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Robust Tracking of a Mobile Beacon using Time Differences of Arrival with Simultaneous Calibration of Receiver Positions

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ABSTRACT

With the increasing interest in location-aware services, the accurate localization of mobile devices becomes substantially more important. Especially in GPS-denied environments, dedicated approaches for the positioning of devices are required. Recently, the technology based on time differences of arrival (TDOA) has turned out to be promising, even when neither the receiver nor the beacon positions are known a priori. To easily set up such systems and to adapt them to changing conditions, however, the ability for self-calibration is required to identify the positions of the static receivers and of the moving sender.

In this paper, we consider calibration-free tracking of a mobile beacon using TDOA. Our approach does not require to measure the receiver positions manually, which is a tedious and time-consuming task. We address the problem of simultaneous localization using TDOA in a probabilistic formulation, making it robust against measurement outliers and incorrect initialization. In particular, we estimate the position of a mobile beacon and the receivers in a particle filter. We propose a probabilistic sensor model for TDOA data which explicitly considers the measurement uncertainty and takes into account disproportional errors caused by measurement outliers. For robust initialization of the particle filter, we apply an iterative optimization approach to multiple subsets of TDOA data, where the best solution is implicitly selected by appropriate weighing of the sensor model.

We verify the robustness of our approach in extensive experiments in an indoor environment of 200 m^2 by an ultrasound beacon moving on a 180 m long trajectory. We demonstrate that our approach ensures proper initialization of the particle filter and provides accurate position estimates for the signal beacon and the receivers even in case of measurement errors. Compared to position references of an optical motion capture system we achieve mean location errors below 5 centimeters.

KEYWORDS: TDOA, localization, calibration-free, ultrasound, particle filter