RFM-SLAM: Exploiting Relative Feature Measurements to Separate Orientation and Position Estimation in SLAM

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Introduction: Full SLAM

Drive robot around environment

Store sensor data (odometry, rangebearing etc.)

Solve non-linear optimization problem

Non-linear optimization-based SLAM solvers often get stuck in local minima

Culprit: Odometry-based guess to initialize optimizer can be arbitrarily bad

Example Problem: 2D Feature-based SLAM

Traditional approach may lead to non-robust estimates



The Solution: Separate Orientation Estimation



Result: RFM-SLAM

RFM-SLAM avoids catastrophic failure

RFM-SLAM Estimate



Key Takeaway

Separate Orientation and Position Estimation for Robust SLAM Solutions

Method: Step 1



Method: Step 2



Setup Relative orientation constraint from feature to feature measurements

Solve on-manifold optimization using MANOPT*

*Boumal, N., Mishra, B., Absil, P.A. and Sepulchre, R, "Manopt: a Matlab Toolbox for Optimization on Manifolds", Journal of Machine Learning Research, 2014, Vol. 15 1455--1459

Method: Step 4



Solve linear least squares problem to compute robot and landmark position

Result: Increasing odometry noise



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Result: Increasing range-bearing noise



 α : Odometry noise scaling factor

β: Range-bearing noise scaling factor

Summary

- Problem: Non-linear SLAM solver prone to local minima
- Solution: Decouple orientation from position
- Result:
 - Accuracy degrades gracefully as noise goes up
 - Empirical results show RFM-SLAM avoids catastrophic failure
- Impact: Use RFM-SLAM to bootstrap non-linear solvers

Relevant Related Work

- K. Khosoussi, S. Huang, and G. Dissanayake, "Exploiting the separable structure of slam," in *Proceedings of Robotics: Science and Systems*, Rome, Italy, July 2015.
- L. Carlone, R. Aragues, J. A. Castellanos, and B. Bona, "A fast and accurate approximation for planar pose graph optimization," *The International Journal of Robotics Research*, vol. 33, no. 7, pp. 965–987, 2014.
- L. Carlone and A. Censi, "From angular manifolds to the integer lattice: Guaranteed orientation estimation with application to pose graph optimization," *IEEE Transactions on Robotics*, vol. 30, no. 2, pp. 475–492, April 2014.
- N. Boumal, A. Singer, and P. A. Absil, "Robust estimation of rotations from relative measurements by maximum likelihood," in *52nd IEEE Conference on Decision and Control*, Dec 2013.

https://github.com/sauravag/edpl-rfmslam

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