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Impact of Landmark Parametrization on Monocular EKF-SLAM with Points and Lines

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Abstract This paper explores the impact that landmark parametrization has in the performance of monocular, EKF-based, 6-DOF simultaneous localization and mapping (SLAM) in the context of undelayed landmark initialization.

Undelayed initialization in monocular SLAM challenges EKF because of the combination of non-linearity with the large uncertainty associated with the unmeasured degrees of freedom. In the EKF context, the goal of a good landmark parametrization is to improve the model's linearity as much as possible, improving the filter consistency, achieving robuster and more accurate localization and mapping.

This work compares the performances of eight different landmark parametrizations: three for points and five for straight lines. It highlights and justifies the keys for satisfactory operation: the use of parameters behaving proportionally to inverse-distance, and landmark anchoring. A unified EKF-SLAM framework is formulated as a benchmark for points and lines that is independent of the parametrization used. The paper also defines a generalized linearity index suited for the EKF, and uses it to compute and compare the degrees of linearity of each parametrization. Finally, all eight parametrizations are benchmarked employing analytical tools (the linearity index) and statistical tools (based on Monte Carlo error and consistency analyses), with simulations and real imagery data, using the standard and the robocentric EKF-SLAM formulations.

Keywords Monocular vision · Simultaneous localization and mapping · Structure from motion · Landmark parametrization · Kalman filtering · Benchmarking · Linearity · Consistency

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1 Introduction

Simultaneous localization and mapping (SLAM) is the problem of concurrently estimating in real time the structure of the surrounding world (the *map*), perceived by moving exteroceptive sensors, while simultaneously getting *localized* in it. The seminal solution to the problem by Smith and Cheeseman (1987) employs an extended Kalman filter (EKF) as the central estimator, and has been used extensively. In EKF-SLAM, the map is a large vector stacking