

## What is SLAM?

Estimate the robot's path and the map

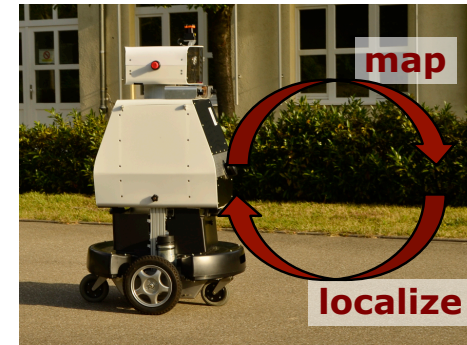
$$p(x_{0:T}, m \mid z_{1:T}, u_{1:T})$$

distribution path map given observations controls

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## The SLAM Problem

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



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## Three Main Paradigms

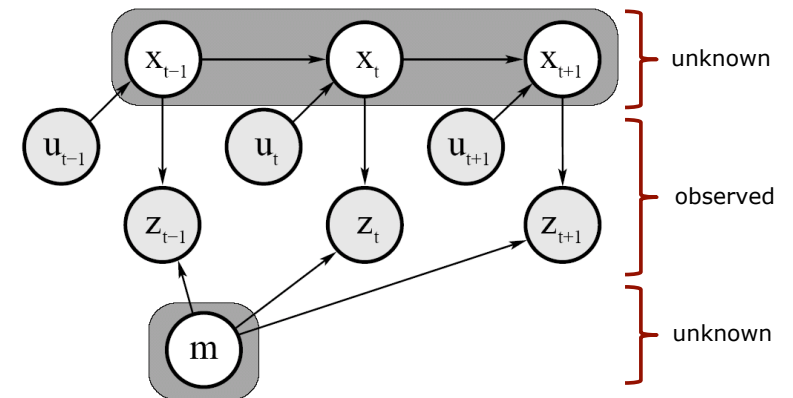
Kalman filter

Particle filter

Graph-based

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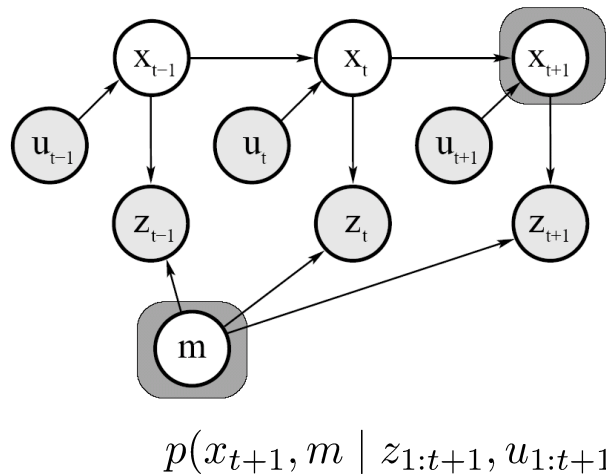
## Graphical Model of Full SLAM



$$p(x_{0:T}, m \mid z_{1:T}, u_{1:T})$$

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## Graphical Model of Online SLAM



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## 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

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## Comparison of Approaches

- KF
- EKF
- UKF
- EIF
- SEIF
- FastSLAM
- Grid-FastSLAM
- Graph-Based SGD/TORO
- Graph-Based GN & LM

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## Where Do You See Open Issues?

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## 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

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## Sensor-Related Issues

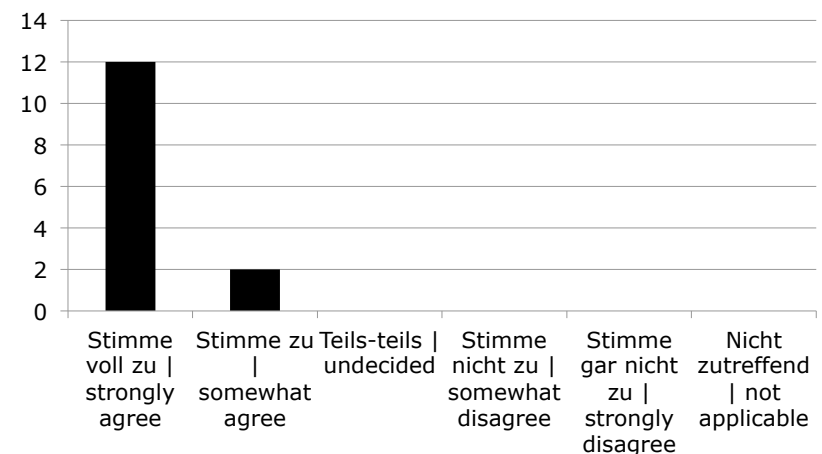
- Efficient data association
- Sensor-related limitations such as:
  - Poorly structured scenes
  - Missing light for vision
  - Monocular SLAM  
(in large environments)

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## Course Evaluation

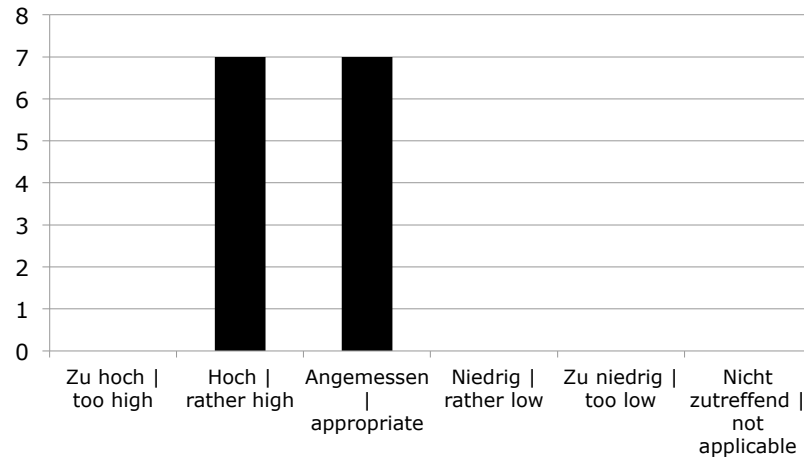
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## Learning Achievement



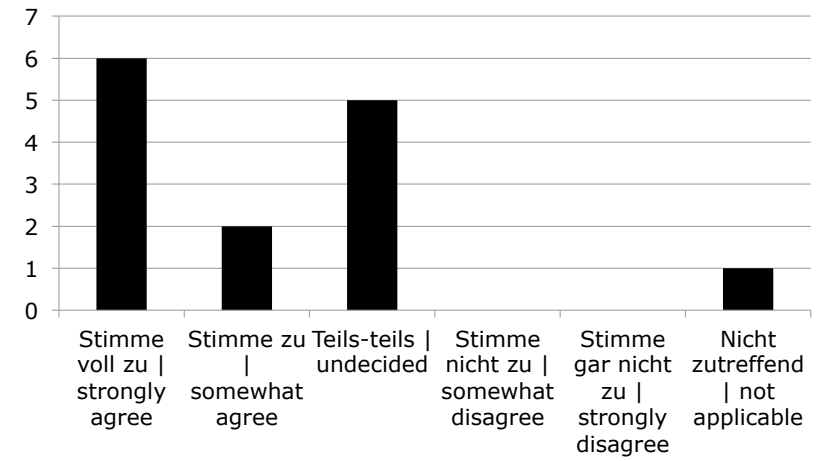
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## Content Level



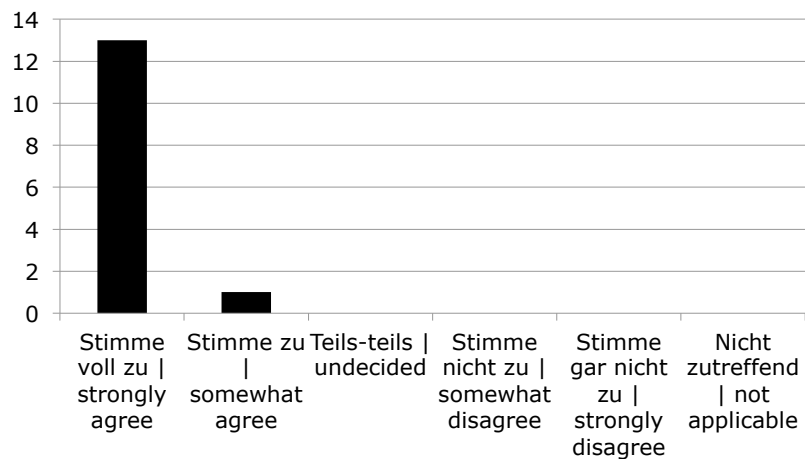
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## Connections to Other Courses



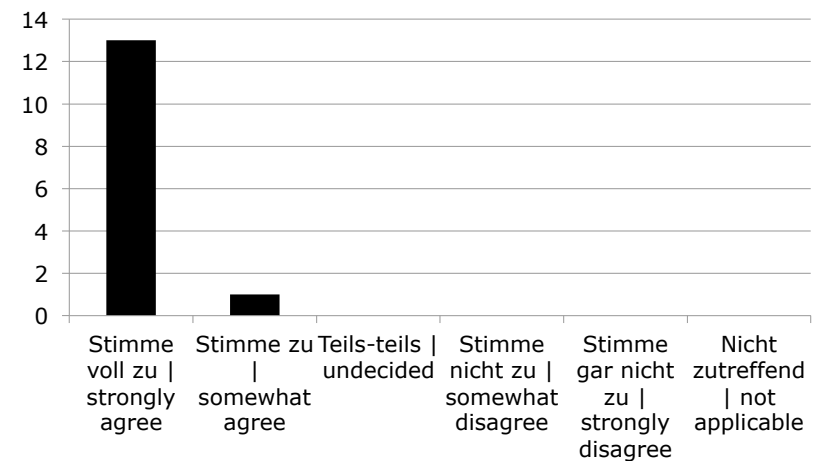
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## Central Theme is Clear



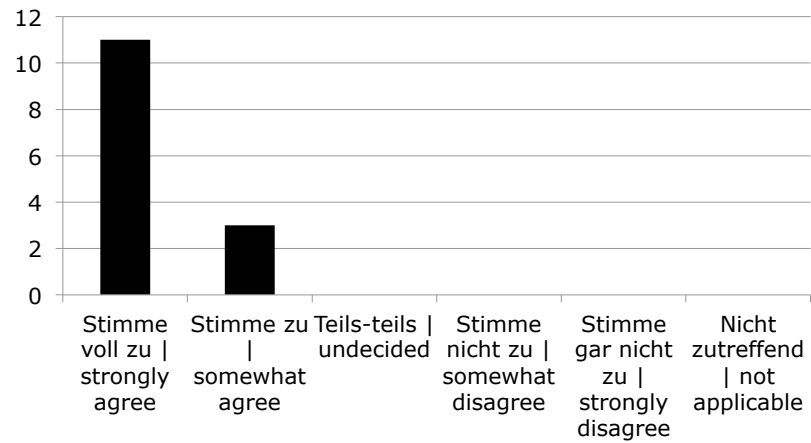
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## Quality of Slides & Material



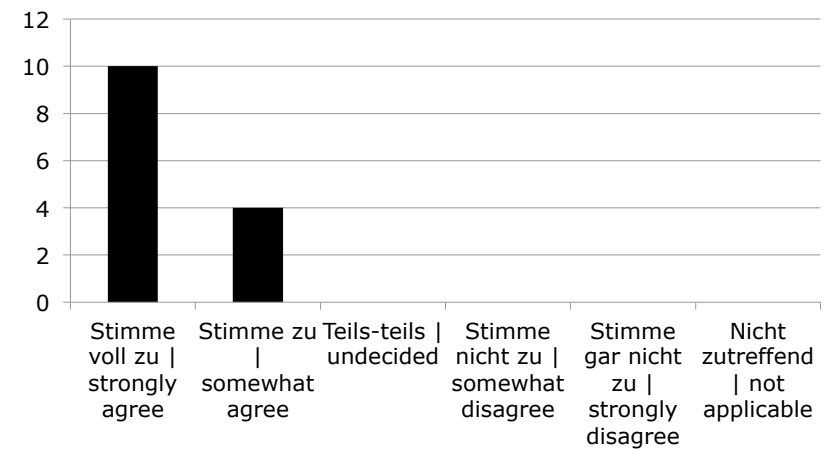
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## Quality of Explanations



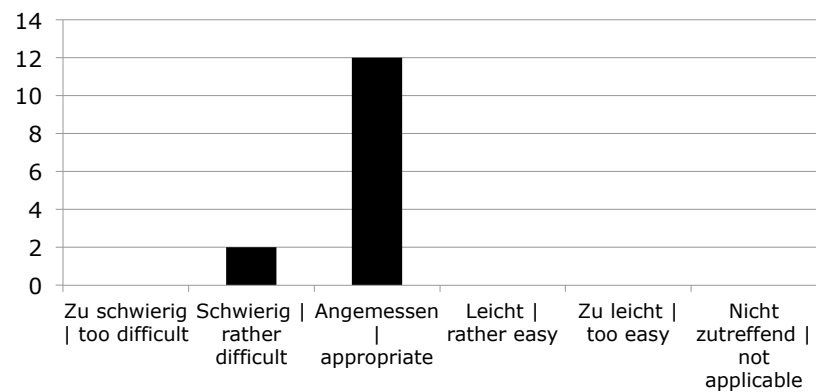
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## Response to Questions



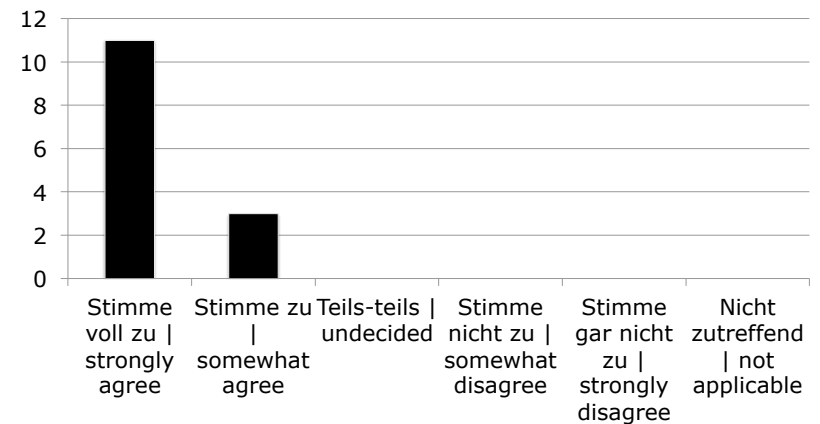
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## Difficulty of the Exercises



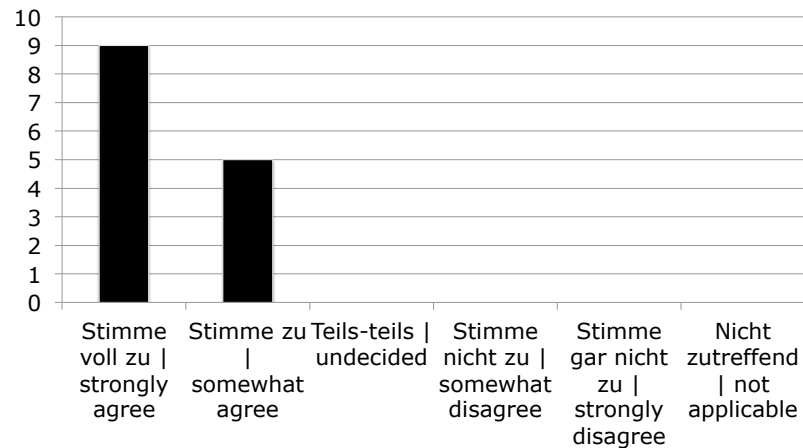
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## Tutorials are a Good Addition to the Lecture



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## Explanations of the Tutors Are Helpful



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## 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"

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## 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)"

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## 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"

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## Course Evaluation

**Thank you!**

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## Which Topics Did You Miss?

(and what should be discarded then)

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## SS'13: Introduction to Mobile Robotics

Mondays 10-12 and Tuesdays 10-12

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## Good Luck for the Exam

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

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