HF-Fuzzy Logic based Mobile Robot Navigation; A Solution to Finite Escape Time

Hamzah Ahmad [1], Nur Aqilah Othman [2]

[1 1,2,3,4] Faculty of Electrical & Electronics Engineering, Universiti Malaysia Pahang, Pekan Campus, 26600 Pekan, Pahang, Malaysia
E-Mail: hamzah@ump.edu.my

ABSTRACT
This paper deals with H_∞ Filter(HF)-Fuzzy logic based mobile robot localization and mapping as an approach to prevent the Finite Escape Time(FET) problem in HF. The FET problem has been limiting the HF capabilities in estimation for decades and has been one of the important aspect to be considered to ensure HF performs well during mobile robot observations. The proposed technique focusses on the HF innovation stage by including very few Fuzzy Logic rules, and fuzzy sets. The design is generally divided into two stages; firstly, the analysis of HF innovation characteristics and then the implementation of Fuzzy Logic technique into the system. The analysis also presents the preliminary study on different membership functions to discover the best possible technique to combine with HF based mobile robot localization. The simulation results proved that Fuzzy Logic can be used to avoid the FET from occurred while at the same time improving the estimation of both mobile robot and landmarks.

Keywords: Mobile Robot · Navigation · H_∞ Filter · Fuzzy Logic · Finite Escape Time

INTRODUCTION

Development of mobile robot in navigation has gained much interest for decades. One of the main reasons is because the research attempts to build a truly autonomous mobile robot that able to explore and identify the surrounding area especially in hazardous conditions. One of the famous problem in navigation is the Simultaneous Localization and Mapping(SLAM) which requires the mobile robot to observe the area of interest and concurrently build a map while at the same time localize itself in the map(Thrun S, et al., 2000)(Thrun S, et al., 2005). The study has cover varieties of issues such as the inconsistencies of estimation, existent of uncertainties, data association problem, and computational complexity(Huang, S et al, 2007).

During mobile robot observations, there are a lot of uncertainties needs to be taken into account. To tolerate this condition, Extended Kalman Filter(EKF) is aggressively used to infer the mobile robot locations and any identified landmarks. Unfortunately, EKF cannot works well in an environment that has non-Gaussian noise. Owing to this limitation, its other family known as H_∞ Filter(HF) offers better solution(Ahmad, H et al. 2011a, Ahmad, H et al. 2011b). In these reports, certain conditions are satisfied, HF surpassed the Kalman Filter performance. HF is employed when the noise energy is bounded and in unknown noise characteristics. The technique attempts to minimize the estimation error in the form of energy gain.

Several papers has been investigated the performance of HF regarding its capability and performances. To list few of them are as analyzed by Ahmad, H et al. about the filter theoretical behavior(Ahmad, H et al.2011, Ahmad, H et al(2015), the marine applications(Wang J.H et al, 2010), and sensor fusion(Gualda, D et al, 2014). Even the performance is promising, the filter may exhibit Finite Escape Time(FET) problem during mobile robot navigation. To avoid this, a switching strategy or the suboptimal condition has been proposed. The switching strategy only modifies the value of γ to make HF similar to EKF and the suboptimal technique adds some pseudo state covariance which finally increases the state covariance. However, none of the research was found to design and combine the HF with Fuzzy Logic in mobile robot navigation even though a number of research have successfully implemented the hybrid approach through EKF-Fuzzy combination(Abdelnour, G 1993, Asadian A, 2005, Choonmang R et al.,2005, Ip Y.L, 2010, Kobayashi K, 2008, Raimondi F.M, 2006).

Motivated by this reason, this paper proposed a HF-Fuzzy Logic technique to refrain the FET from occurring during mobile robot observations. This is done by modifying the innovation error exhibits during measurements to pose appropriate information. Innovation error which contains the information of error generated by the actual measurement and measurement estimation of the relative angle and distance errors defines how the state covariance characteristics. This will be shown later in the next section. It is found that by reducing this error through observation of the innovation characteristics, the mobile robot preserve better estimation and at the same time is able to avoid the FET from happening.

This paper is organized as follows. In section 2, the proposed technique is presented. This is followed by section 3 which demonstrates the simulation results and the comparison with the original HF approach. Finally, our work of this paper is summarized in the last section.