

Chapter 22

Distributed Cooperative Localization

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ABSTRACT

Localization for mobile platforms, in indoor scenarios, represents a cornerstone achievement to effectively develop service and field robots able to safely cooperate. This paper proposes a methodology to achieve such a result by applying a completely decentralized and distributed algorithm. The key idea of the solution developed is to enable a dynamic correction of the position estimate, computed by robots, through information, shared during random rendezvous. This objective is reached using a specific extension of the Extended Kalman Filter, called Interlaced Extended Kalman Filter, which allows exchanging the estimation performed by any single robot together with the corresponding uncertainties. The proposed unsupervised method provides a large flexibility: it facilitates the handling of heterogeneous proprioceptive and exteroceptive sensors, that can be merged taking into account both their accuracy and the system model one. The solution is particularly interesting for rescue scenario, since it is able to cope with irregular communication signals and loss of connectivity among robots team without requiring any synchronization.

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1. INTRODUCTION

Localization is one of the key issues for team of autonomous robots: to successfully plan missions and accomplish tasks, each team-member needs to be localized to both workspace and the other elements that operate in the environment.

In the literature, localization is approached using supervised and unsupervised communication paradigms. In the first case, a centralized supervisor (i.e., a base station) collects all the data coming from the robots and provides an estimate for the pose of the whole team. In the second approach, each robot runs a local algorithm to estimate its pose, using only its own sensors, and shares data with its neighbors.

The complexity of a centralized algorithm grows exponentially with the number of robots. Moreover, this solution forces all mobile robots to communicate continuously with the supervisor: thereafter, robots need either to move closely to the supervisor location, or to set up a hierarchical network (Antonelli, Aricchiello, Chiaverini & Setola, 2006). In both cases, some constraints over team mobility are imposed to guarantee that, at each moment, at least one communication-path from any robot to the supervisor exists.

According to the decentralized approach, each robot in the team collaborates to solve the localization problem. The easiest solution is achieved by decomposing the localization problem of the team into autonomous and independent localization tasks. Therefore, each robot implements its own localization algorithm, ignoring the presence of the other robots in the workspace. In other words, the localization problem is solved by multiplexing single robot localization, without exploiting additional information extracted from neighbors. Moreover, no relative measures are used, even if this information could be very important (i.e., formation control, collaborative exploration tasks). For these reasons, in the literature, the multi-robot localization problem is referred to as collaborative/cooperative localization, when the team exploits information sharing.

The relevance of information sharing during localization is particularly useful when it faces heterogeneous robot teams. In this case, some robots are equipped with expensive, high accuracy sensors (i.e., GPS, laser rangefinders, smart camera), while the others are equipped with low-cost sensors (i.e., sonar, web-cam). Hence, information sharing enhances sensor data, since collaborative multi-robot localization exploits high-accuracy sensors across teams.

This paper proposes an efficient probabilistic algorithm, the Interlaced Extended Kalman Filter (IEKF) (Panzieri, Pascucci, & Setola, 2006), for collaborative multi-robot localization. It is based on the well-known prediction-update scheme of Bayesian filter and represents a sub-optimal solution for probabilistic state estimate. According to this approach, robots are able to compute their poses, exploiting the detection of other robots. Indeed, each robot implements an EKF to localize itself, using proprioceptive sensors and measurements retrieved from the environment. When two robots are visible to each other, they exchange information about their estimated poses and their measurements. By doing so, each robot takes advantage of its neighbors, using them as further virtual sensors. To cope with the noise and the ambiguity arising in real-world scenarios, observation models are set up in a probabilistic framework. Indeed, the covariance matrices related to these virtual devices are suitably manipulated to accommodate the different levels of uncertainties typical of pose estimates. The whole team localization problem is split over the robot network decomposing the whole filter into N sub-filters, where N is the cardinality of the team.

IEKF allows cooperative localization under severe communication and computational constraints. In fact, the communications are performed only during rendezvous and only limited data are broadcast.

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