What is SLAM?

Estimate the robot’s path and the map

\[ p(x_{0:T}, m | z_{1:T}, u_{1:T}) \]

distribution  path  map  given  observations  controls
The SLAM Problem

- SLAM is a *chicken-or-egg* problem:
  - a map is needed for localization and
  - a pose estimate is needed for mapping
Three Main Paradigms

Kalman filter

Particle filter

Graph-based
Graphical Model of Full SLAM

\[ p(x_{0:T}, m \mid z_{1:T}, u_{1:T}) \]
Graphical Model of Online SLAM

\[ p(x_{t+1}, m \mid z_{1:t+1}, u_{1:t+1}) \]
What You Should Have Learned

- SLAM problem
- Build landmark and grid maps
- EKF SLAM
- SEIF SLAM
- Particle filter-based SLAM
- Graph-based SLAM
- Front-Ends
- Hands-on experience (programming)
- Understand average SLAM papers
Comparison of Approaches

- KF
- EKF
- UKF
- EIF
- SEIF
- FastSLAM
- Grid-FastSLAM
- Graph-Based SGD/TORO
- Graph-Based GN & LM
Where Do You See Open Issues?
Open Issues in SLAM

- Dynamic environments
- Systematically changing environments
- Seasonal changes
- Online solutions
- Life-long operation
- Resource-constraint systems
- Failure recovery/zero user intervention
- Exploiting prior knowledge
- Robots sharing maps
Sensor-Related Issues

- Efficient data association
- Sensor-related limitations such as:
  - Poorly structured scenes
  - Missing light for vision
  - Monocular SLAM (in large environments)
Course Evaluation
Learning Achievement

Stimme voll zu | strongly agree
Stimme zu | somewhat agree
Teils-teils | undecided
Stimme nicht zu | somewhat disagree
Stimme gar nicht zu | strongly disagree
Nicht zutreffend | not applicable
Content Level

- Zu hoch | too high
- Hoch | rather high
- Angemessen | appropriate
- Niedrig | rather low
- Zu niedrig | too low
- Nicht zutreffend | not applicable
Connections to Other Courses

- Stimme voll zu | strongly agree
- Stimme zu | somewhat agree
- Teils-teils | undecided
- Stimme nicht zu | somewhat disagree
- Stimme gar nicht zu | strongly disagree
- Nicht zutreffend | not applicable

Graph showing the distribution of responses.
Central Theme is Clear

- Stimme voll zu | strongly agree
- Stimme zu | somewhat agree
- Teils-teils | undecided
- Stimme nicht zu | somewhat disagree
- Stimme gar nicht zu | strongly disagree
- Nicht zutreffend | not applicable
Quality of Explanations

- Stimme voll zu | strongly agree
- Stimme zu | somewhat agree
- Teils-teils | undecided
- Stimme nicht zu | somewhat disagree
- Stimme gar nicht zu | strongly disagree
- Nicht zutreffend | not applicable
Response to Questions

0 2 4 6 8 10 12

Stimme voll zu | strongly agree
Stimme zu | somewhat agree
Teils-teils | undecided
Stimme nicht zu | somewhat disagree
Stimme gar nicht zu | strongly disagree
Nicht zutreffend | not applicable
Tutorials are a Good Addition to the Lecture
Explanations of the Tutors Are Helpful

- Stimme voll zu | strongly agree
- Stimme zu | somewhat agree
- Teils-teils | undecided
- Stimme nicht zu | somewhat disagree
- Stimme gar nicht zu | strongly disagree
- Nicht zutreffend | not applicable
I liked...

- “Slides, material, recordings”
- “Explanations”
- “Discussions in the course”
- “Intermediate feedback”
- “Alignment of course and exercises”
- “No boring framework programming”
- “I really like the course and don't think there is too much space for improving it”
Could Be Improved...

- “Programming everything would be ideal although probably difficult...”
- “I would love to have a testing strategy whether the program works correctly”
- “I don't feel like the exercises have prepared me well for the exam (more non-programming exercises)”
Could Be Improved…

- “I would love to see more examples on how the theory fits to the final implementation and what are the most common pitfalls”
- “I would gladly give more time for a more extensive summary and introduction to each lecture and how that fits into the overall course”
- “Discuss more of the open research questions”
Course Evaluation

Thank you!
Which Topics Did You Miss?

(and what should be discarded then)
SS’13: Introduction to Mobile Robotics

Mondays 10-12 and Tuesdays 10-12
Good Luck for the Exam

(visit me or the tutors if you have questions during the preparation)