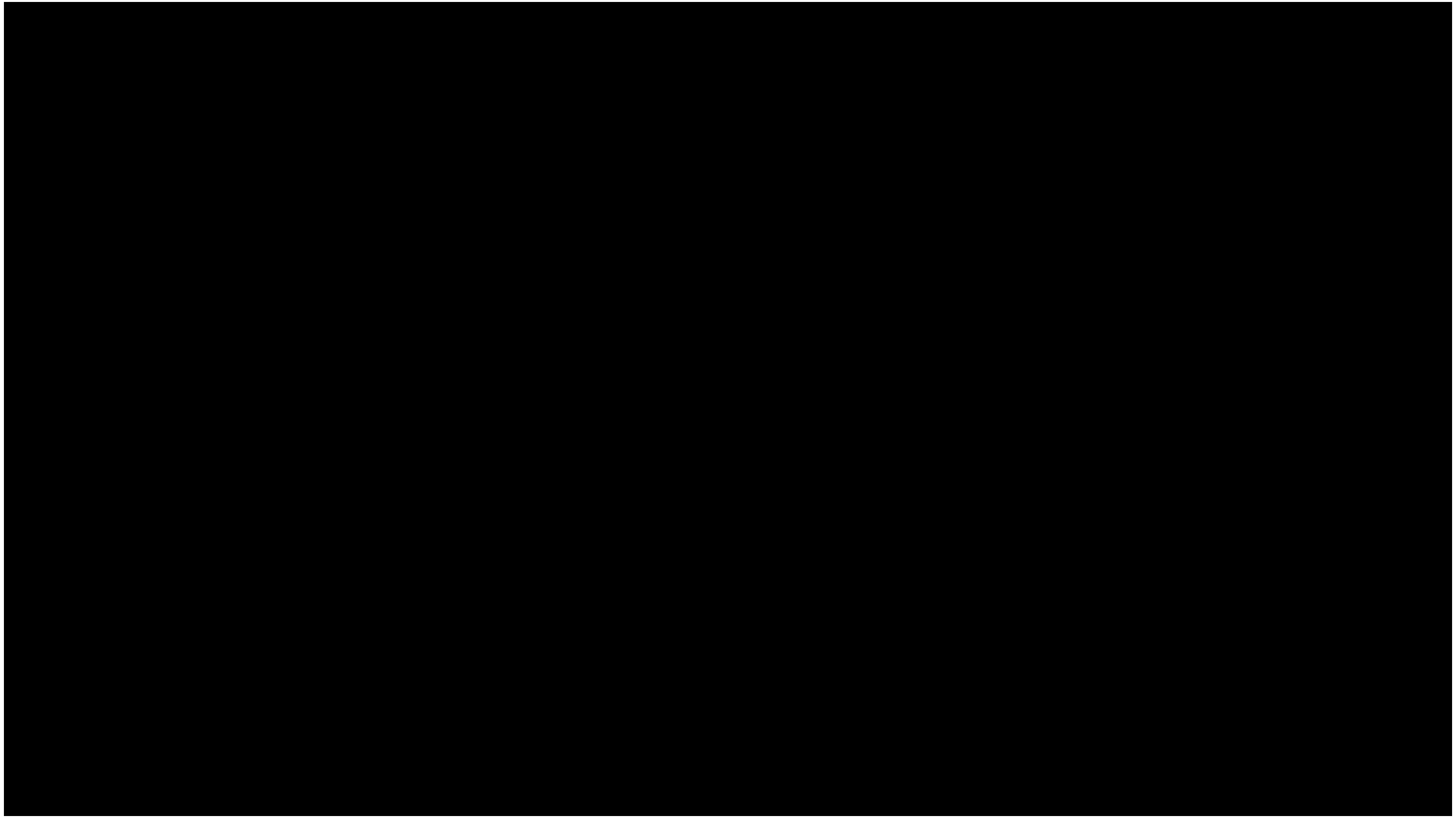


The Helpmate System

DARPA Grand Challenge

Walking Robots

Driving in the Waymo Car

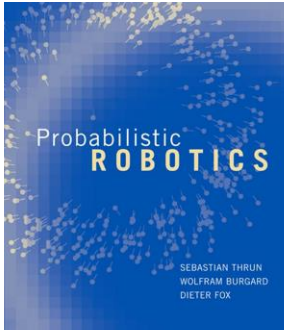


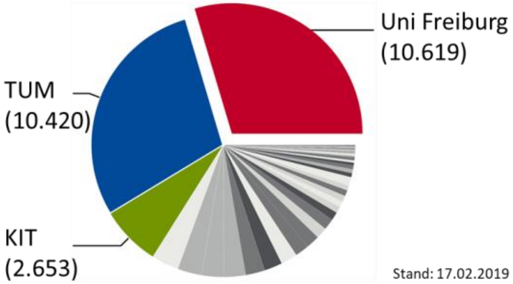
Autonomous Vacuum Cleaners

Folding Towels

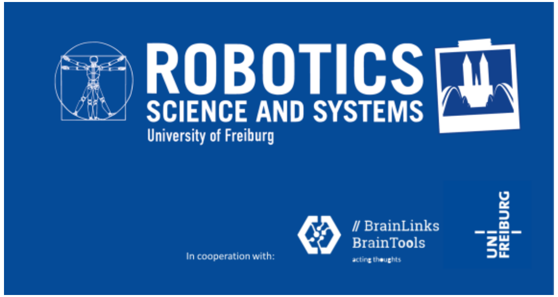
Robotics Has a Long History in Freiburg

- Probabilistic Robotics – Wolfram Buragrd
  - Autonomous Navigation
- Artificial Intelligence Planning - Bernhard Nebel
  - Robocup
- Highest number of citations in Germany





Robotics citations since 2008
Updated: 17.02.2019



Minerva (CMU + Univ. Bonn, 1998)

Autonomous Quadrotor Navigation

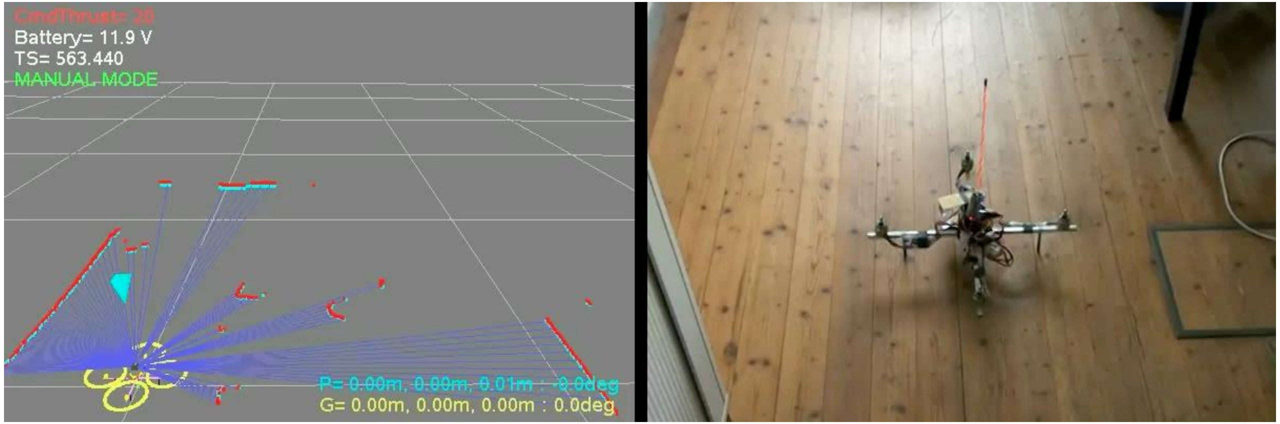
Custom-built system:

laser range finder

inertial measurement unit

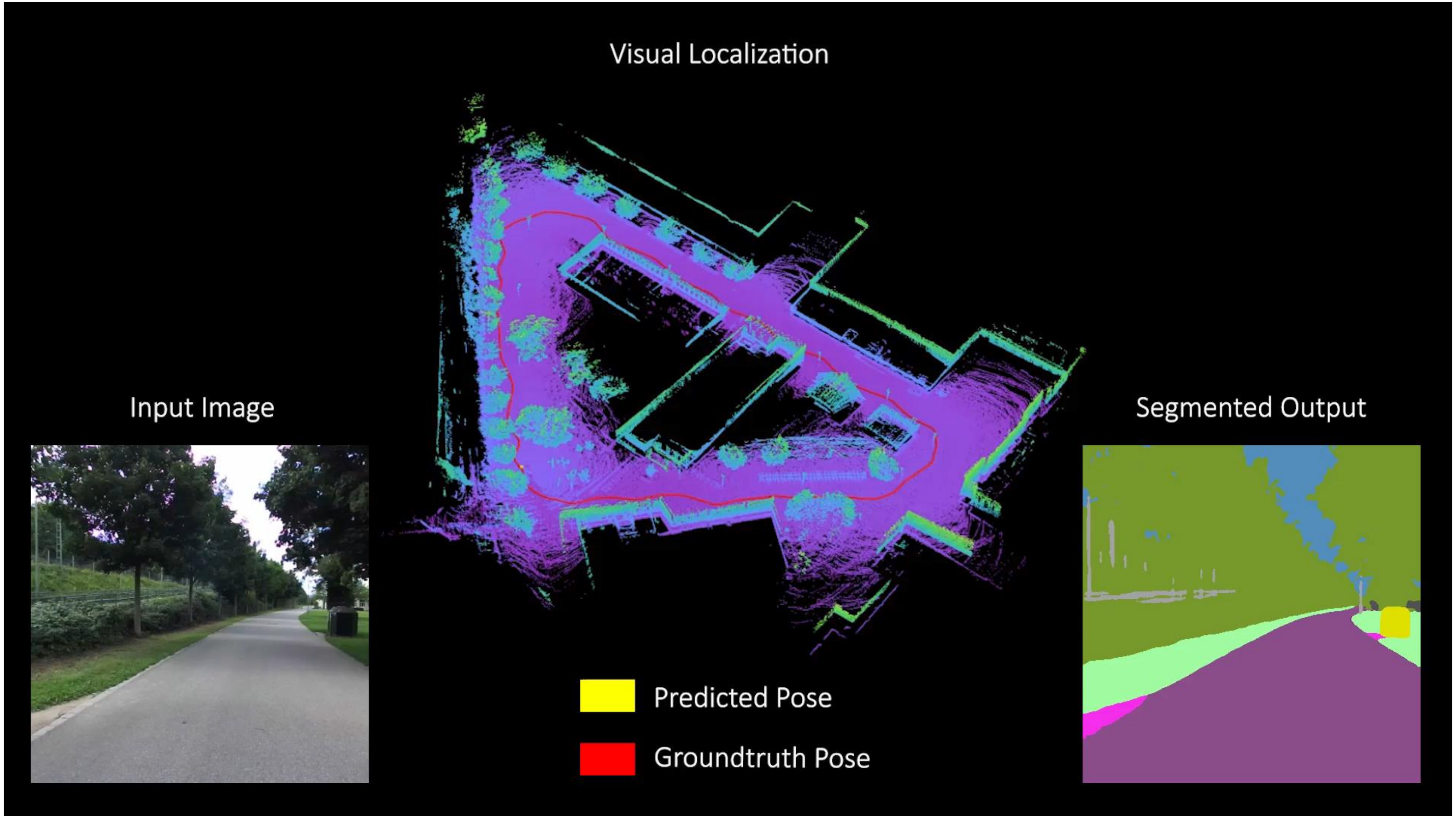
embedded CPU

laser mirror



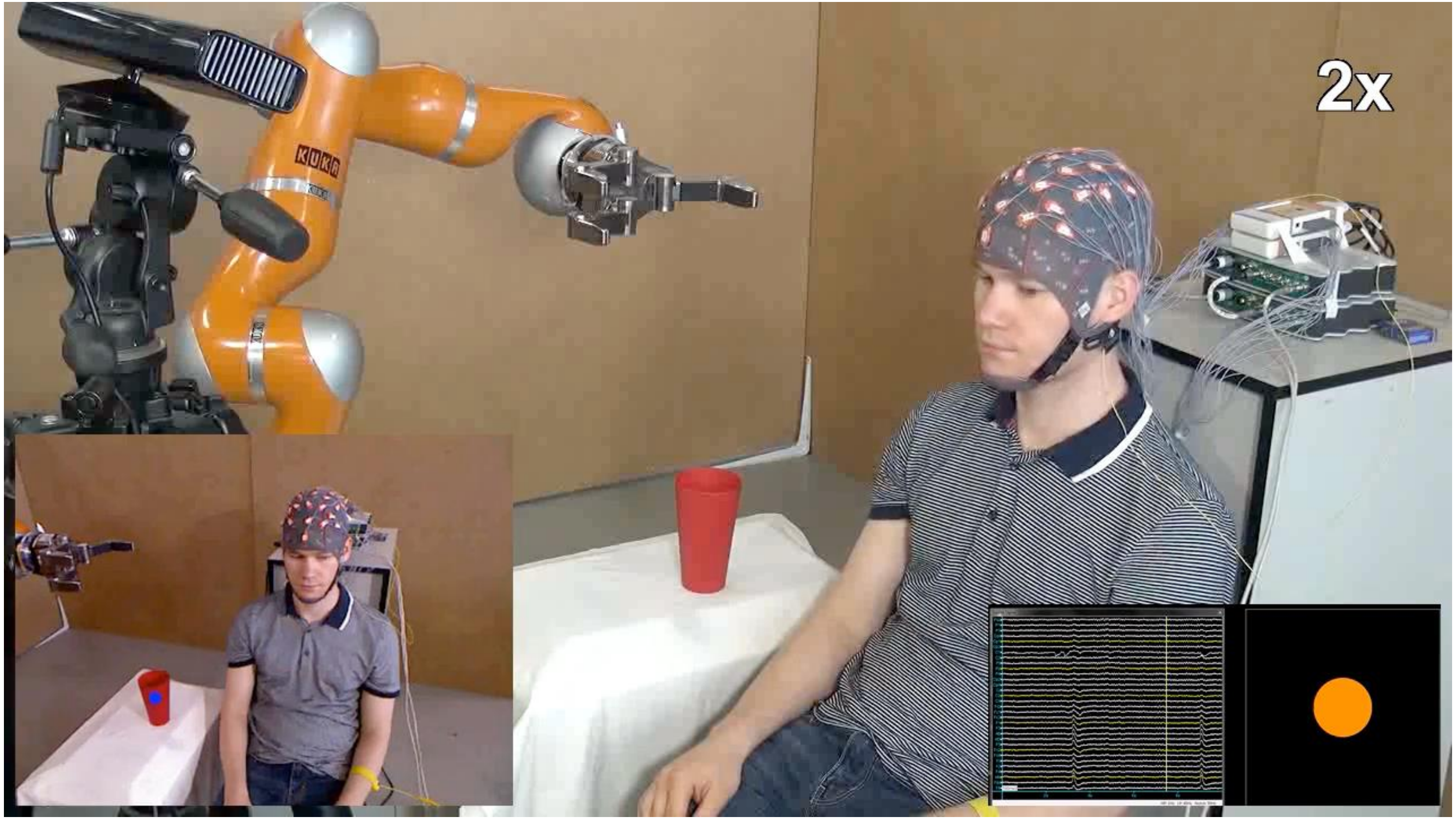
Obelix – Navigating to Downtown Freiburg

Obelix on Campus



Viona Navigating to Schauinsland

Brain-controlled Robots

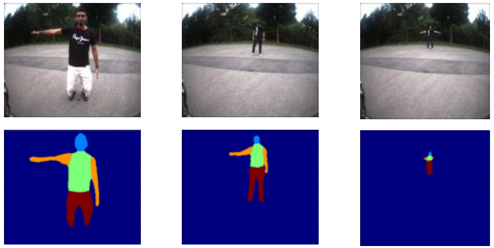


Deep Learning Applications

- RGB-D

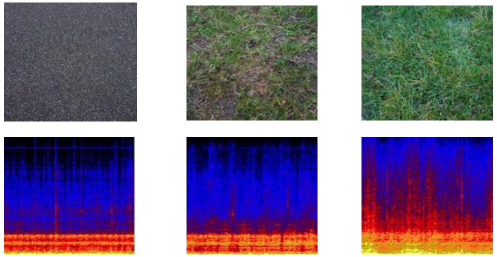
Object Recognition

- Images



Body part Segmentation

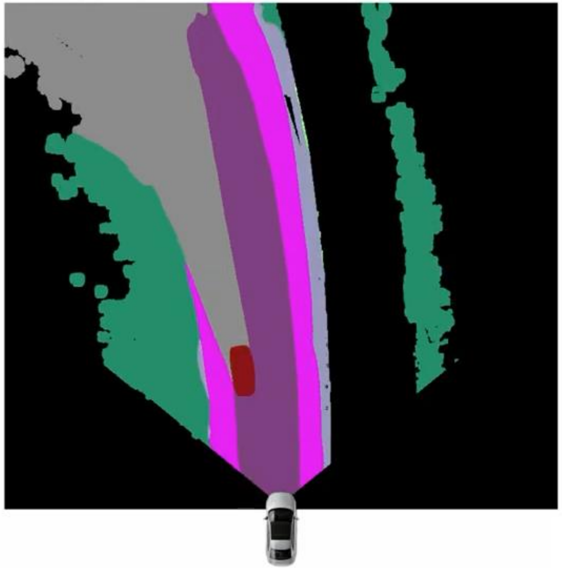
- Sound



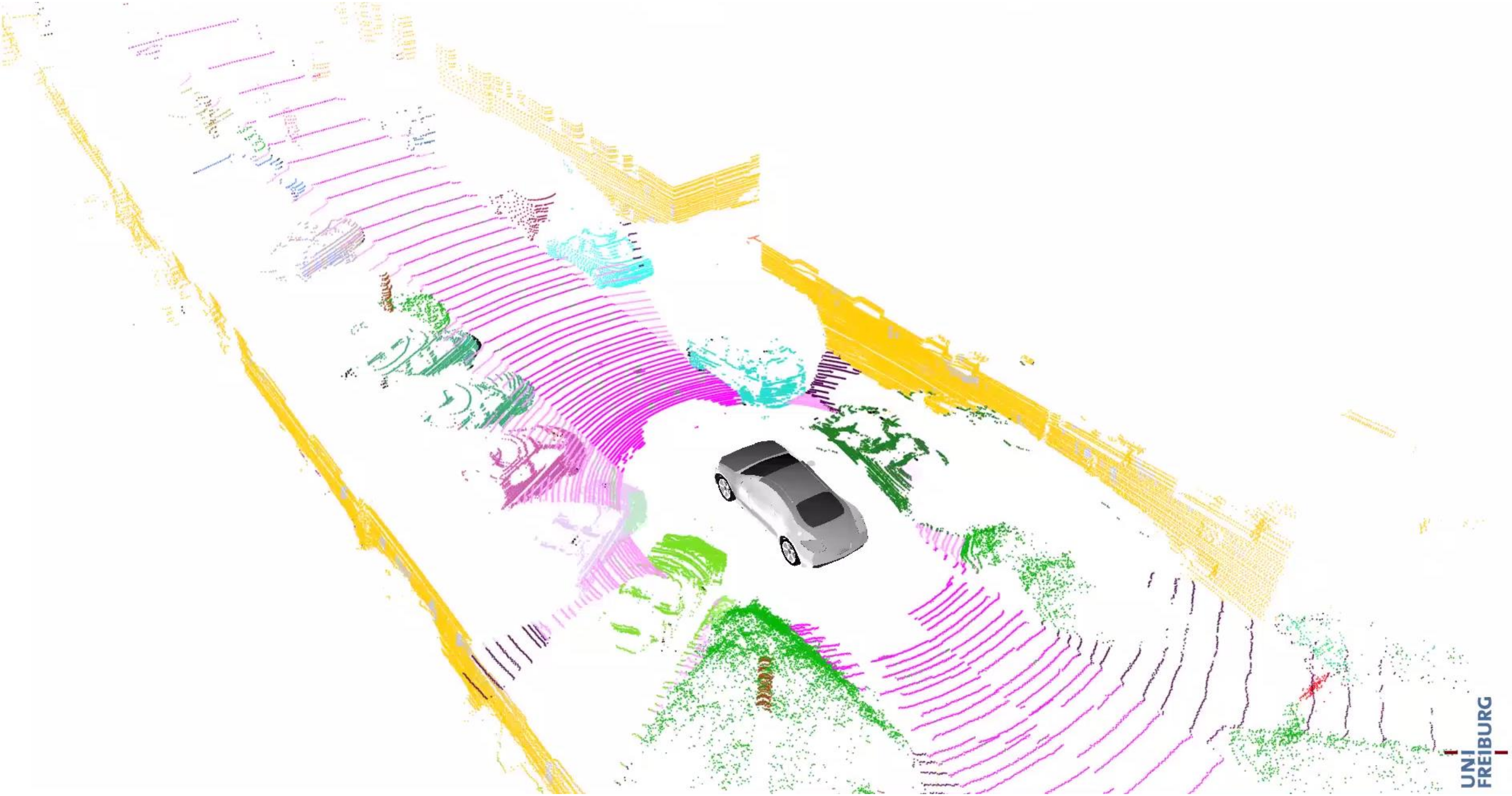
Terrain Classification

Bird’s Eye View Panoptic Segmentation

- Panoptic segmentation: semantic + instance segmentation
- Goal: Learn it in the bird’s eye view (BEV) from monocular images
- Network consists of encoder, dense transformer, semantic head, instance head, panoptic fusion module
- Dense transformer maps vertical and flat regions of an image into the BEV

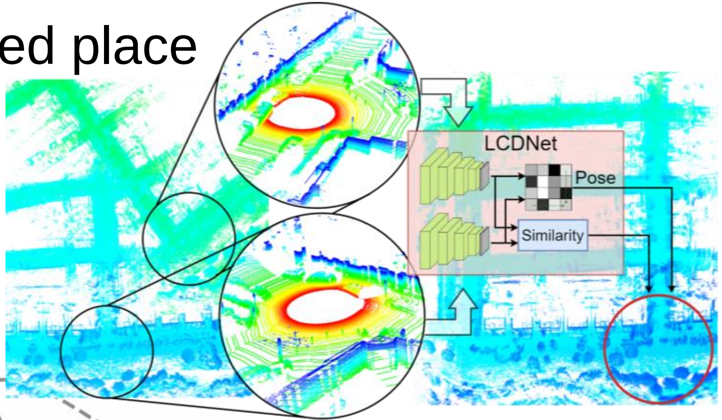


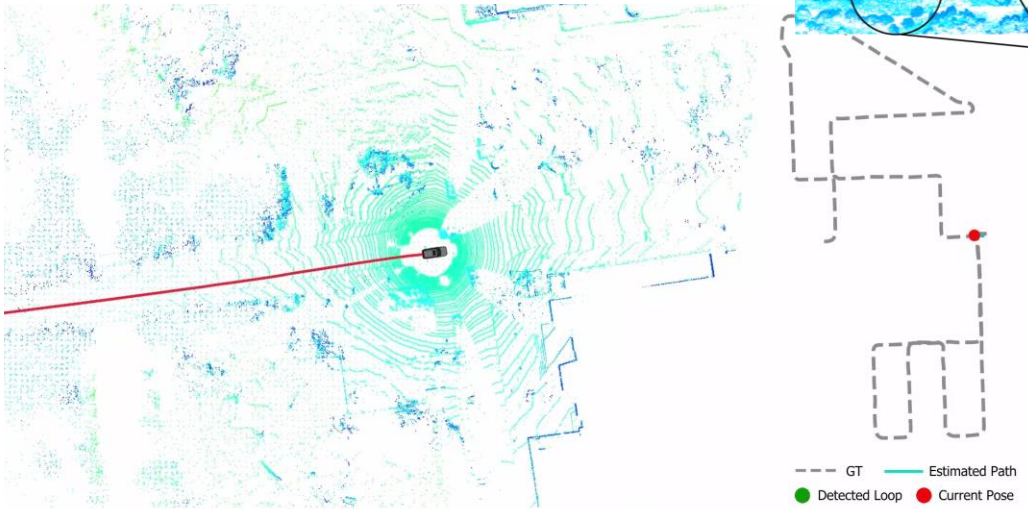
LiDAR Panoptic Segmentation



Learning Loop Closure Detection

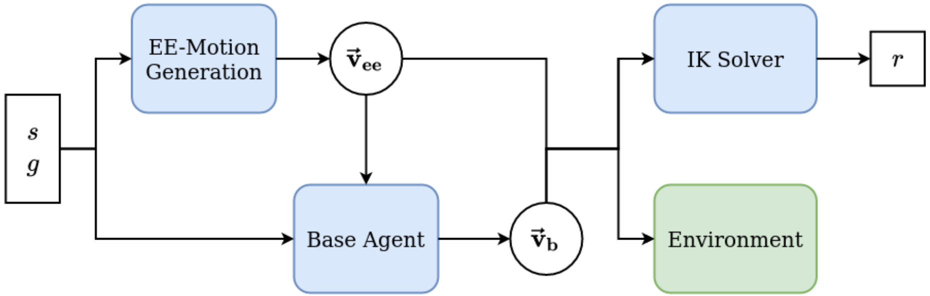
- Loop closing: identifying a previously visited place
- Goal: Learn loop detection and point cloud registration
- Network: feature extractor, place recognition head, relative pose head





Learning Kinematic Feasibility

- Mobile manipulation: mobile robot with arm to manipulate objects
- Goal: Learn feasible motions for a base, given an end-effector goal
- Decompose mobile manipulation
  - Arbitrary end-effector planner
  - Reinforcement learning agent controlling the base

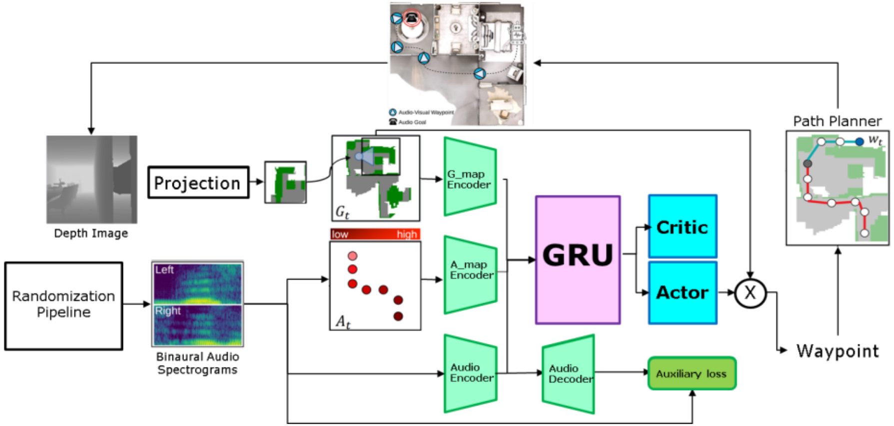


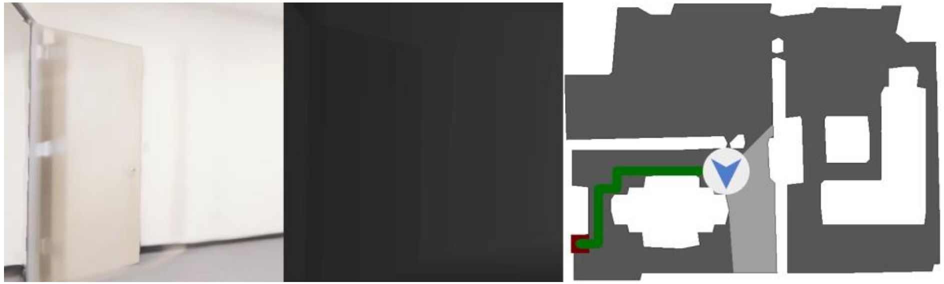
Object Detection with Sound

- Goal: Localize moving objects in images using only sound
- Use pre-trained RGB, depth and thermal teacher networks to train an audio student in a self-supervised manner
- While testing: localize objects in the image field using only sound

Audio-Visual Navigation

- Goal: Navigate to a sound source in unmapped environments
- Fuse audio-visual features spatially to learn correlations of geometric information inherent in both local maps and audio signals
- Self-supervised audio reconstruction





- Winner of CVPR 2021 Embodied AI challenge

Questions?

Thank you

… and enjoy the course!