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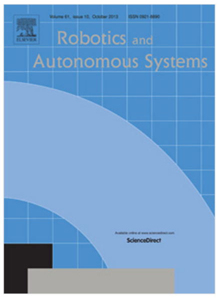

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A multihypothesis set approach for mobile robot localization using heterogeneous measurements provided by the Internet of Things

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Abstract
Mobile robot localization consists in estimation of robot pose by using real-time measurements. The Internet of Things (IoT) adds a new dimension to this process by enabling communications with smart objects at anytime and anywhere. Thus data used by localization process can come both from the robot on-board sensors and from environment objects, mobile or not, able to sense the robot. The paper considers localization problem as a nonlinear bounded-error estimation of the state vector whose components are the robot coordinates. The approach based on interval analysis is able to answer the constraints of IoT by easily taking account a heterogeneous set and a variable number of measurements. Bounded-error state estimation can be an alternative to other approaches, notably particle filtering which is sensible to non-consistent measures, large measure errors, and drift of robot evolution model. The theoretical formulation of the set-membership approach and the application to the estimation of the robot localization are addressed first. In order to meet more realistic conditions the way of reducing the effect of environment model inaccuracies, evolution model drift, outliers and disruptive events such as robot kidnapping is introduced. By integrating these additional treatments to the set-membership approach we propose a bounded-error estimator using multihypothesis tracking. Simulation results show the contribution of each step of the estimator. Real experiments focus on global localization and specific treatments for synchronizing measurements and processing outliers.

Keywords: Robot mobile localization · Interval analysis · Bounded-error estimator· Outlier, Model inaccuracy and drift · Multi-hypothesis tracking.

1. Introduction

Localization of mobile robots estimates the position and the orientation of the vehicle (pose) related to a reference frame. Two different approaches have been distinguished. Local localization or pose tracking provides a new pose given a previous pose and proprioceptive information. However an accurate initial pose is needed. Global localization is designed to provide the robot pose without any a priori, given exteroceptive observations. Global localization is used for initializing the pose estimate of the robot at the beginning of the localization process or for solving the lost robot problem. Several localization strategies have been proposed combining proprioceptive and exteroceptive information. However the Internet of Things (IoT) has added new dimensions by enabling communications with and among smart objects, thus leading to the vision of ‘‘anytime, anywhere, anymedia, anything” [1]. So strategies have to adapt themselves in order to take into account the new context of IoT.
In current localization approach, strategies which track a single hypothesis or multiple hypotheses about robot pose are generally considered as a state estimation problem [2]. Extended Kalman Filter (EKF) has been early investigated for solving localization problem [3, 4, 5, 6]. However, as in many cases real-world disturbances do not satisfy statistical assumptions, the EKF is not guaranteed to converge. In addition, the tuning of parameters can be difficult and EKF needs an accurate initialization. Tracking multiple hypotheses by multiple Kalman filters allows significant improvement but at the expense of increased complexity [7]. EKF drawbacks have led to the development of other filters. The particle filtering (PF) is one of the most effective localization algorithms [8, 9]. PF presents advantage that non-Gaussian distributions and non-linear models can be incorporated. PF is known for its robustness and the ease of implementation if the state dimension is low, but might also be difficult to tune. In fact the efficiency of the filter depends mostly on the number of particles and on the way to re-allocate the weights of particles. The number of particles results of a compromise between robustness, accuracy and computing time. For Gustafson [9] who has surveyed PF theory and practice for positioning applications, PF is not practically useful when extending the models to more realistic cases. Three main cases are mentioned: i) High-dimensional state-space models, typically motion in more than three-dimensions space (six-dimensional pose), ii) More dynamic states (accelerations, unmeasured velocities), iii)Sensor bias and model drift. The Marginalized Particle Filter (MPF) brings an answer to the case of high-dimensional state-space models as long