SLAM

Survey: Simultaneous Localization and Mapping

Martin Poppinga

T|A
M|S

University of Hamburg
Faculty of Mathematics, Informatics and Natural Sciences
Department of Informatics

Technical Aspects of Multimodal Systems

23. November 2015

Outline

Outline

Mobile Robotics

- ▶ (Partly) autonomous Systems
- ▶ Many applications
  - ▶ SAR (Search and Rescue)
  - ▶ Exploration (Areal, Underwater, Space)
  - ▶ Service
- ▶ Challenges
  - ▶ Mapping
  - ▶ Localization

SLAM

- ▶ Challenge
  - ▶ Map → Localization
  - ▶ Localization → Map
  - ▶ Chicken-egg problem
- ▶ SLAM brings this together
- ▶ Different approaches
  - ▶ Filtering
  - ▶ Sensors

Outline

History

- ▶ First steps
  - ▶ In mid 80s
  - ▶ Mapping and localization
  - ▶ Limited in computation power
- ▶ Breakthrough
  - ▶ In mid 90s
  - ▶ Convergence of errors
  - ▶ Mapping and localization together
  - ▶ Demonstration on real systems
- ▶ Wide interest in 2000s
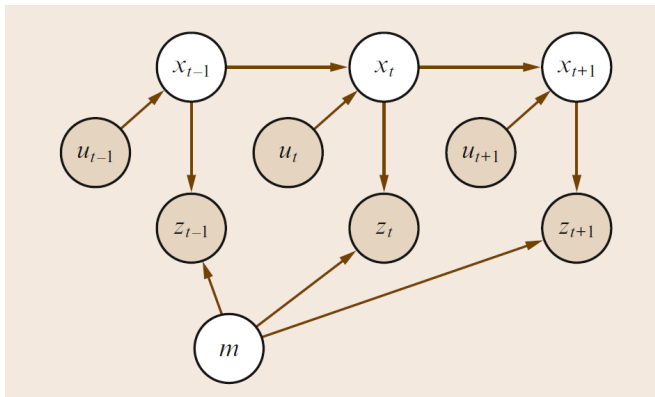
Outline

University of Hamburg

Definition

- ▶ Existing information
  - ▶ robots Controls / odometry
    - ▶ $U_T = \{u_1, u_2, u_3, ... u_T\}$
  - ▶ Observations
    - ▶ $Z_T = \{z_1, z_2, z_3, ... z_T\}$
- ▶ Needed information
  - ▶ Map (with its features)
    - ▶ m
  - ▶ Path of the robot
    - ▶ $X_T = \{x_0, x_1, x_2, ... x_T\}$

Graphical Model

[3]

Probabilistic SLAM

- ▶ World is not perfect!
- ▶ Full SLAM
  - ▶ $p(X_T, m | Z_T, U_T)$
- ▶ Online SLAM
  - ▶ $p(x_t, m | Z_T, U_T)$
- ▶ This has to be estimated
- ▶ Different problems different estimators
- ▶ Choosing one based on the problem

Different Problems

- ▶ **Static vs dynamic**
- ▶ Volumetric vs feature based
- ▶ Topologic vs metric
- ▶ Known vs unknown correspondence
- ▶ Large vs small uncertainty
- ▶ Active vs passive
- ▶ Single- vs multiagent
- ▶ Any time and any space
- ▶ ⇒ Lots of different approaches

Different Problems

- ▶ Static vs dynamic
- ▶ Volumetric vs feature based
- ▶ Topologic vs metric
- ▶ Known vs unknown correspondence
- ▶ Large vs small uncertainty
- ▶ Active vs passive
- ▶ Single- vs multiagent
- ▶ Any time and any space
- ▶ ⇒ Lots of different approaches

Different Problems

- ▶ Static vs dynamic
- ▶ Volumetric vs feature based
- ▶ Topologic vs metric
- ▶ Known vs unknown correspondence
- ▶ Large vs small uncertainty
- ▶ Active vs passive
- ▶ Single- vs multiagent
- ▶ Any time and any space
- ▶ ⇒ Lots of different approaches

Different Problems

- ▶ Static vs dynamic
- ▶ Volumetric vs feature based
- ▶ Topologic vs metric
- ▶ Known vs unknown correspondence
- ▶ Large vs small uncertainty
- ▶ Active vs passive
- ▶ Single- vs multiagent
- ▶ Any time and any space
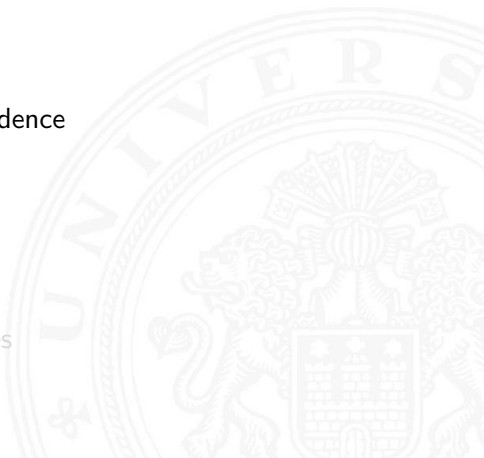- ▶ ⇒ Lots of different approaches

Different Problems

- ▶ Static vs dynamic
- ▶ Volumetric vs feature based
- ▶ Topologic vs metric
- ▶ Known vs unknown correspondence
- ▶ Large vs small uncertainty
- ▶ Active vs passive
- ▶ Single- vs multiagent
- ▶ Any time and any space
- ▶ ⇒ Lots of different approaches

Different Problems

- ▶ Static vs dynamic
- ▶ Volumetric vs feature based
- ▶ Topologic vs metric
- ▶ Known vs unknown correspondence
- ▶ Large vs small uncertainty
- ▶ Active vs passive
- ▶ Single- vs multiagent
- ▶ Any time and any space
- ▶ ⇒ Lots of different approaches

Different Problems

- ▶ Static vs dynamic
- ▶ Volumetric vs feature based
- ▶ Topologic vs metric
- ▶ Known vs unknown correspondence
- ▶ Large vs small uncertainty
- ▶ Active vs passive
- ▶ Single- vs multiagent
- ▶ Any time and any space
- ▶ ⇒ Lots of different approaches

Different Problems

- ▶ Static vs dynamic
- ▶ Volumetric vs feature based
- ▶ Topologic vs metric
- ▶ Known vs unknown correspondence
- ▶ Large vs small uncertainty
- ▶ Active vs passive
- ▶ Single- vs multiagent
- ▶ Any time and any space
- ▶ ⇒ Lots of different approaches

Different Problems

- ▶ Static vs dynamic
- ▶ Volumetric vs feature based
- ▶ Topologic vs metric
- ▶ Known vs unknown correspondence
- ▶ Large vs small uncertainty
- ▶ Active vs passive
- ▶ Single- vs multiagent
- ▶ Any time and any space
- ▶ ⇒ Lots of different approaches

Sensing

- Range
  - Laser Range sensors
  - Sonar
  - Tactile
  - ...
- Visual
  - Camera
  - 3D Camera
- Other
  - Wi-fi
  - Sound
  - ...

Algorithm

- ▶ Handling the errors
  - ▶ Location
  - ▶ Landmark sensing
- ▶ Features in m
- ▶ Measurement model
- ▶ Motion model
- ▶ Three main filter types
- ▶ Will be partly presented in IR lecture

Filters

- ▶ Kalman Filter
  - ▶ The original technique in SLAM
  - ▶ Reduction of errors
  - ▶ Mathematical model
- ▶ Particle Filter
  - ▶ Sequential Monte Carlo
  - ▶ Particle for possible locations
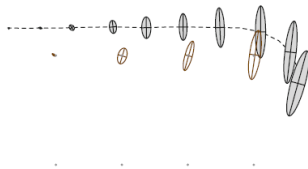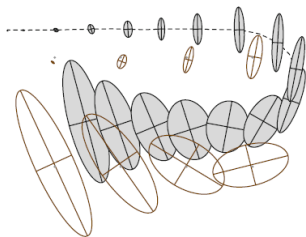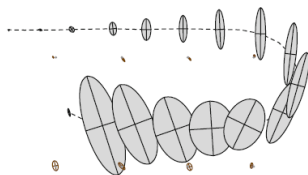- ▶ Graph Based

University of Hamburg

Outline

EKF SLAM

- ▶ First variants of SLAM
- ▶ Kalman-filter based
- ▶ Standard kalman filter
- ▶ Provisional landmark list

a)

b)

c)

d)

[3]
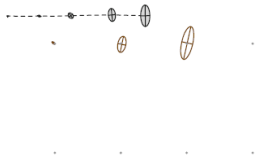
FastSLAM

- ▶ Particle Filter
- ▶ Each particle one Position
- ▶ Rao-Blackwellization
- ▶ Independent features
- ▶ No revising of path on the fly
- ▶ Performance
- ▶ Widely used

GraphSLAM

- ▶ Builds graph
  - ▶ Movement
  - ▶ Observations
- ▶ Flexible edges

Which to Use?

- ▶ Depends
- ▶ EKF SLAM
  - ▶ Quadratic with landmarks
  - ▶ Big maps problematic (submaps)
- ▶ GraphSLAM
  - ▶ Elegant solution
  - ▶ Full SLAM / offline
- ▶ FastSLAM
  - ▶ Data association
  - ▶ Efficient

DARPA

- ▶ US military research
- ▶ Self driving cars in desert
- ▶ GPS not precise enough
- ▶ Stanley, winner grand challenge 2005

Project Tango

- ▶ Project by Google
- ▶ Phablet with special hardware
- ▶ Devkit available
- ▶ Targeted to consumer market

Outline

Current & Future Research

- ▶ Popular on conferences
- ▶ Optimization
  - ▶ Computation power
  - ▶ Sensors
  - ▶ Algorithms
- ▶ New environments
  - ▶ Air
  - ▶ Underwater
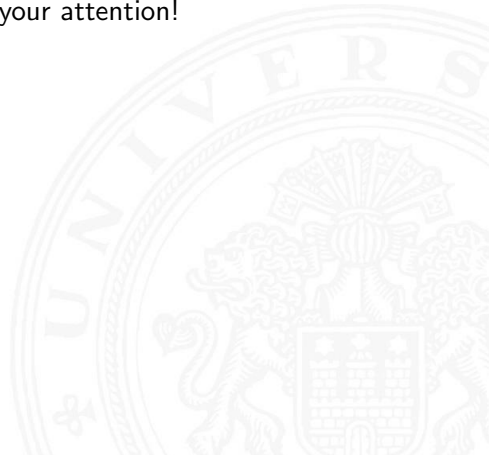- ▶ Feature matching
- ▶ Loop closure

Conclusion

- ▶ First productive systems
- ▶ Need improvement
- ▶ General purpose algorithm difficult
- ▶ Sensor quality important
- ▶ Frameworks & Tools
  - ▶ ROS
  - ▶ OpenSLAM
  - ▶ Mobile Robot Programming Toolkit (MRPT)
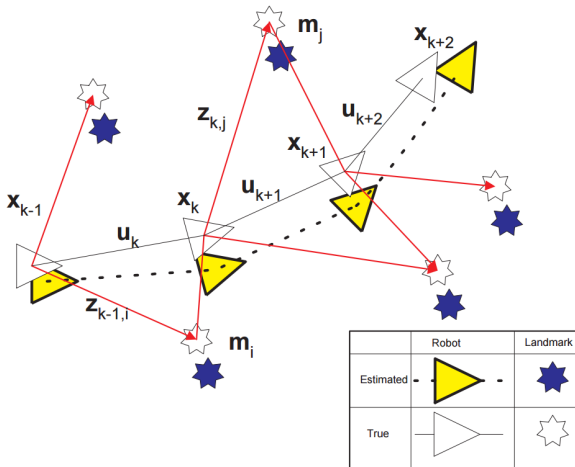
Thank you for your attention!

References

[1] J Aulinas, YR Petillot, J Salvi, and X Lladó.
    The slam problem: a survey.
    CCIA, 2008.

[2] H. Durrant-Whyte and T. Bailey.
    Simultaneous localization and mapping: part i.
    IEEE Robotics & Automation Magazine, 13(2):99–110, 6 2006.

[3] B Siciliano and O Khatib.
    Springer handbook of robotics.
    2008.

University of Hamburg

The SLAM Problem

[2]