Implementation of Correlative Scan Matching for 2D LiDAR-based Localization

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Abstract

implementation details of Correlative Scan Matching (CSM) as described in the paper *2D-LiDAR-based localization method for indoor mobile robots using correlative scan matching.* The implementation is available at GitHub Repository. This report covers key algorithms, and software components of the implementation.

1 Introduction

Correlative Scan Matching (CSM) effectively aligns 2D LiDAR scans with a precomputed likelihood field of the environment.

2 Methodology

The implementation follows the methodology outlined in the paper, consisting of the following major steps:

1. **World to map conversion:** Initially it was very difficult to figure out what the odometry points actually corresponded to on the world map

2. **Map Processing:** The occupancy grid map is preprocessed into a likelihood field using a distance transform. I have utilized OpenCV's L2 distance transform in order to get scores for points

3. **Pose Prediction:** The odometry delta is used to predict newer poses for the robot based in previous poses

4. **LiDAR Dta Processing:** The Lidar data is converted to coordinates on the world map in order to compute scores for corrected pose

5. **Scan Matching:** Candidate poses are evaluated by computing correlation scores against the likelihood field.

6. **Pose Correction:** The best-matching pose is selected and used to update the robot's estimated position.

7. **Failure Detection and Global Localization:** Localization failures trigger a global localization routine based on matching with stored maps.

2.1 Correlative Scan Matching (CSM)

CSM maximizes the correlation between the transformed LiDAR scan and the occupancy grid map by searching for the pose that results in the best alignment. This involves:

- Generating a likelihood field representation of the occupancy grid.
- Evaluating multiple pose candidates by shifting and rotating the LiDAR scan over a local search region.
- Computing correlation scores for each candidate pose.
- Selecting the pose with the highest score as the corrected position.
- implemented a trivial algorithm and then transformed it to vectorized computation for performance

2.2 Global Localization

If the pose confidence drops below a threshold due to localization drift, a global localization module is triggered. This involves:

- Comparing the LiDAR scan to the entire occupancy map instead of a local region.
- Computing an overlap ratio between the scan and map.
- Detecting localization failure based on a predefined overlap threshold.
- Resetting the robot's pose to the best matching location in the map.

3 Implementation Details

The implementation follows a modular approach with separate functions for preprocessing LiDAR scans, odometry interpolation, scan matching, and failure detection. The key considerations include:

- parsed the Odometry data and LiDAR scans
- Determined the relation between the world and map coordinates
- Generate a likelihood fields map by using the occupancy map and removing the green line from it
- added an animation which shows the corrected path taken and the corresponding lidar scan
- Implemented the 2-d slice method as mentioned in the paper
- Handled outliers by implementing a low pass filter which utilizes the correlation between corrected and predicted poses
- Computational optimizations using numpy for real-time performance.

4 Results

The implementation was evaluated using the ACES building dataset available at SLAM. The results demonstrate the effectiveness of CSM in correcting localization errors and ensuring accurate path tracking.

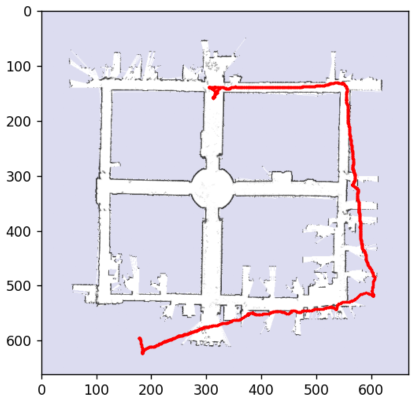
5 Conclusion

This report presents the implementation details of Correlative Scan Matching for indoor robot localization. The approach effectively corrects odometry errors and recovers from localization failures, ensuring reliable navigation in structured environments.

6 Results and Future Work

The implementation successfully estimates the robot's pose by aligning LiDAR scans with the likelihood field. Future improvements include:

- Implementing adaptive thresholds for failure detection.



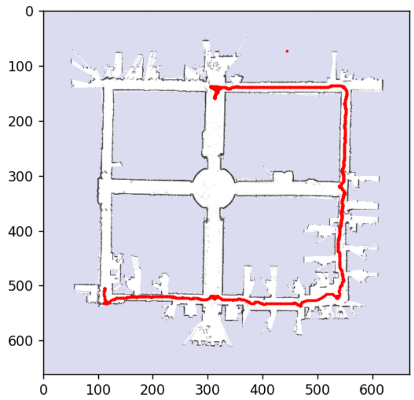


Figure 1: Comparison of incorrect localization (left) and corrected localization (right) using CSM.

- Optimizing search space for scan matching.
- Incorporating particle filters for global localization.
- making use of the 2-d slices method by fine tuning parameters

References

[1] Jung, S., Youn, S., & Han, C. (2023). *2D-LiDAR-based localization method for indoor mobile robots using correlative scan matching*. Robotica. [.]