Introduction to Mobile Robotics

Welcome

Lukas Luft, Wolfram Burgard
Today

- This course
- Robotics in the past and today
Organization

- **Wed** 14:00 – 16:00
  - lectures, discussions

- **Fr** 16:00 – 17:00
  - homework, practical exercises (Python)

- **Fr** 17:00 – 18:00
  - homework, practical exercises (Python)

Web page: [www.informatik.uni-freiburg.de/~ais/](http://www.informatik.uni-freiburg.de/~ais/)

- Exam: Oral or written
People

Teaching:
- Wolfram Burgard

Teaching assistants:
- Marina Kollmitz
- Johannes Meyer
- Iman Nematollahi
- Lukas Luft
- Daniel Büscher
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
Reference Book

Thrun, Burgard, and Fox: “Probabilistic Robotics”
Relevant other Courses

- Foundations of Artificial Intelligence
- Computer Vision
- Machine Learning

- and many others from the area of cognitive technical systems.
Opportunities

- Projects
- Practicals
- Seminars
- Thesis

- ... your future!
Tasks Addressed that Need to be Solved by Robots

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

Autonomous Robot Systems

- perceive their environment and
- generate actions to achieve their goals.
Autonomous Robot Systems

World model

Sensor data

Control system

Actions
Robotics Yesterday
Current Trends in Robotics

Robots are moving away from factory floors to

- Entertainment, toys
- Personal services
- Medical, surgery
- Industrial automation (mining, harvesting, ...)
- Hazardous environments (space, underwater)
Shakey the Robot (1966)
Shakey the Robot (1966)
Robotics Today

- Lawn mowers
- Vacuum cleaners
- Self-driving cars
- Logistics
- ...

...
The Helpmate System
Autonomous Vacuum Cleaners
Autonomous Lawn Mowers
DARPA Grand Challenge

[Courtesy by Sebastian Thrun]
Walking Robots

[Courtesy by Boston Dynamics]
Androids

Overcoming the uncanny valley

[Courtesy by Hiroshi Ishiguro]
Driving in the Google Car
Autonomous Motorcycles

[Courtesy by Anthony Levandowski]
The Google Self Driving Car
Folding Towels

Cloth Grasp Point Detection based on Multiple-View Geometric Cues with Application to Robotic Towel Folding

Jeremy Maitin-Shepard
Marco Cusumano-Towner
Jinna Lei
Pieter Abbeel

Department of Electrical Engineering and Computer Science
University of California, Berkeley

International Conference on Robotics and Automation, 2010
Rhino  
(Univ. Bonn + CMU, 1997)
Robotics in Freiburg
Autonomous Parking
Autonomous Quadrotor Navigation

Custom-built system:
laser range finder
inertial measurement unit
embedded CPU
laser mirror
Precise Localization and Positioning for Mobile Robots
Obelix – A Robot Traveling to Downtown Freiburg
The Obelix Challenge
(Aug 21, 2012)
The Tagesthemen-Report

Since the Gaul Obelix
Brain-controlled Robots
Teaching: Student Project on the Autonomous Portrait Robot
Other Cool Stuff from AIS
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
Deep Learning to Manipulate from Parallel Interaction

Source: Google Research Blog
Learning User Preferences

- Task preferences are **subjective**
- Fixed rules do not match all users
- Constantly querying humans is suboptimal
- How to handle new objects?
Collaborative Filtering
Collaborative Filtering

| Flakes | | | |
|--------| | | |
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Online Prediction of Preferences
Localization in Urban Environments

- Inaccurate (if even available) GPS signal
- No map
- Limited Internet
Motivation
Example
Example contin.

Text: irpostbankfmarzcenter tllgi
Matched Landmarks:
- Postbank finanzcenter

Text: melange
Matched Landmarks:
- Melange
- Melange

Text: casanova
Matched Landmarks:
- Casanova
Example
Deep Learning Applications

- RGB-D
  - object recognition

- Images
  - human part segmentation

- Sound
  - terrain classification
DCN for Object Recognition

- Fusion layers automatically learn to combine feature responses of the two network streams.
- During training, weights in first layers stay fixed.

```math
p(y \mid x, d)
```
# Learning Results

**Category-Level Recognition [%] (51 categories)**

<table>
<thead>
<tr>
<th>Method</th>
<th>RGB</th>
<th>Depth</th>
<th>RGB-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNN-RNN</td>
<td>80.8</td>
<td>78.9</td>
<td>86.8</td>
</tr>
<tr>
<td>HMP</td>
<td>82.4</td>
<td>81.2</td>
<td>87.5</td>
</tr>
<tr>
<td>CaRFs</td>
<td>N/A</td>
<td>N/A</td>
<td>88.1</td>
</tr>
<tr>
<td>CNN Features</td>
<td>83.1</td>
<td>N/A</td>
<td>89.4</td>
</tr>
<tr>
<td><strong>This work, Fus-CNN</strong></td>
<td><strong>84.1</strong></td>
<td><strong>83.8</strong></td>
<td><strong>91.3</strong></td>
</tr>
</tbody>
</table>

[Lai et. al, 2011]
Network Architecture

- Fully convolutional network
  - Contraction and expansion of network input
  - Up-convolution operation for expansion
- Pixel input, pixel output
**Deep Learning for Body Part Segmentation**

- **Input Image**
- **Ground Truth**
- **Segmentation mask**

<table>
<thead>
<tr>
<th>Method</th>
<th>Head</th>
<th>Torso</th>
<th>Arms</th>
<th>Legs</th>
<th>IOU</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCN</td>
<td>52.71</td>
<td>62.49</td>
<td>35.04</td>
<td>43.25</td>
<td>43.20</td>
</tr>
<tr>
<td>Ours</td>
<td>80.56</td>
<td>79.45</td>
<td>63.93</td>
<td>64.91</td>
<td>71.99</td>
</tr>
</tbody>
</table>
Deep Learning for Terrain Classification using Sound
Network Architecture

- Novel architecture designed for unstructured sound data
- Global pooling gathers statistics of learned features across time
Data Collection

Wood
Linoleum
Carpet

Wood
Linoleum
Carpet

P3-DX

Asphalt
Mowed Grass
Grass
Paving
Cobble Stone
Offroad
## Results - Baseline Comparison

<table>
<thead>
<tr>
<th>Features</th>
<th>SVM Linear</th>
<th>SVM RBF</th>
<th>k-NN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ginna [1]</td>
<td>44.87 ± 0.70</td>
<td>37.51 ± 0.74</td>
<td>57.26 ± 0.60</td>
</tr>
<tr>
<td>Spectral [2]</td>
<td>84.48 ± 0.36</td>
<td>78.65 ± 0.45</td>
<td>76.02 ± 0.43</td>
</tr>
<tr>
<td>Ginna &amp; Shape [3]</td>
<td>85.50 ± 0.34</td>
<td>80.37 ± 0.55</td>
<td>78.17 ± 0.37</td>
</tr>
<tr>
<td>MFCC &amp; Chroma [4]</td>
<td>88.95 ± 0.21</td>
<td><strong>88.55 ± 0.20</strong></td>
<td>88.43 ± 0.15</td>
</tr>
<tr>
<td>Trimbral [5]</td>
<td>89.07 ± 0.12</td>
<td>86.74 ± 0.25</td>
<td>84.82 ± 0.54</td>
</tr>
<tr>
<td>Cepstral [6]</td>
<td><strong>89.93 ± 0.21</strong></td>
<td>78.93 ± 0.62</td>
<td><strong>88.63 ± 0.06</strong></td>
</tr>
</tbody>
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**98.9% improvement over the previous state of the art**

Thank you

... and enjoy the course!