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Autonome Mobile Serviceroboter

Landmark Rating and Selection According to Localization Coverage

Addressing the challenge of lifelong operation of SLAM in service robots

Siegfried Hochdorfer, Christian Schlegel

Department of Computer Science

University of Applied Sciences Ulm, Germany

http://www.zafh-servicerobotik.de/ULM/en/index.php

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Outline

- Introduction / Problem description
- Landmark rating and selection
- Real world experiment
- Conclusions and future work

Video: Visual SLAM in everyday environments

Problem description:

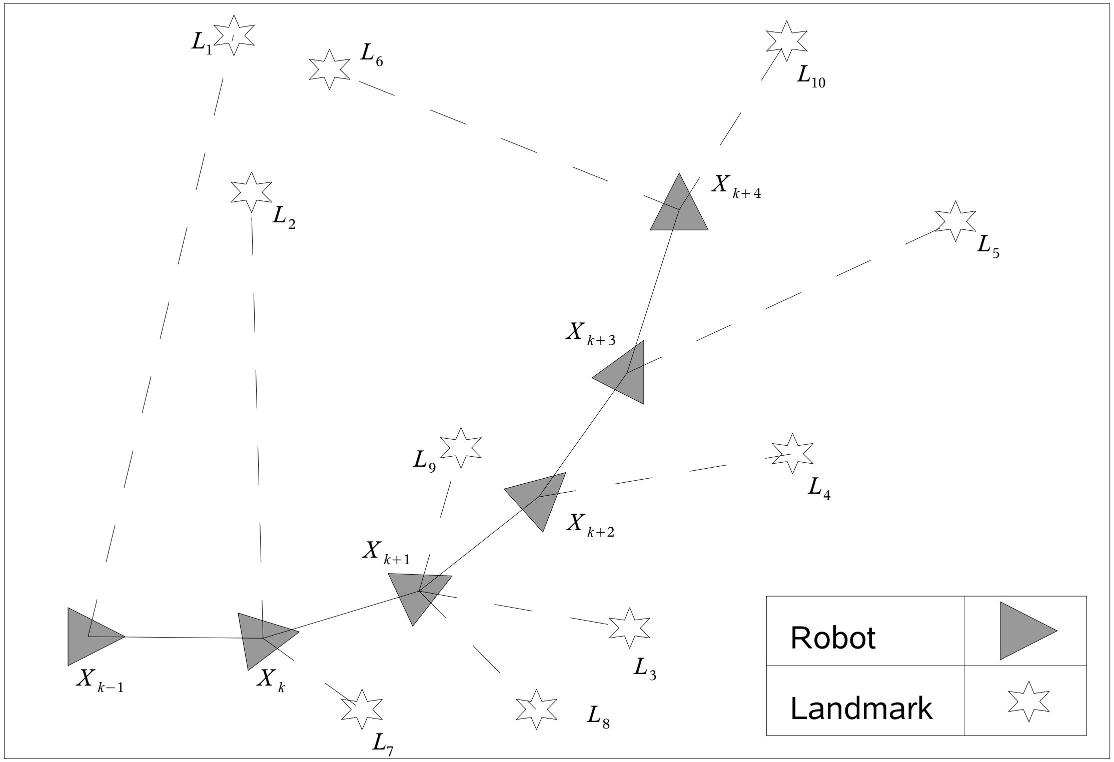
Service robots should be designed for life-long and robust operation in dynamic environments.

Problem description

- **Goal:** life-long operation
- **Problem:**
  - Typically, feature based SLAM approaches just accumulate features over time and do not discard them anymore.
  - Therefore, the required resources in terms of memory and processing power are growing over time.
- **Solution:**
  - Restrict the absolute number of landmarks by an upper bound.
  - Evaluate landmarks based on their utility for localization purposes which is different from just replacing the most uncertain landmark.

Problem description

Feature-Based EKF SLAM



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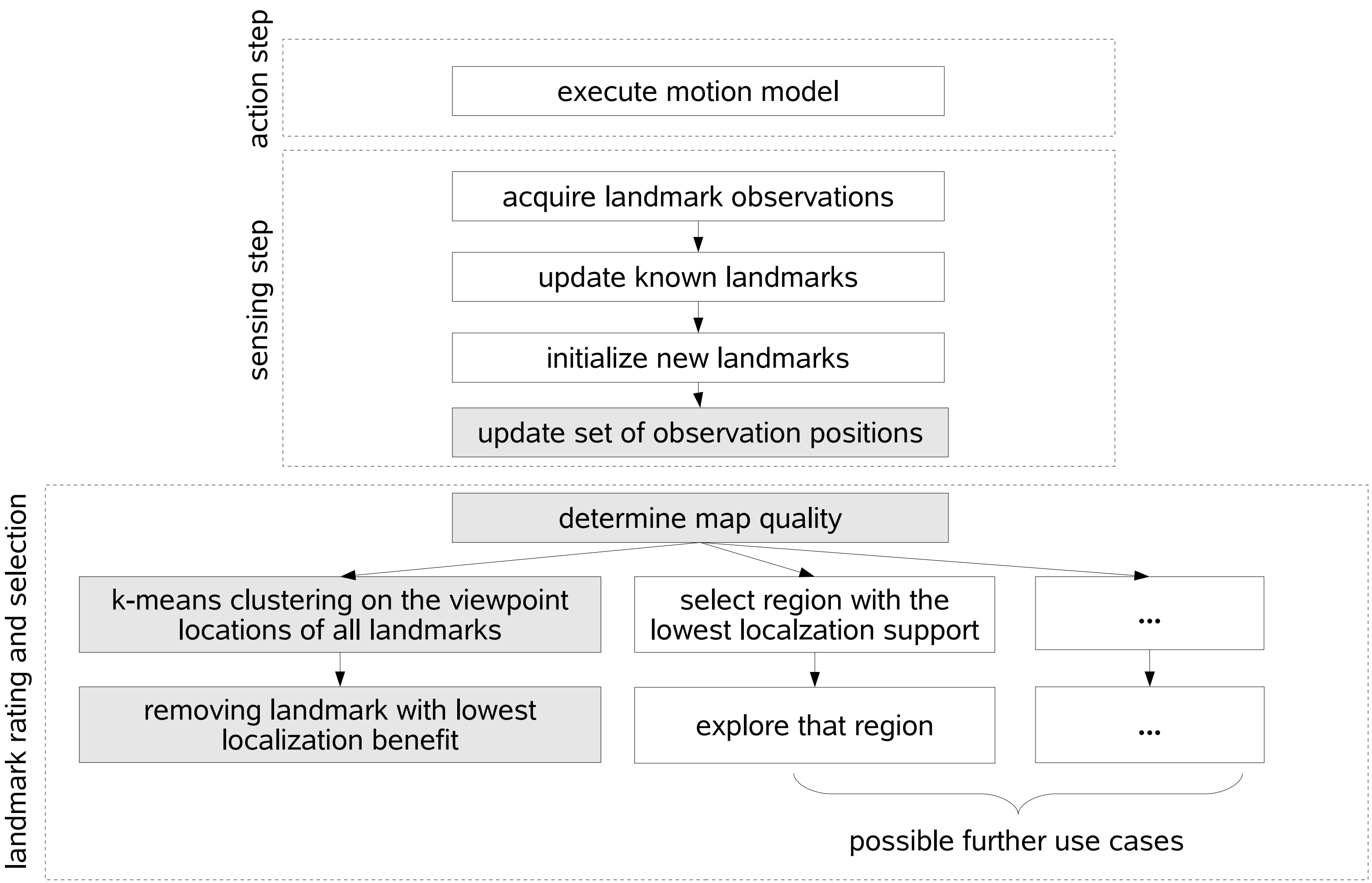
System Overview



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EKF SLAM with delayed Landmark initialization (Bailey [1])

$$x=\left[x_v^T, x_{v_m}^T, \ldots, x_{v_1}^T, x_{f_1}^T, \ldots, x_{f_n}^T\right]$$

state vector

$$x_v=\left[x_v, y_v, \varphi_v\right]^T$$

vehicle pose (constant size)

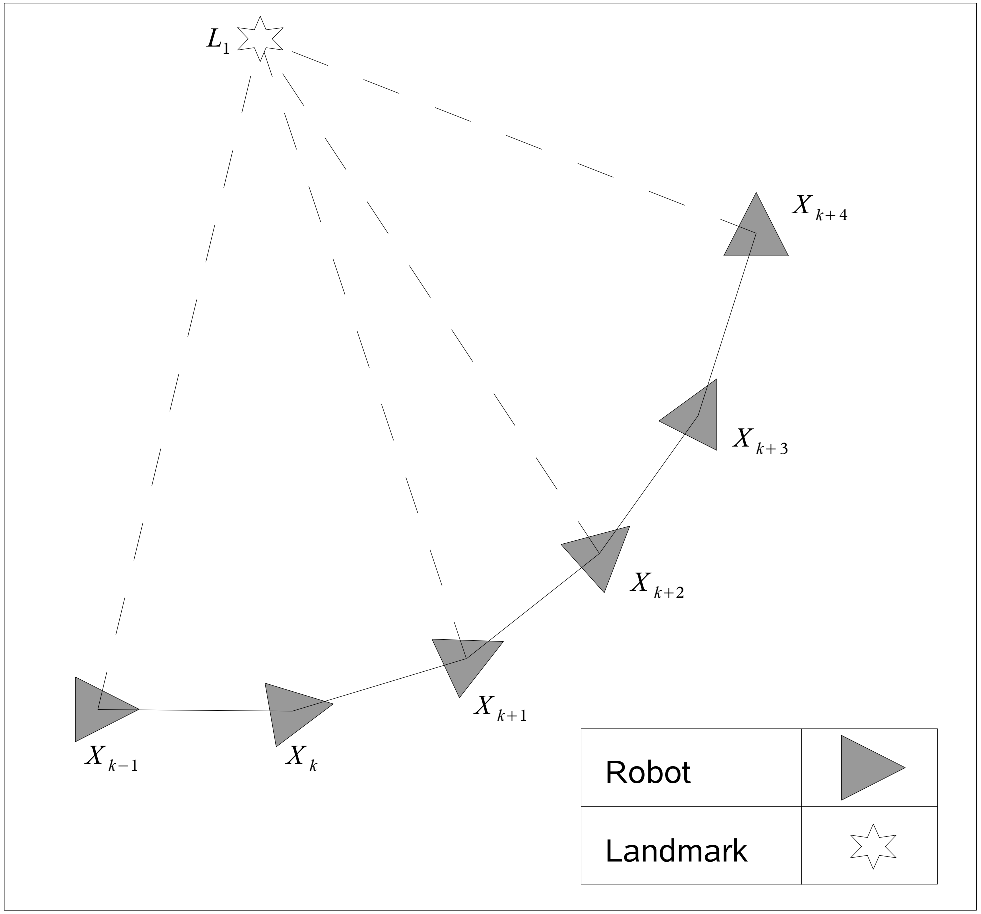
$$x_{v_i}=\left[x_{v_i}, y_{v_i}, \varphi_{v_i}\right]^T$$

observation pose where not yet evaluated measurements are available (growing over time)

$$x_{f_i}=\left[x_{f_i}, y_{f_i}\right]^T$$

initialized landmarks (growing over time)

Landmark rating and selection



- The position of a landmark does not itself give a hint on its usefulness for localizing a robot.
- In fact, we require to know the poses from which a landmark can be observed to know in which parts of an environment this landmark can be used for localization purposes.
- represent the observability region of each landmark by calculating arithmetic mean of the observation poses

Landmark rating and selection

Landmark observability region representation

- calculating recursive the arithmetic mean E(X)

$$E(X_{new}) = \frac{(n-1)E(X_{old}) + X_n}{n}$$

$$E(X_{old}) = \text{previous mean}$$
$$X_n = \text{current observation pose}$$
$$n = \text{number of observations}$$

Calculation of Information Content of a Landmark

covariance matrix

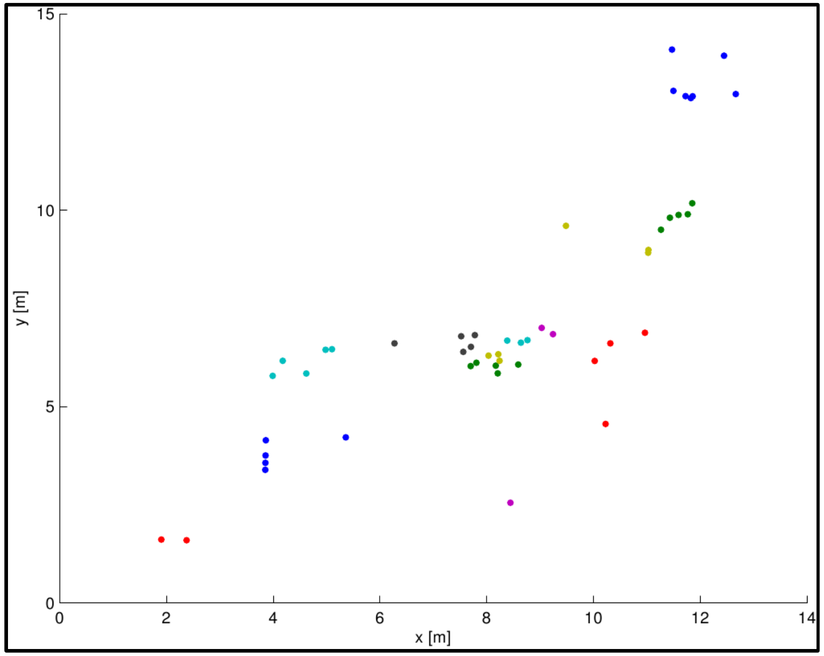
$$cov(L) = \begin{bmatrix} \sigma_{xx}^2 & \sigma_{yx}^2 \\ \sigma_{xy}^2 & \sigma_{yy}^2 \end{bmatrix}$$

Information content Dissanayake[2]:

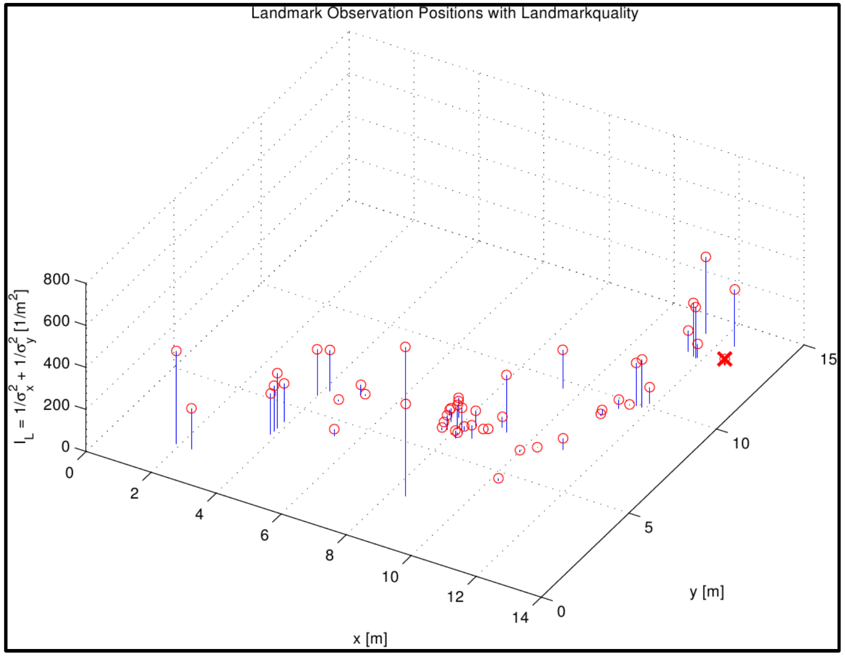
$$I_L = \frac{1}{\sigma_{xx}^2} + \frac{1}{\sigma_{yy}^2}$$

Landmark rating and selection

Select Landmark with Lowest Localization Benefit



A cluster comprises several landmark representatives. All representatives belonging to a cluster are drawn with the same color.

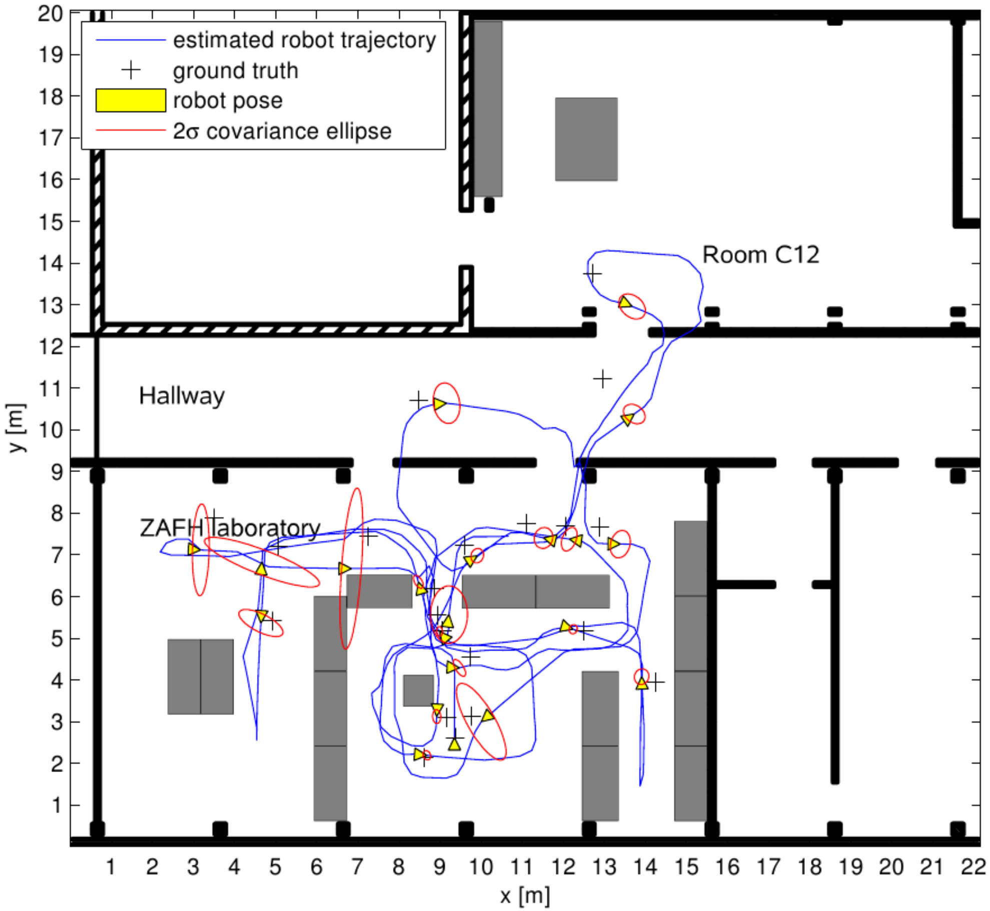


For all landmarks, the estimated observation positions are plotted with the information content on the z-axis. The landmark with the lowest benefit for localization is marked by a red cross.

Results

Experimental Setup

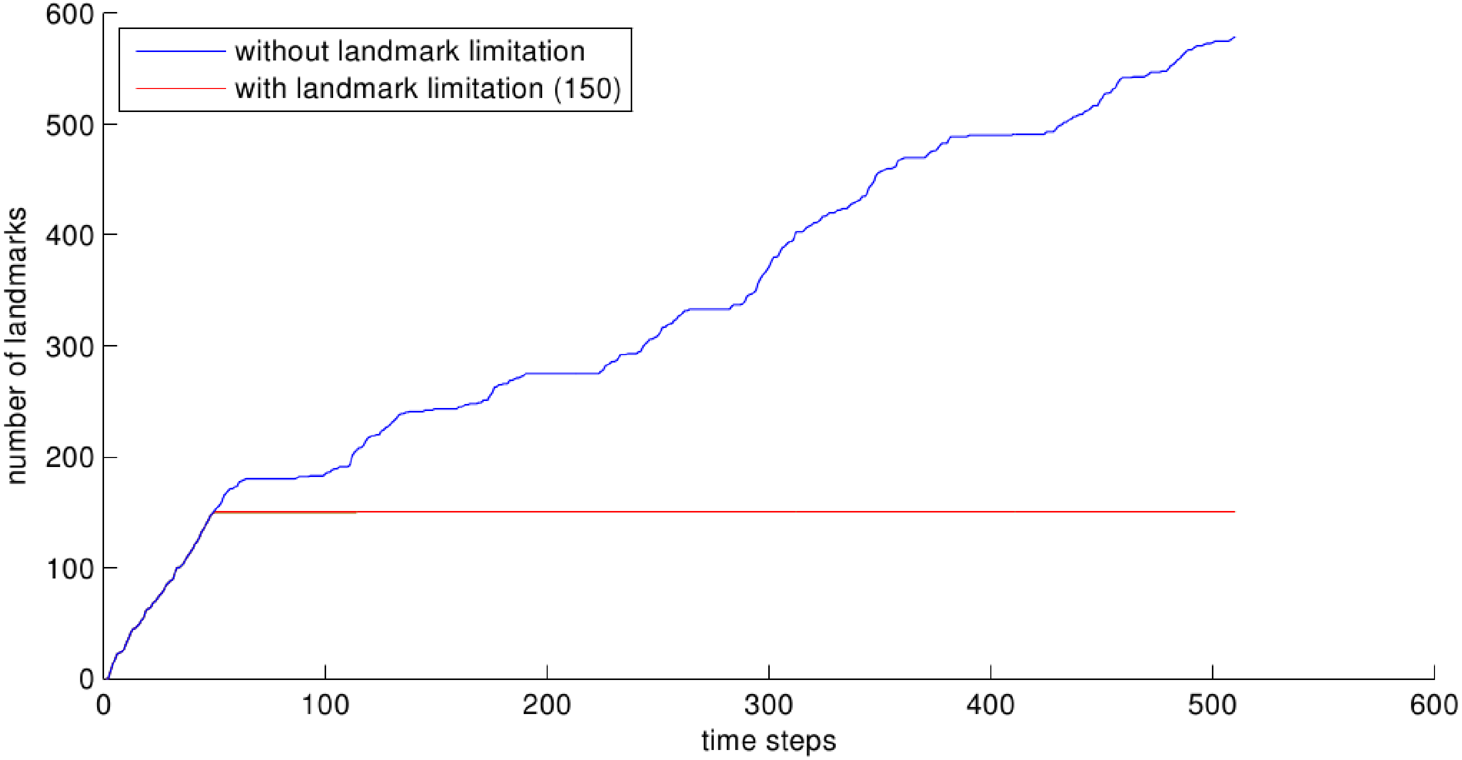
Results



- EKF based bearing-only SLAM
- indoor environment
- varying lighting conditions
- landmark limit = 150
- dynamic objects (persons)
- path length = 150m
- 510 time steps

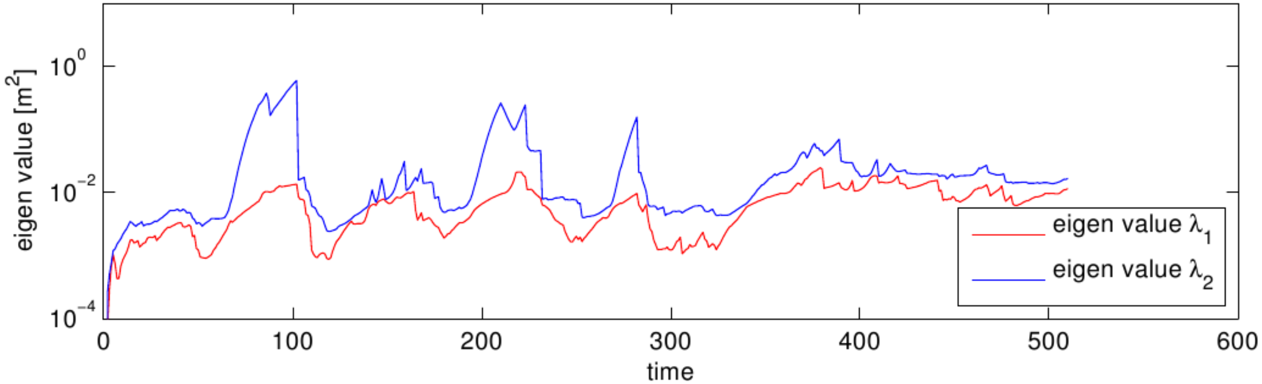
Results

Number of landmarks during the experiments

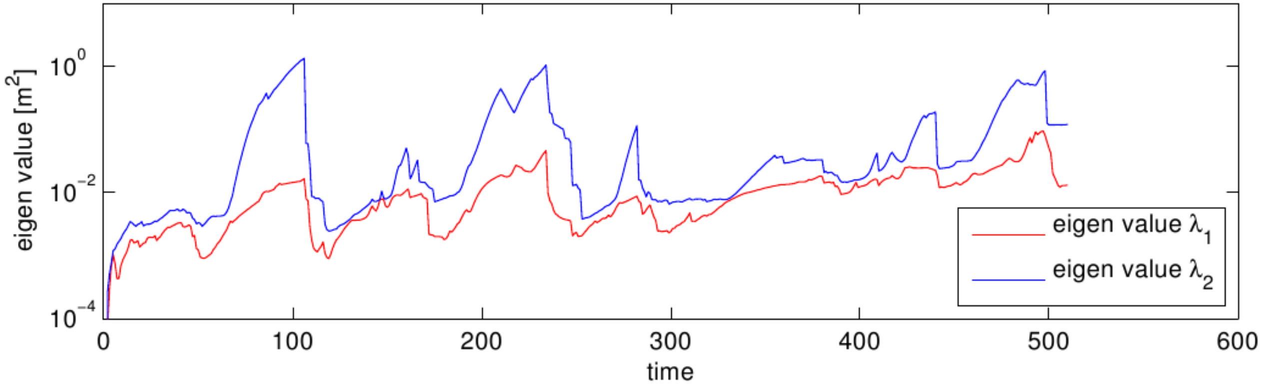


Results

Eigen values of the robot position covariance matrix during the run.



without landmark limitation



with landmark limitation (150)

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Conclusions And Future Work

Conclusions:

- The approach successfully solved the SLAM task even with limited system resources
- Suitability for daily use as mandatory in service robotics

Future Work:

- We will focus on evaluating further approaches for landmark rating
- Improve the representation of landmark observability regions
- Integration into a SmartSoft Component (http://smart-robotics.sourceforge.net/)

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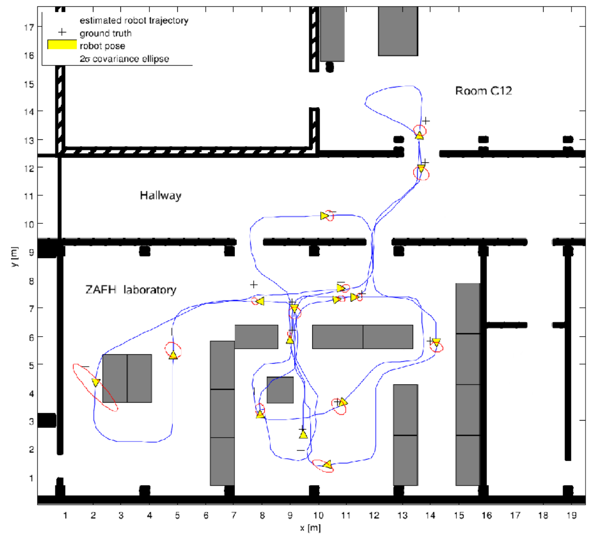
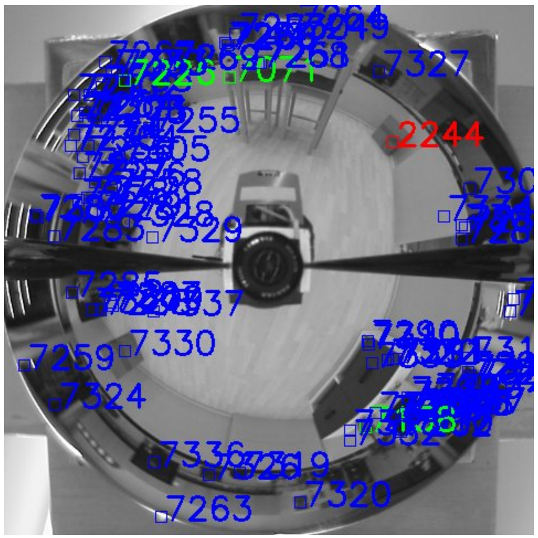
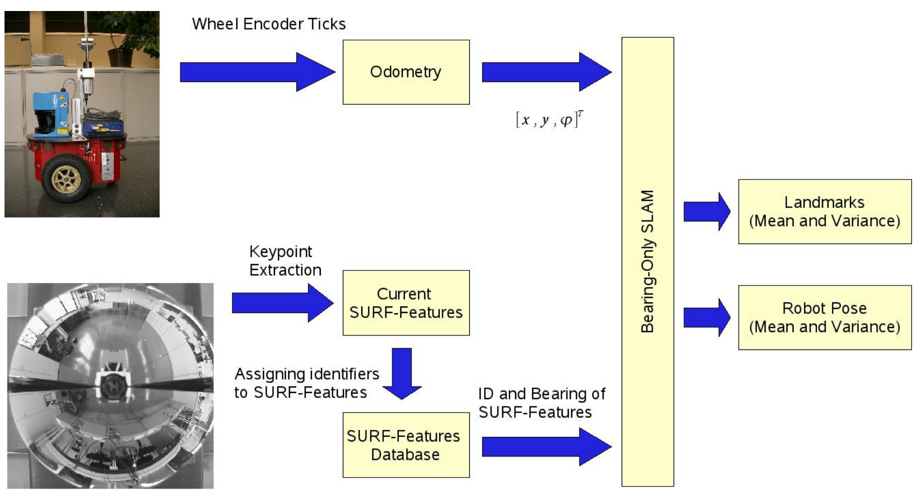
Questions?







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References

[1] Bailey, T. (2003). Constrainted Initialisation for Bearing-Only SLAM, Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), pp. 1966-1971, Taipei, Taiwan

[2] G. Dissanayake, H. F. Durrant-Whyte, and T. Bailey, “A Computationally Efficient Solution to the Simultaneous Localisation and Map Building (SLAM) Problem,” in IEEE International Conference on Robotics and Automation (ICRA), 2000, pp. 1009–1014.