Towards a robust Visual SLAM Approach: Addressing the Challenge of life long Operation

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Problem description:

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

==> goal 1: life-long operation

==> goal 2: robust operation in dynamic environments

Problem description

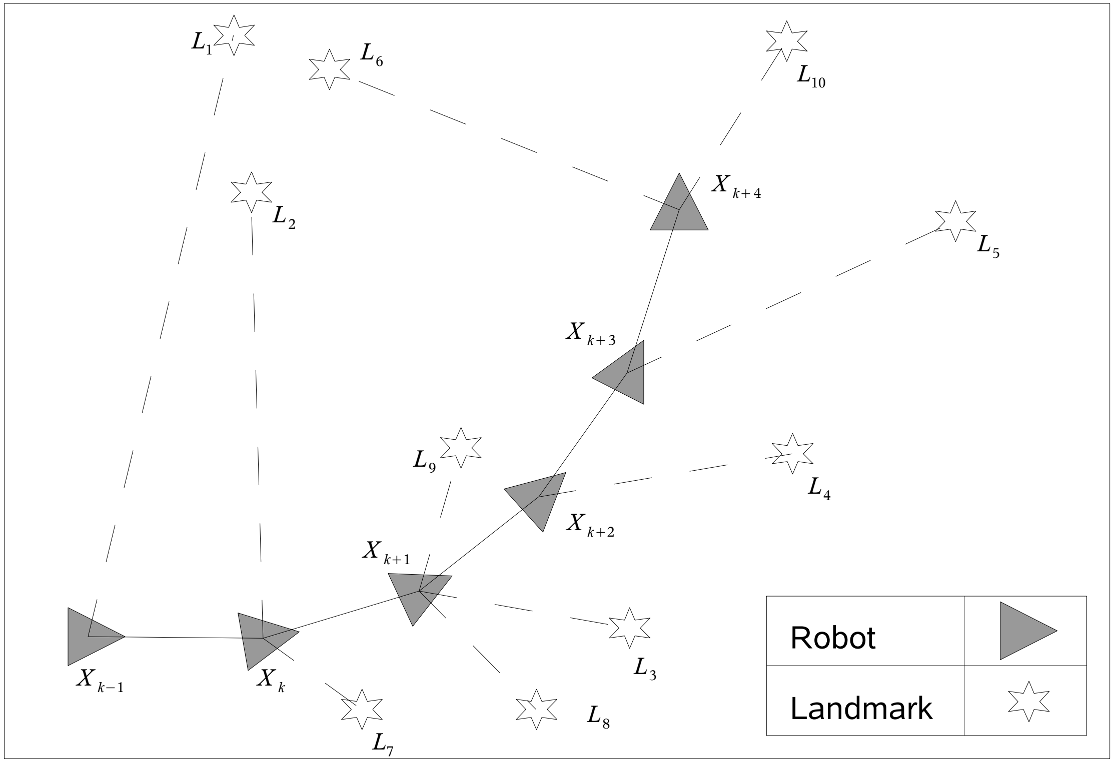
- **Goal 1:**
  - life-long operation

- **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



EKF SLAM

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

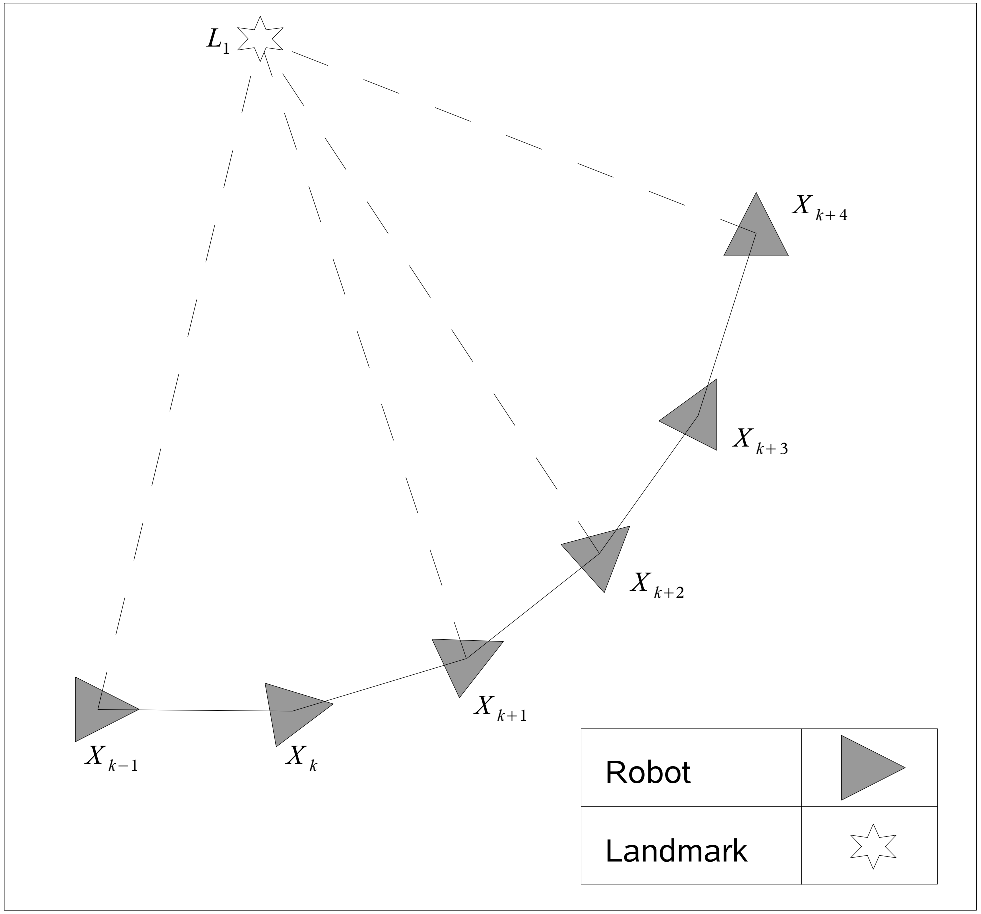
$$x=\left[x_v^T, x_{v_m}^T, \ldots, x_1^T, x_{f_1}^T, \ldots, x_{f_n}^T\right]$$ state vector

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

$$x_{v_i}=\left[x_{v_i}, y_{v_i}, \varphi_{v_i}\right]^T$$ observation pose where not yet evaluated measurements are available

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

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 recursive the arithmetic mean

$$E(X_{new}) = \frac{n\,E(X_{old}) + X_{i+1}}{n_{old}+1}$$

Landmark rating and selection

Recursive Observation pose estimation

- Berechnung der Beobachtungsposition (E(X))

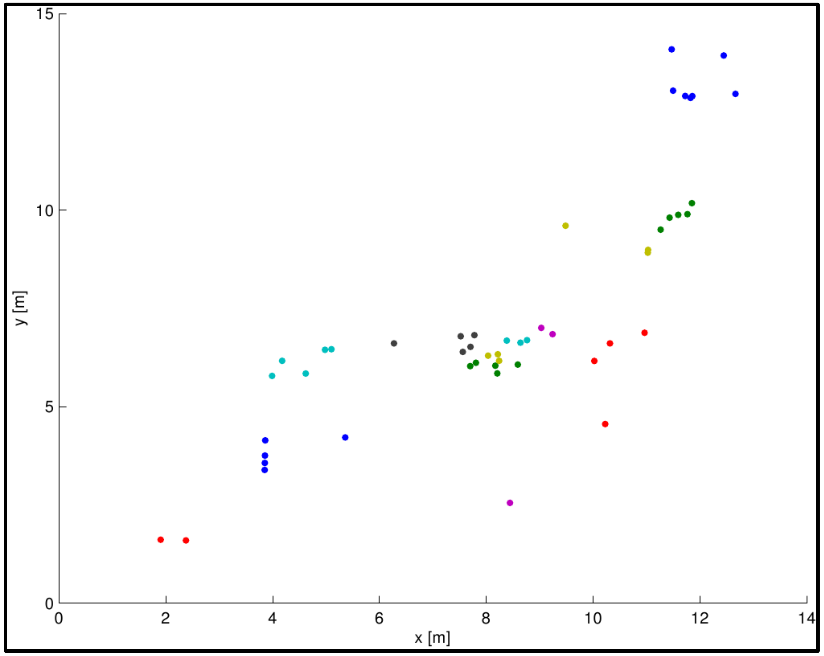
$$E(X_{new}) = \frac{n E(X_{old}) + X_{i+1}}{n_{old} + 1}$$

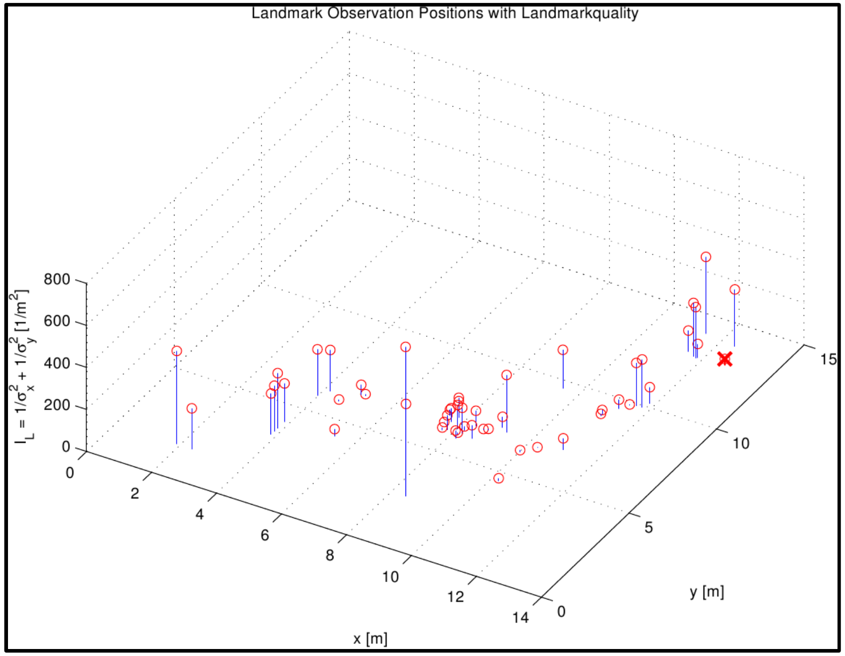
Calculation of Information Content of a Landmark

- Bewertung der Landmarken Qualität (1/variance)

Landmark rating and selection

Select Landmark with Lowest Localization Benefit





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Landmark rating and selection

- Recursive estimation of the observation position mean E(X)

$$E(X_{new}) = \frac{n\,E(X_{old}) + X_{i+1}}{n_{old}+1}$$

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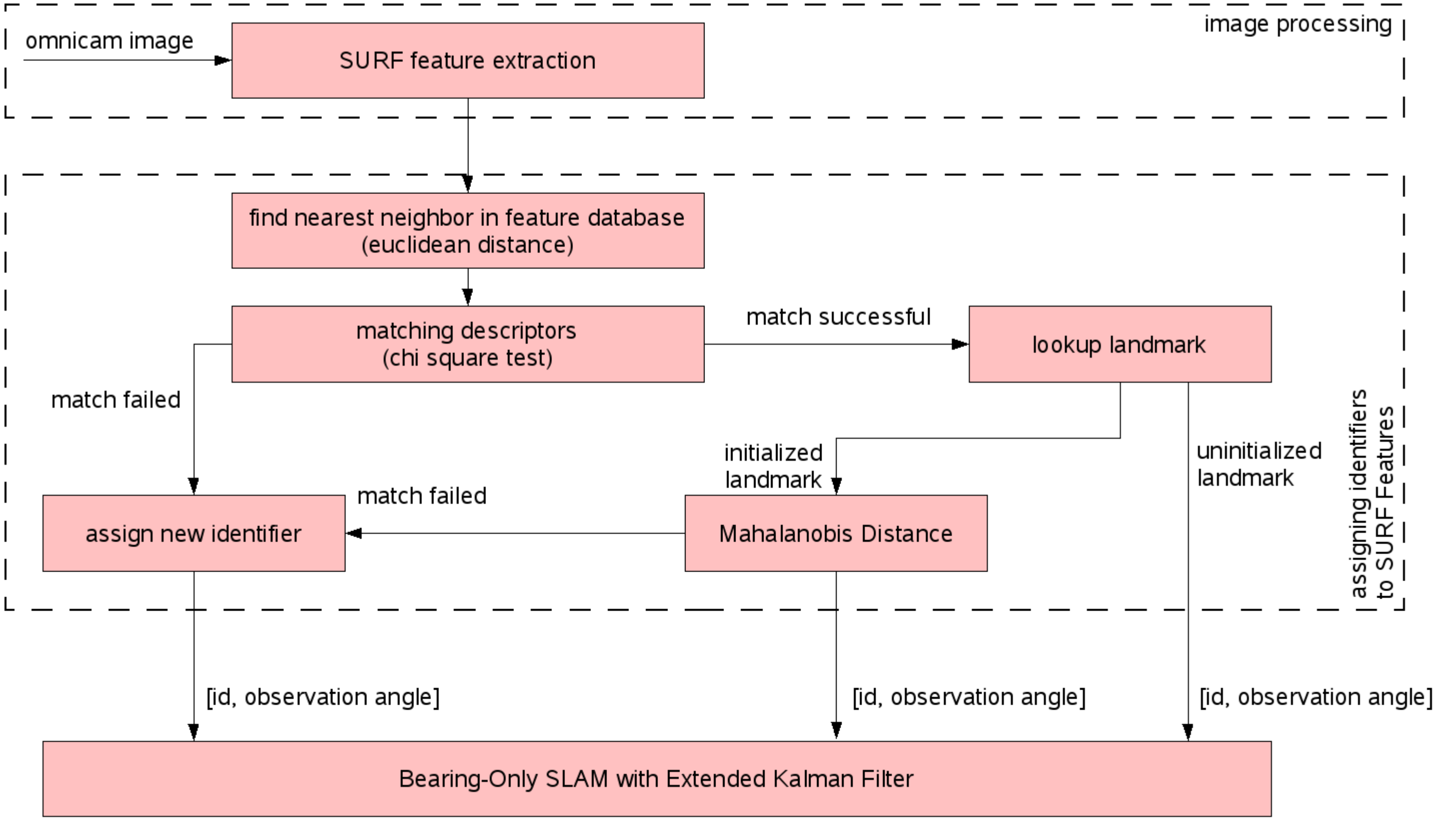
Problem description

- **Goal 2:**
  - Robustness in everyday environments
- **Problem:**
  - Natural landmarks often identified on recurring structures like doors and window frames. How can we distinguish them?

    --> landmark assignment problem
- **Solution:**
  - combine efficient feature retrieval with spatial plausibility

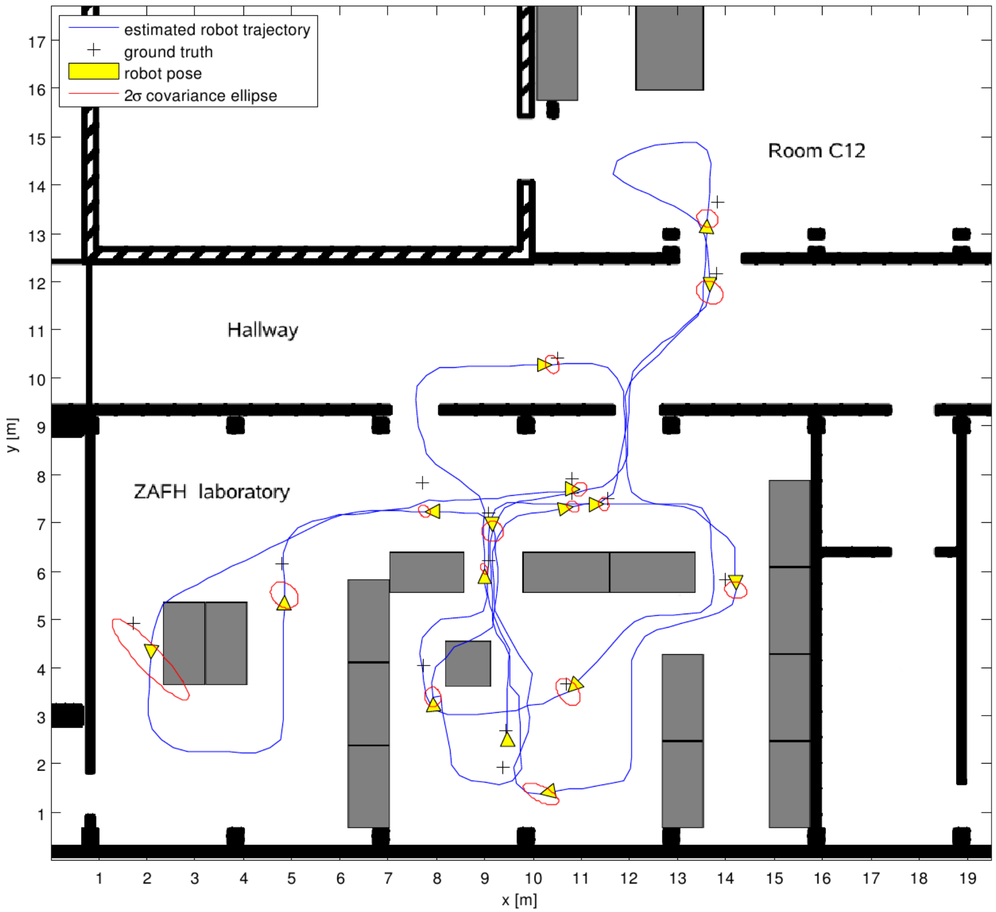
Assigning identifiers to SURF-Features



Results

Experimental Setup

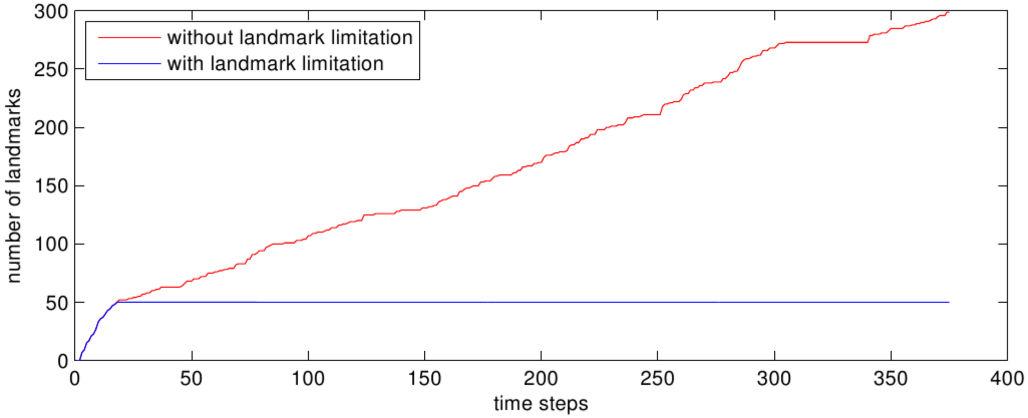
Results

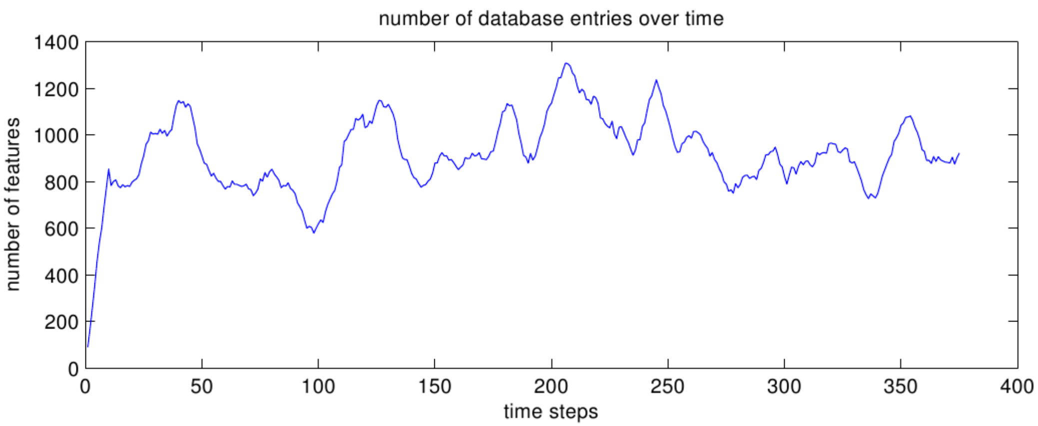


- indoor environment
- varying lighting conditions
- landmark limit = 50
- dynamic objects (persons)
- path length = 115m
- 375 time steps
- loop closing (8m, 10m, 14m)

Results

Feature Database and State Vector Size





all limited ;-)

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
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Future Work:

- We will focus on evaluating further approaches for landmark rating
- Reimplementation of the matlab parts in C++
- Integration into the SmartSoft Framework
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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