Probabilistic Techniques for Robot Navigation

A Key Technology for Our Future Society

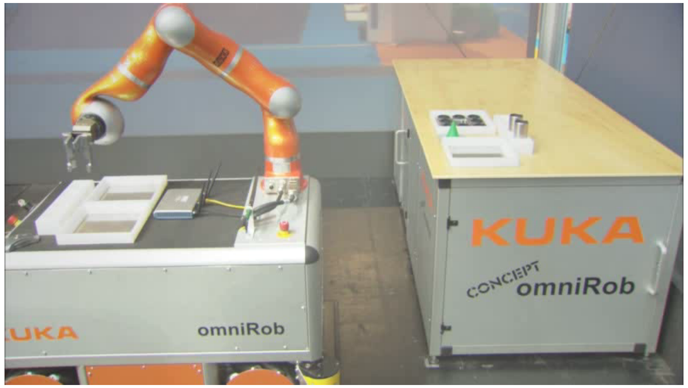
Wolfram Burgard

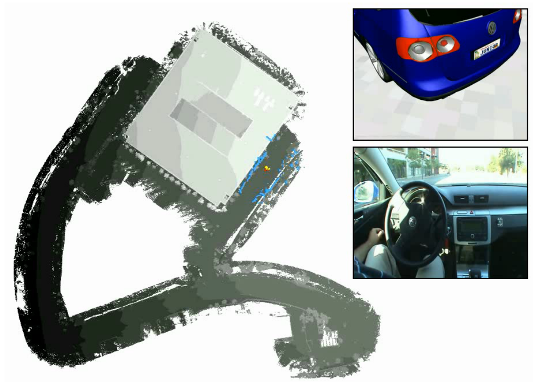
Key Challenges in Navigation

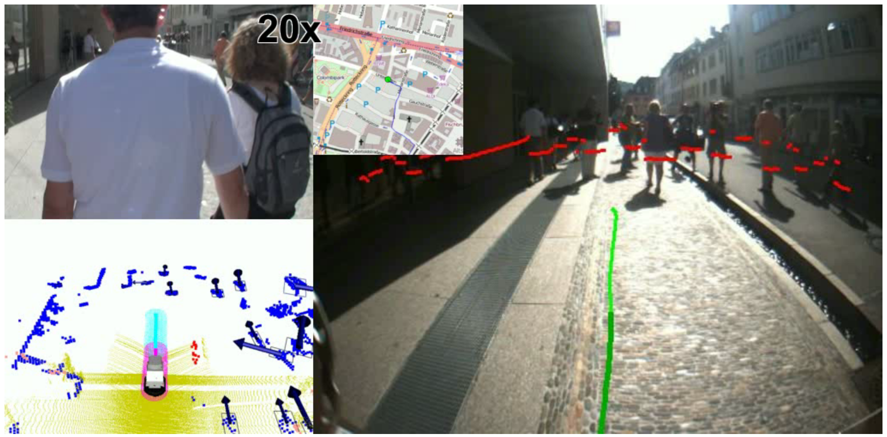
Highly accurate localization

Robust mapping

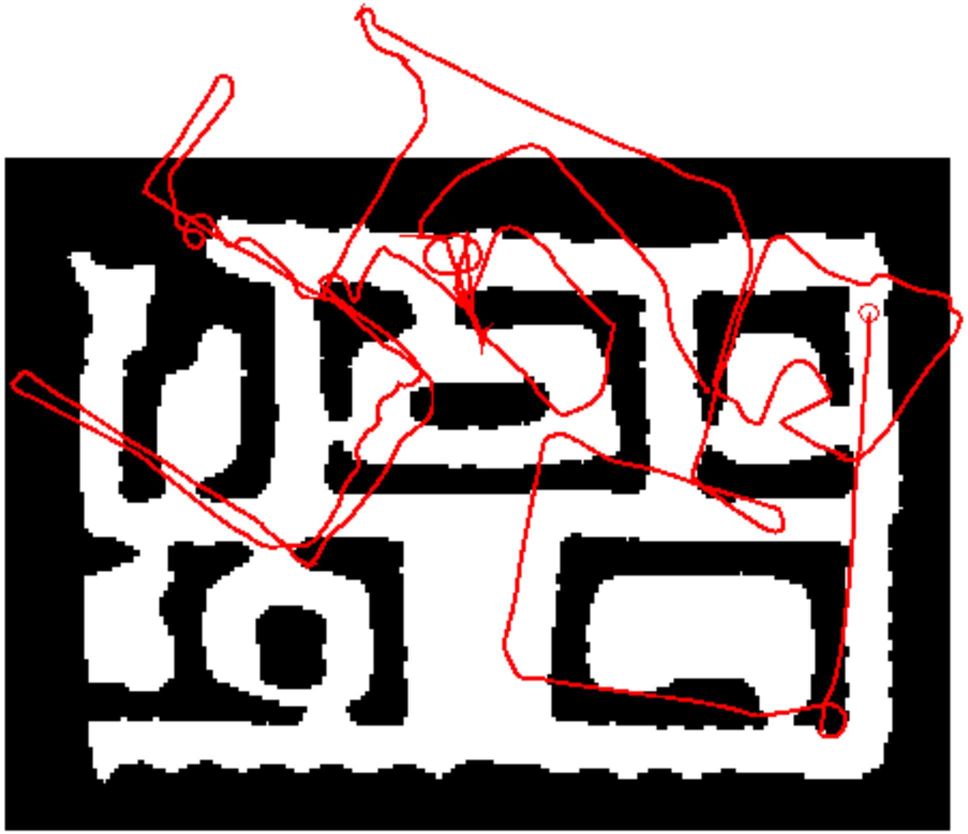
Long-term autonomy



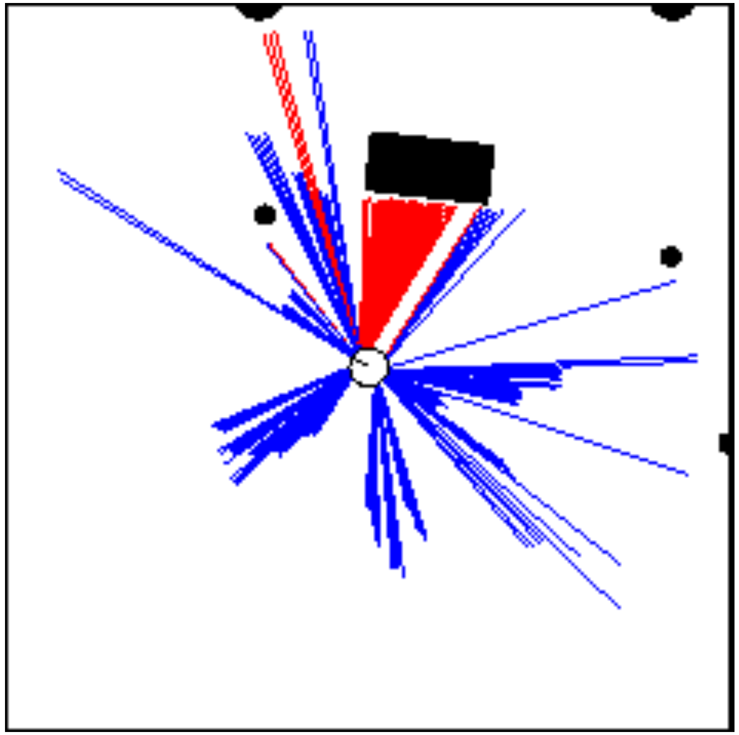




Nature of Data



Odometry Data



Range Data

Probabilistic Robotics

Explicit representation and utilization of uncertainty

- Perception = state estimation
- Action = utility optimization

Probabilistic Robotics

Explicit representation and utilization of uncertainty

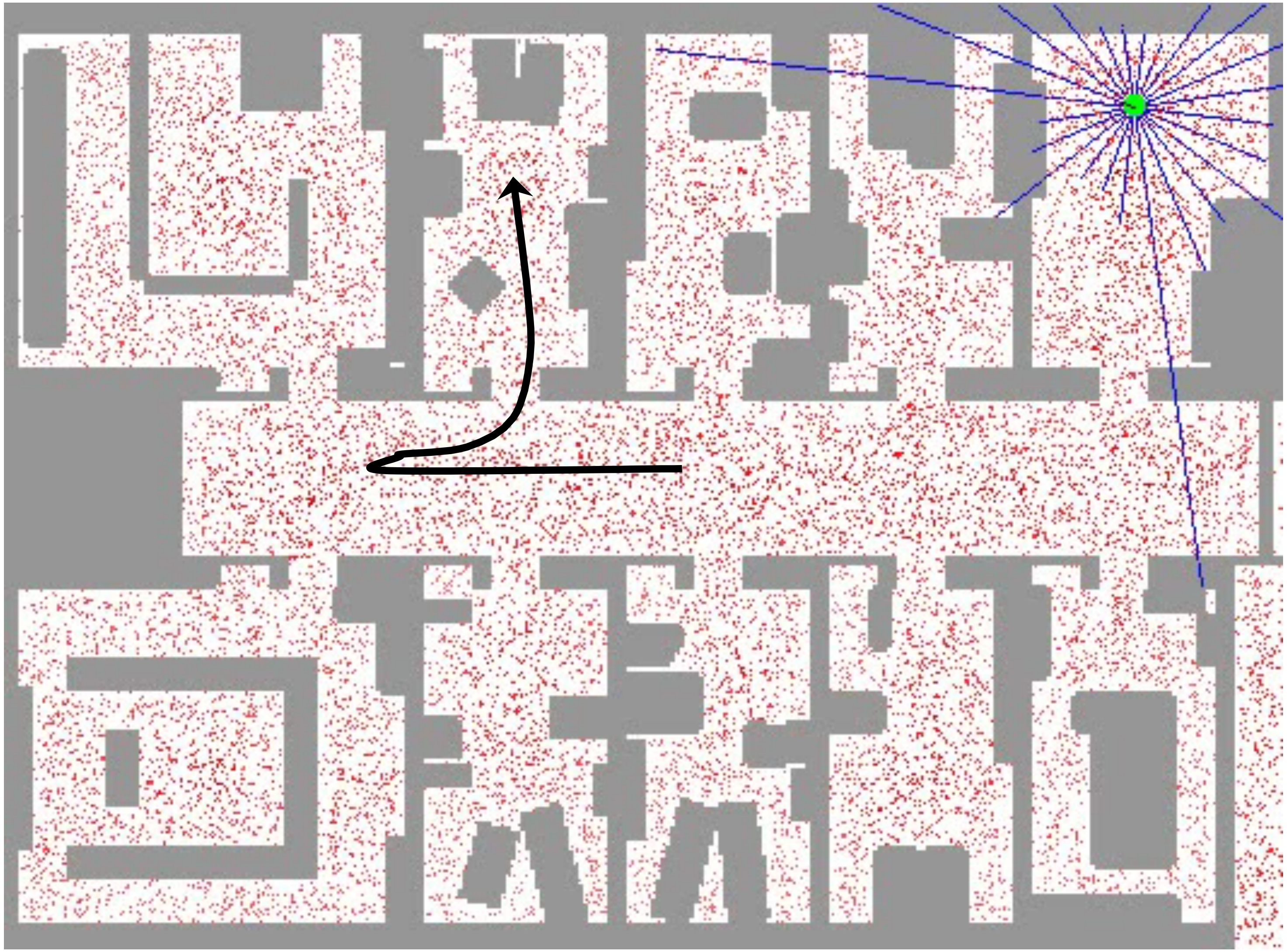
- Perception = state estimation

$$Bel(x \mid z, u) \;=\; \alpha\, p(z \mid x) \int_{x'} p(x \mid u, x')\; Bel(x')dx'$$

- Action = utility optimization

$$\pi^*(x) = \operatorname*{argmax}_u \sum_{x'} p(x' \mid u, x) V^*(x')$$

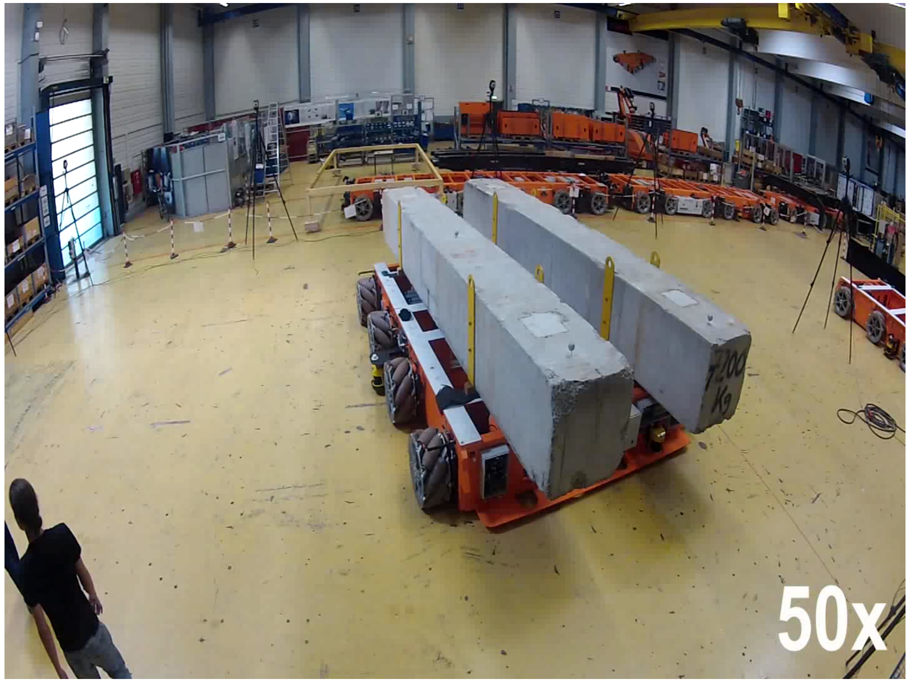
MCL: Global Localization (Sonar)

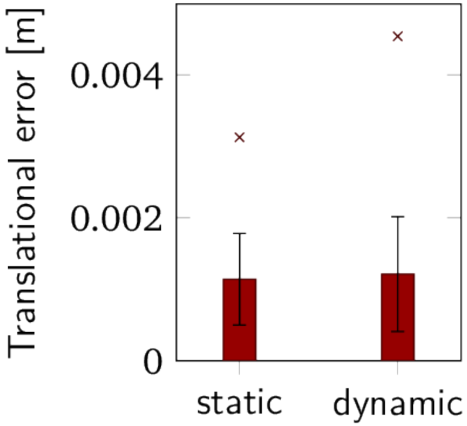


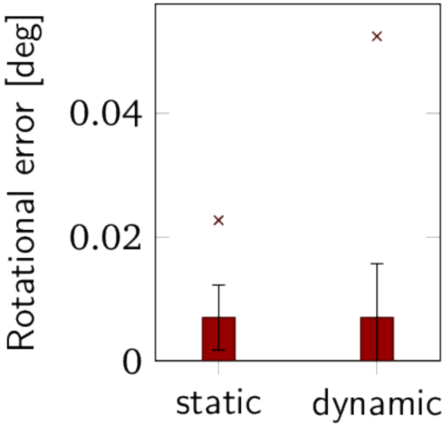
Precise Localization and Positioning for Mobile Robots

Accurate Localization

- KUKA omniMove (11t)
- Safety scanners
- Error in the area of millimeters
- Even in dynamic environments

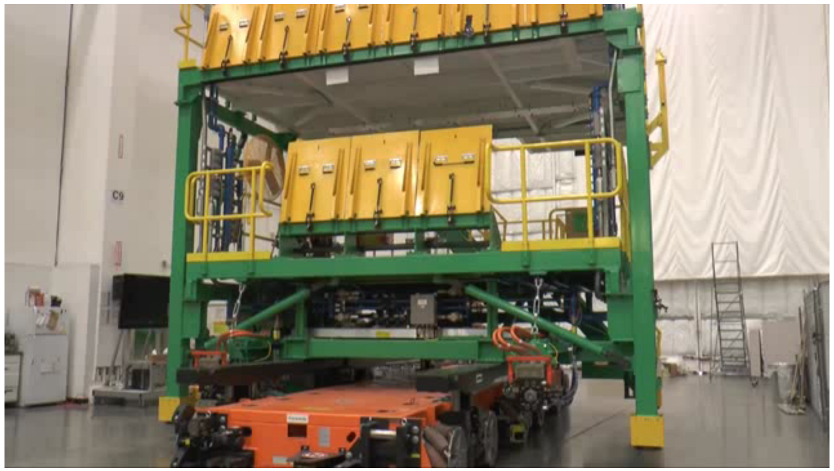






26 Units installed at Boeing

- Fuselage assembly
- 20 vehicles to transport industrial robots for drilling and filling of 60,000 fasteners in
- 6 vehicles for logistics of parts, work stands and fuselages



Accurate Indoor RGB-D Localization with a Google Tango Device based on 2D Floor Plans

Wera Winterhalter, Freya Fleckenstein,
Bastian Steder, Wolfram Burgard,
Luciano Spinello

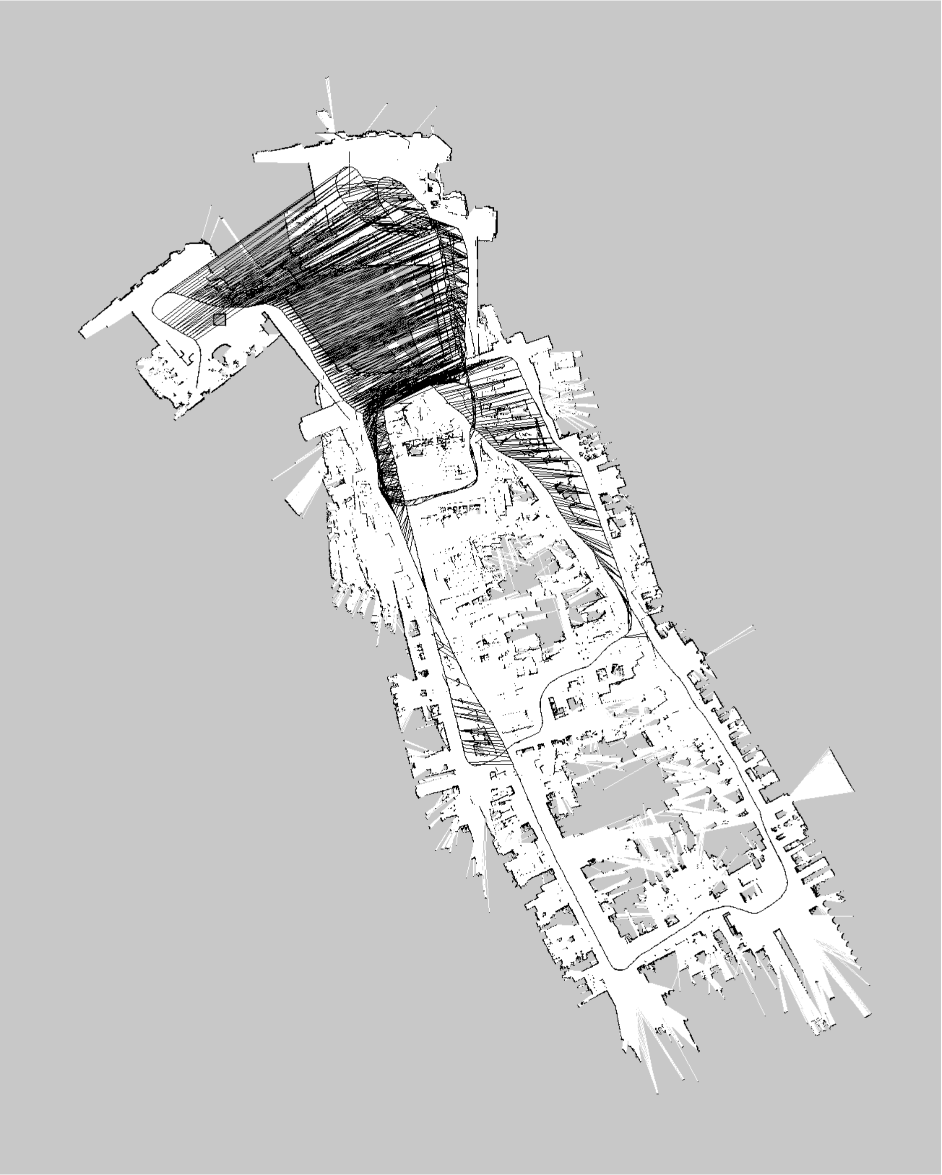
AIS Autonomous Intelligent Systems

UNI FREIBURG

How to Learn a Map: SLAM

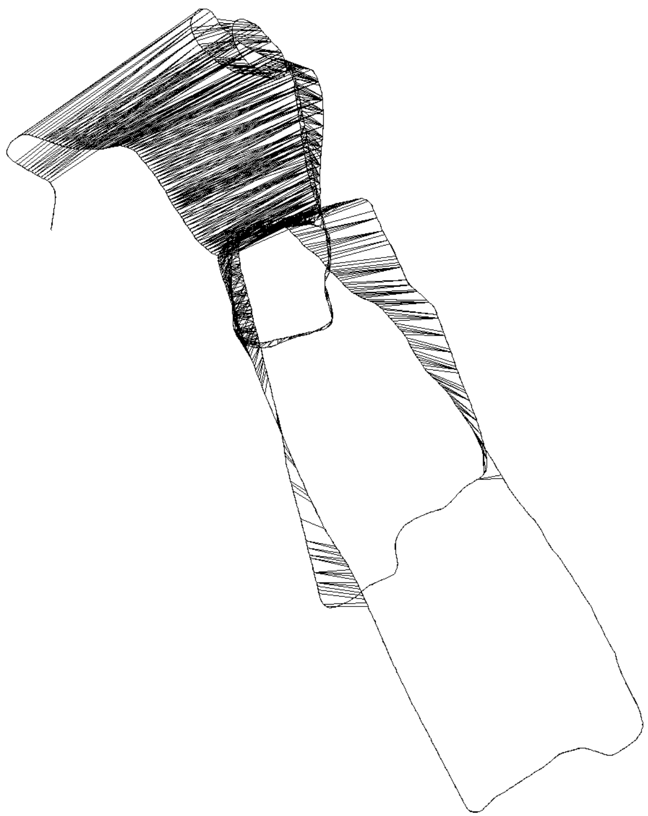
Graph-Based SLAM in a Nutshell

- Problem described as a graph
  - Every node corresponds to a robot position and to a laser measurement
  - An edge between two nodes represents a data-dependent spatial constraint between the nodes



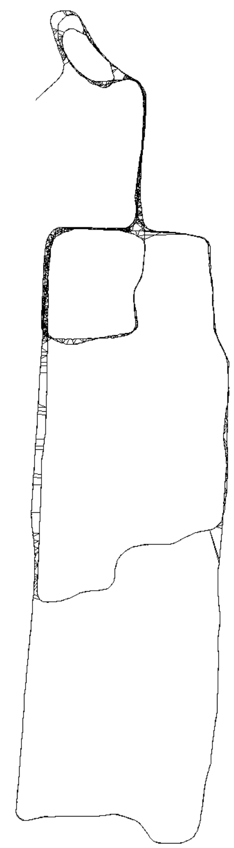
Graph-Based SLAM in a Nutshell

- Once we have the graph, we determine the most likely map by "moving" the nodes



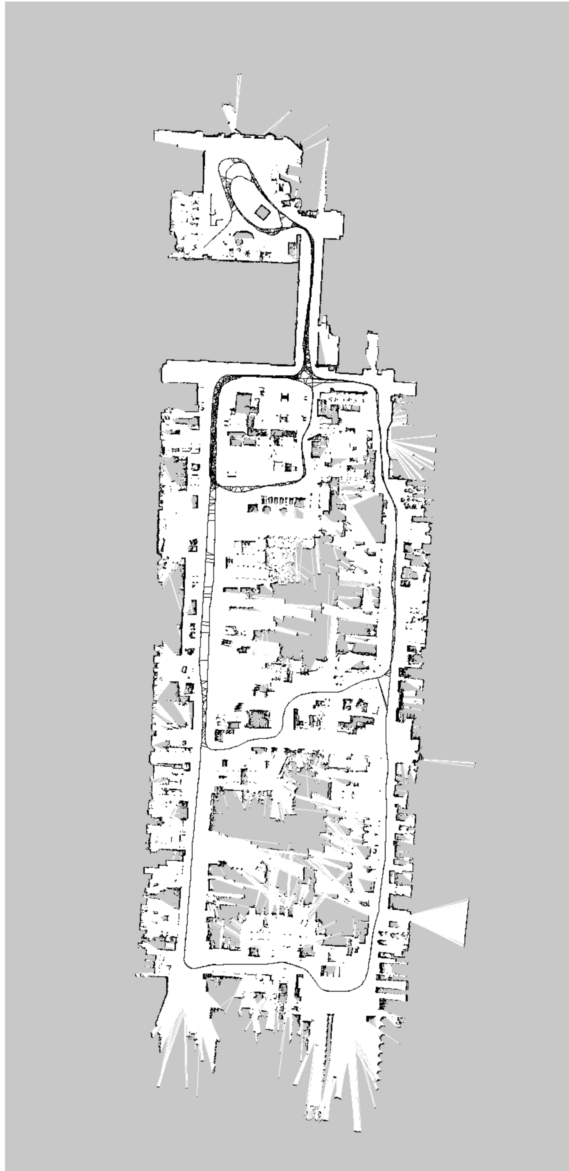
Graph-Based SLAM in a Nutshell

- Once we have the graph, we determine the most likely map by "moving" the nodes
- … like this.

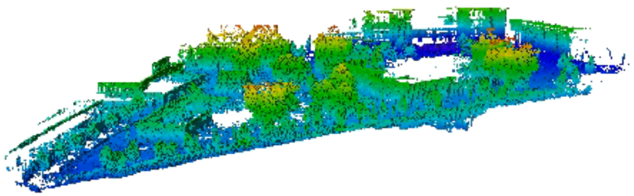


Graph-Based SLAM in a Nutshell

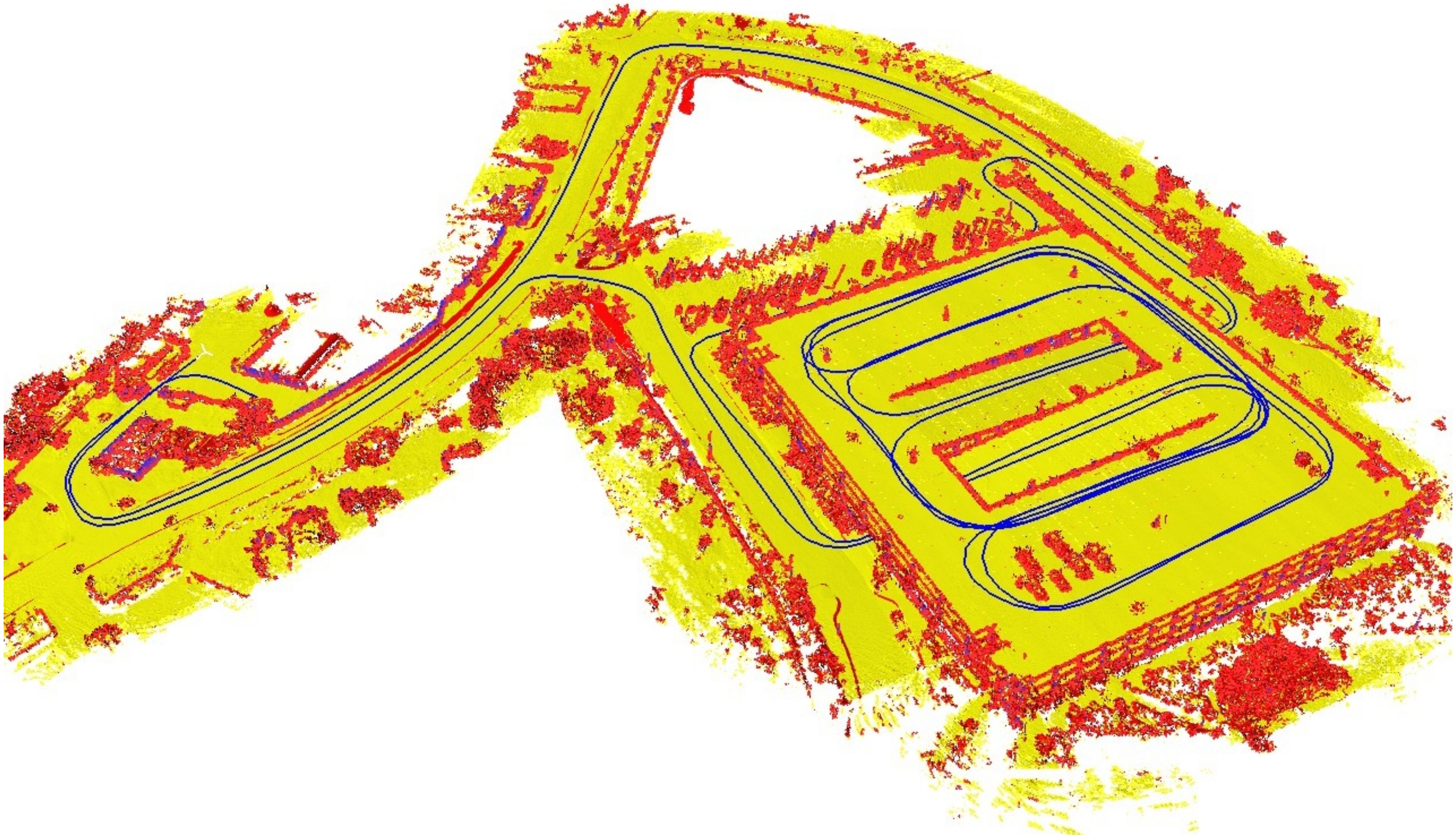
- Once we have the graph, we determine the most likely map by "moving" the nodes
- … like this.
- Then we render a map based on the known poses



Freiburg Campus Octomap

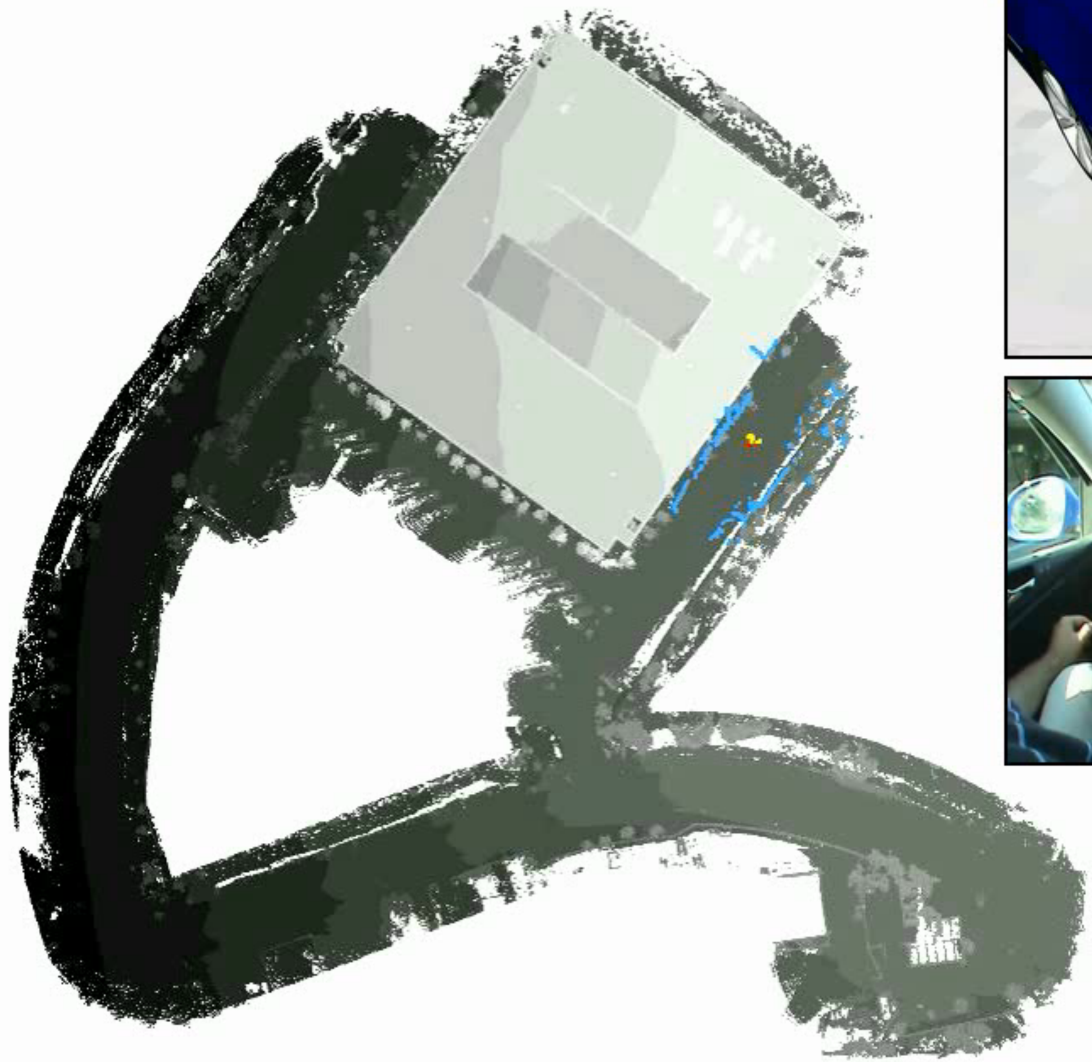


3D Map of the Stanford Parking Garage



approx. 260MB

Autonomous Parking



Autonomous Navigation in Urban Areas

Can we build a robot that is able to navigate autonomously through city centers?

EUROPA 2

EUROPA

SEVENTH FRAMEWORK PROGRAMME

Challenge: Canals

Challenge: Kids

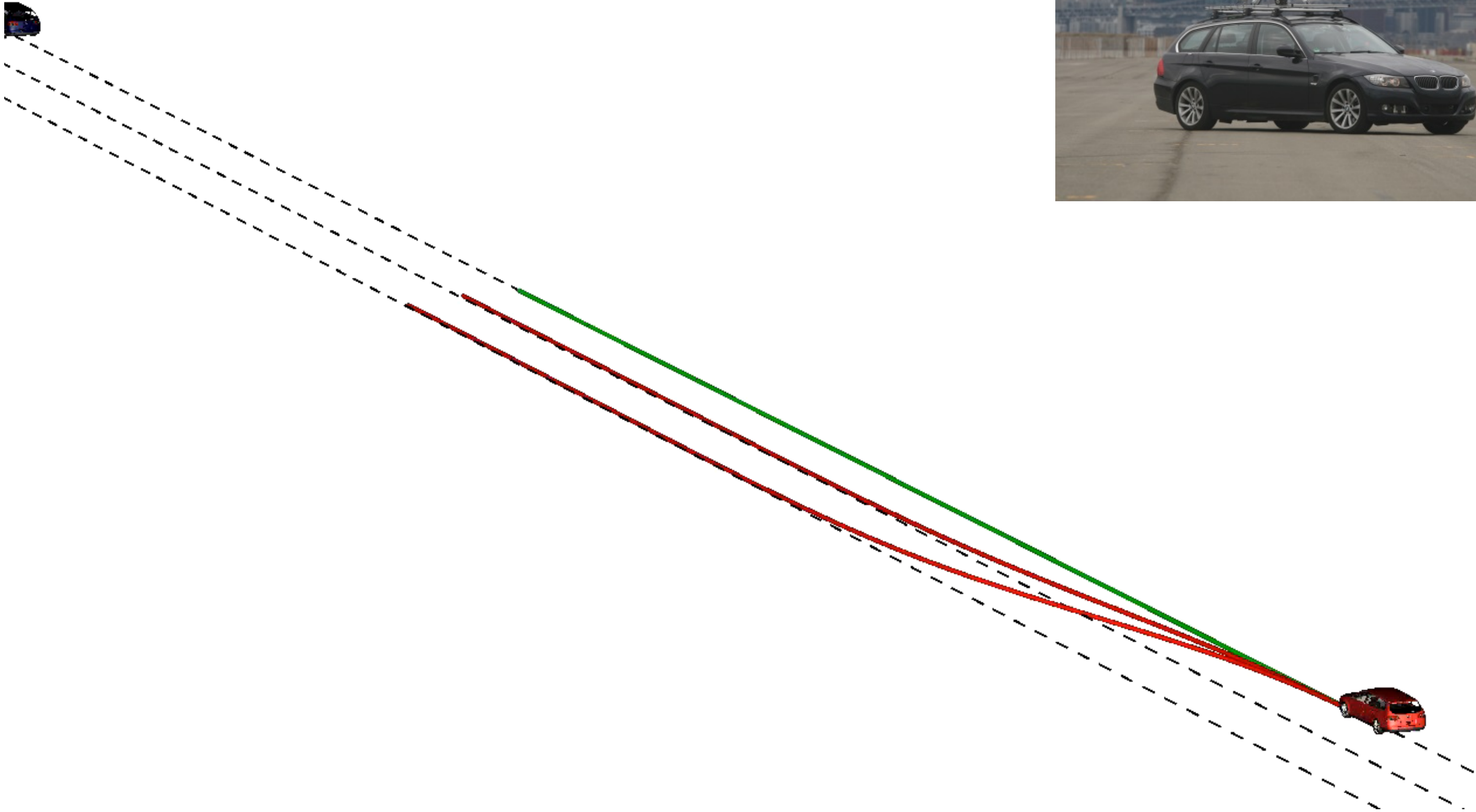
The Tagesthemen-Report

Learning Driving Styles

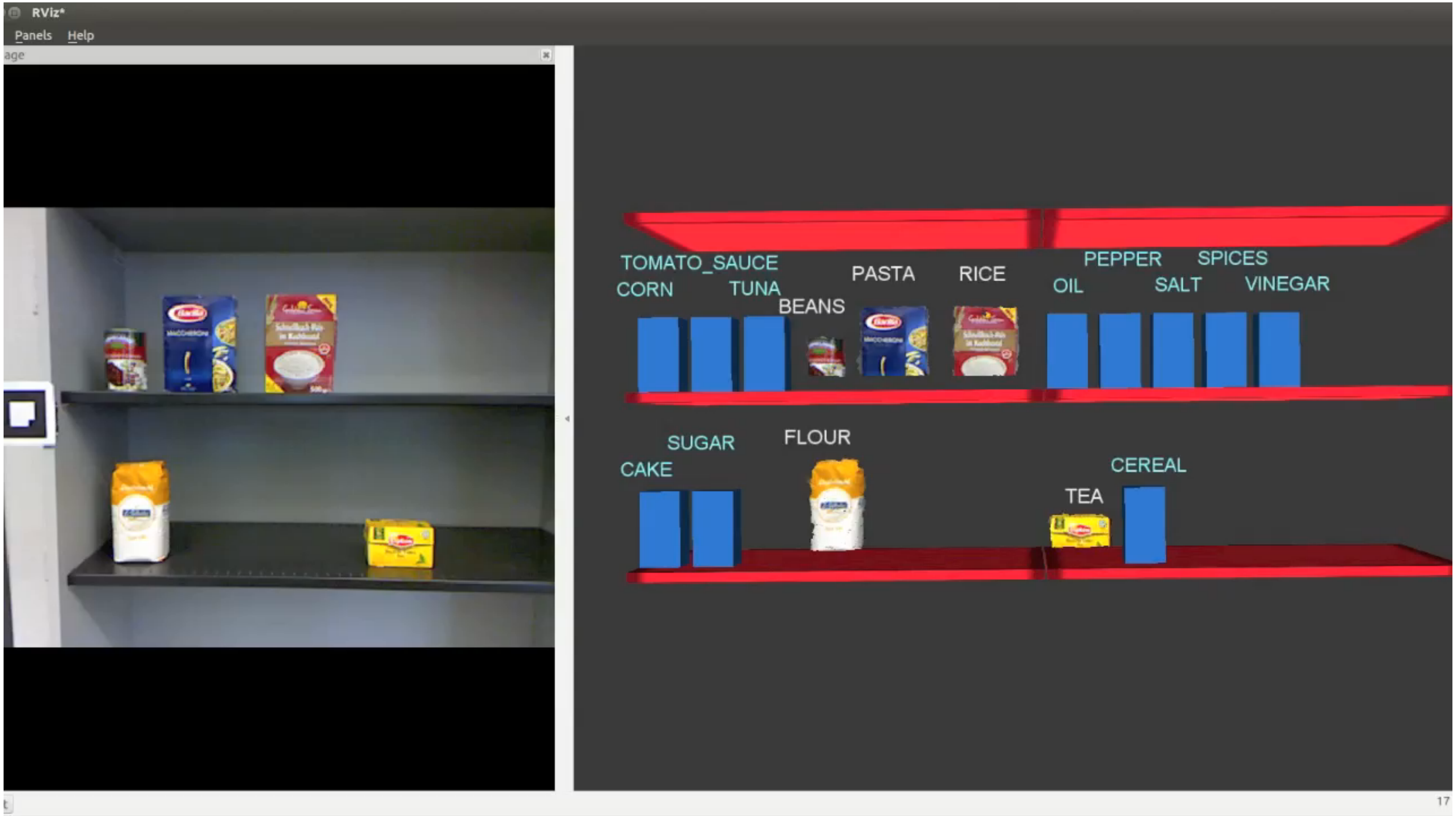
- Users have different expectations

- Many parameters such as accelerations, distances, velocities, etc.
- Difficult to tune parameters for non-technical users

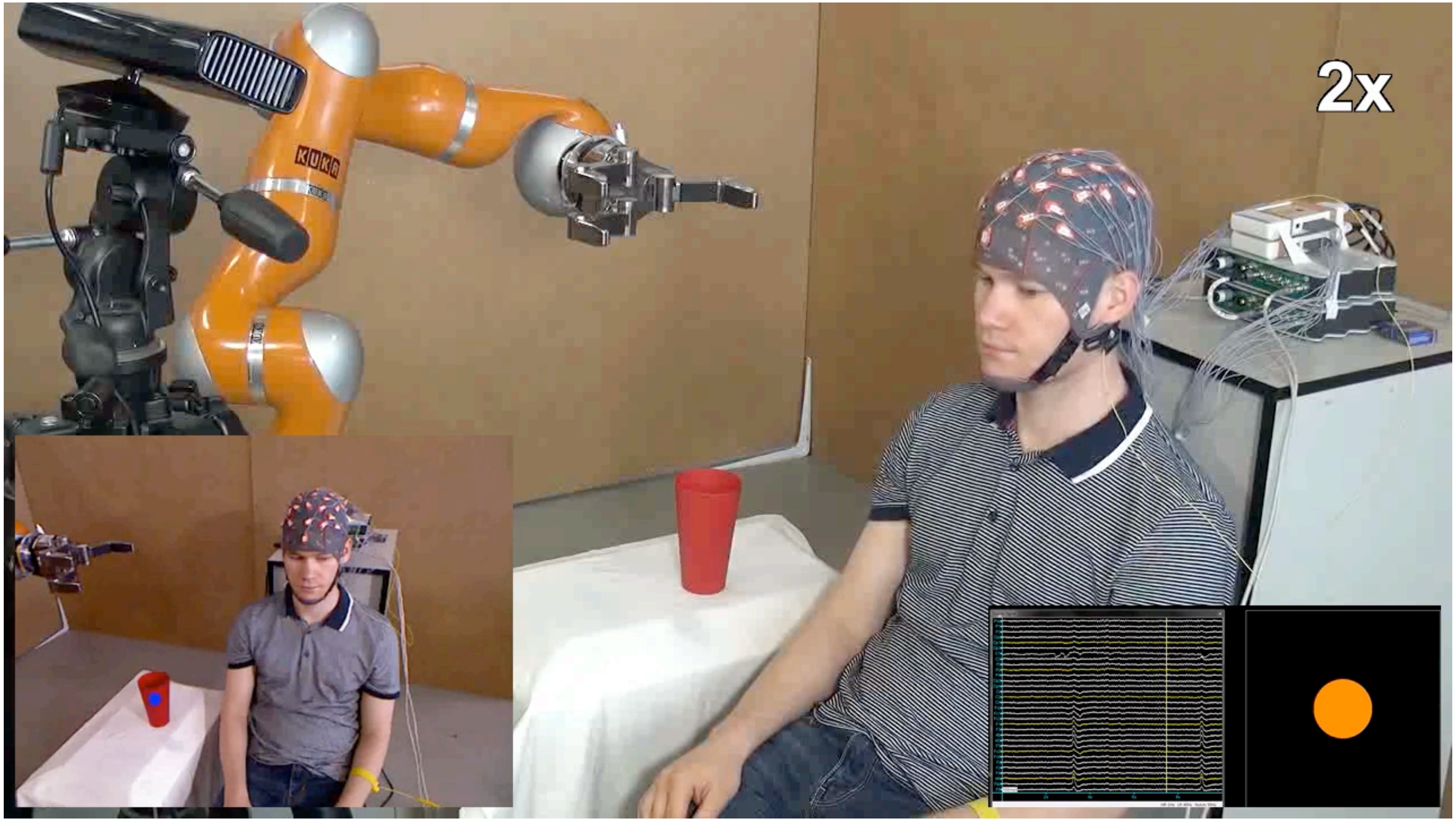
Learning Driving Behavior



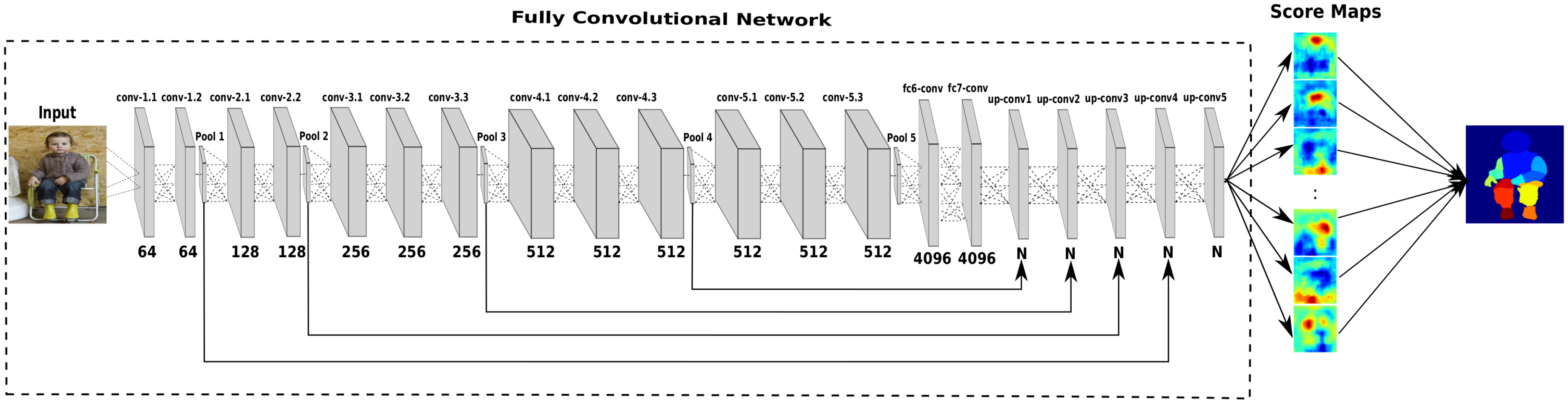
Online Prediction of User Preferences



Neurobots



And what's next?



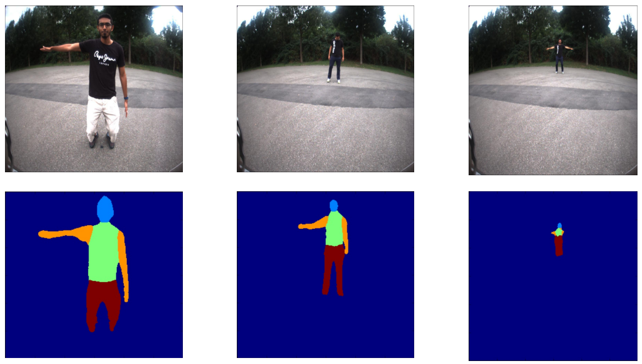
Deep Learning

Applications in Robotics …

- RGB-D

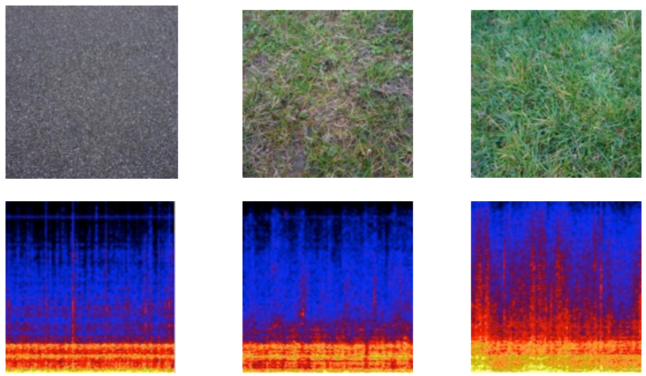
object recognition

- Images



human part segmentation

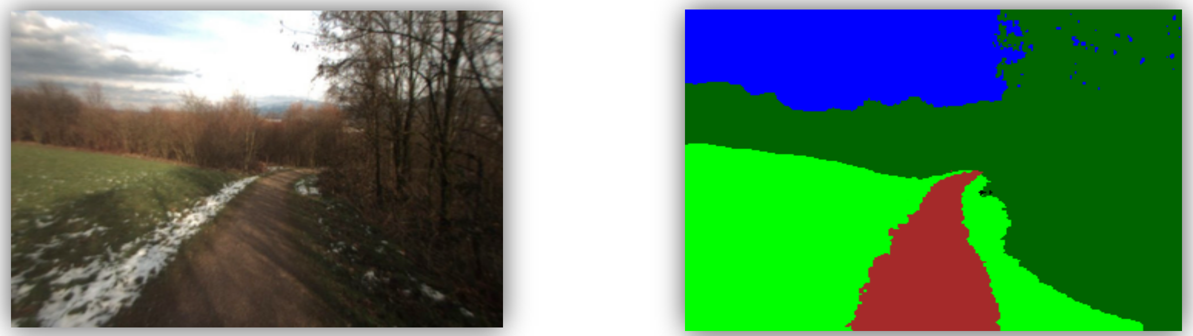
- Sound



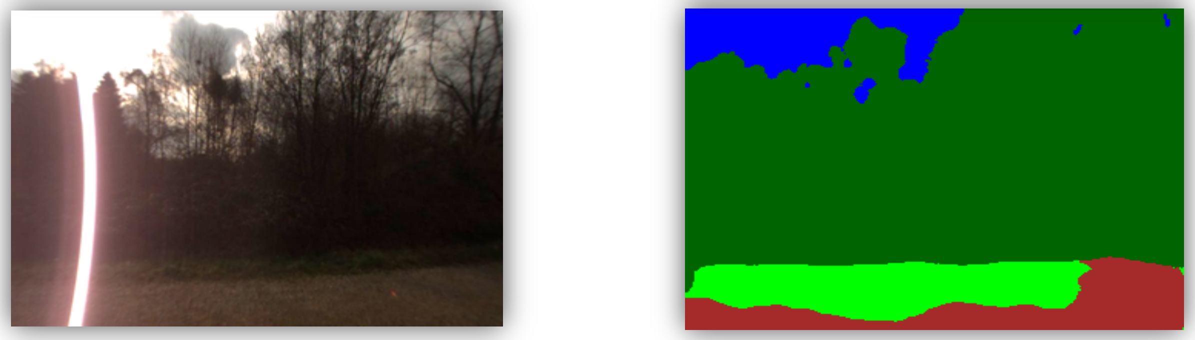
terrain classification

Terrain Classification using a Late Fusion DCNN Architecture

Snow



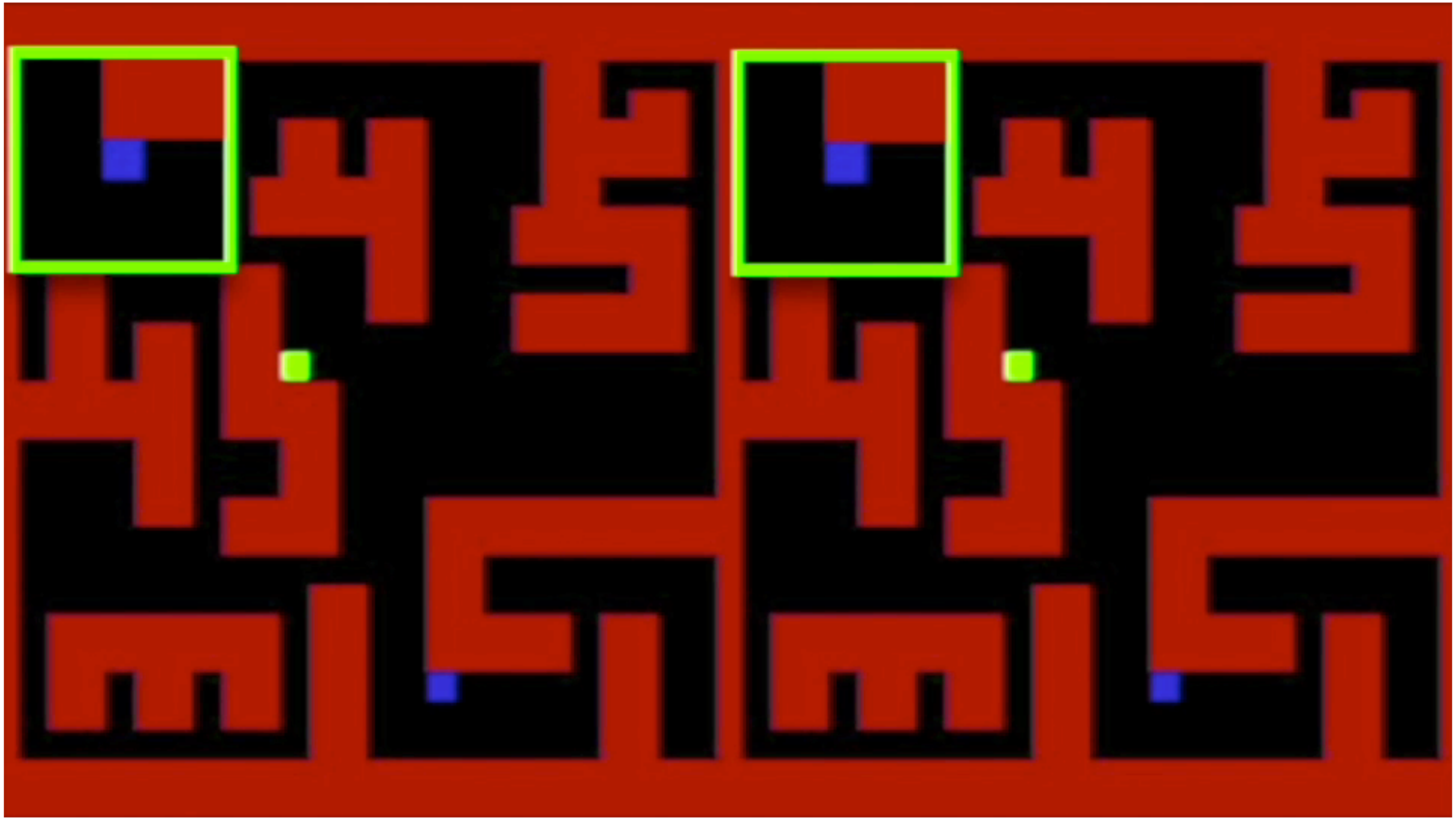
Glare



Low
Lighting

Autonomous Navigation in Outdoor Areas

… and End to End Navigation



Outlook

- With deep learning a new **massively parallel** and **data intensive** paradigm has come up that outperforms classical approaches

- **Deep learning** will play a major role in robotics through the concept of end-to-end learning where **no programming** is needed.

Summary

- Probabilistic methods are a powerful tool for realizing autonomous systems
- The corresponding state estimation procedures provide the means for robust navigation systems