FEKF Estimation for Mobile Robot Localization and Mapping Considering Noise Divergence

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ABSTRACT
This paper proposed an approach of Fuzzy-Extended Kalman Filter(FEKF) for mobile robot localization and mapping under unknown noise characteristics. The technique apply the information extracted from EKF measurement innovation to derive the best estimation output for a mobile robot during its observations. These information is then fuzzified using Fuzzy Logic technique with very few design rules to control the information which at the end further reducing the error about the measurement and consequently provide better localization and mapping. Simulation results are also presented to describe the efficiency of the proposed method in comparison with the normal EKF estimation that emphasize FEKF exceeds the estimation results of normal EKF in non-Gaussian noise environment.

Keywords: Fuzzy Logic・Kalman Filter・Mobile Robot Localization・Mapping

INTRODUCTION

Mobile robot localization and mapping problem or known as the Simultaneous Localization and Mapping (SLAM) problem addressed a condition where a mobile robot attempts to infer its position relatively to any observed landmarks and then concurrently build a map based on what it has measured (Ahmad et al. 2013,2015). The problem has different types of solution categories including the mathematical, behavioral or the probabilistics approaches (Thrun et al. 2000, 2005). One of the famostly used method is the probabilistics as it offers easier modeling and less computational cost.

Extended Kalman Filter(EKF) is the mostly applied approach to deal with the SLAM problem especially when uncertainties such as the mobile robot kinematic model, sensor errors are concerned. However, it has a shortcomings that could not effectively tolerate in a condition where non-Gaussian noise characteristics is available. Due to this disadvantages, researcher explores other possible solution such as the Particle Filter, Graph-SLAM, Topological SLAM and others, but each of them facing the computational cost and cannot be fully realized in real-time application as what EKF is capable. Hence, EKF is still becomes the ultimate selection in real application.

Observing an environment with a sensors or sensor-array with unknown surface and mobile robot motions requires a good modeling to represent the uncertainties. To aid the system reliability, Kramer et al (Kramer and Kandel, 2011) investigates four techniques which includes the FEKF to identify their strength and weaknesses on different situations for mobile robot localization. It was found that FEKF has better results than EKF and can be further improved if better rules design are provided. In fact, fuzzy logic is the only an adaptive method to be successfully adapt in EKF (Asadian et al, 2005) unline other such as the neural network technologies which requires more computation. Works on the mobile robot control with FEKF was also successfully demonstrated by Raimondi et al. (Raimondi et al, 2006) to control the disturbance of robot motions.

Most of the approaches in FEKF are focused on the state covariance, P, the process noise covariance Q and measurement noise covariance, R (Kobayashi et al. 1998), (Abdelnour et al, 2003). This is motivated by the means that above parameters are showing the amount of uncertainties exists during mobile robot measurements. The approaches attempts to tune the system output based on P, Q and R covariances to obtain small error. The study on FEKF configures inputs from innovation and past information to deal with uncertain noises, yet the output is only based on a singleton decisions which may accidentally neglects some important information(Ip et al, 2010). Wang et al (Wang et al, 2014) examines further the fuzzy logic competencies in EKF by taking into account the error of angle, distance and innovations as the inputs to configure the state covariance update, P in each process. However it is not clearly indicates about the noise characteristics being considered. Besides, bringing three parameters to be calculated parallelly during observations leads to higher processing time and complexity. Moreover, if more rules are designed for the system, it will require more time.

Motivated by the above consequences, this paper deals with FEKF with only considering the measurement innovation information to tune the error appropriately in achieving better estimation results. The technique also look into the estimation results in non-Gaussian environment to analyze the system reliability. The designed rules are also few to reduce the processing time with only three number of fuzzy sets for each input.