A Solution to Finite Escape Time for H_∞ Filter based SLAM

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***Abstract*— This paper proposed a solution to the Finite Escape Time problem in H_∞ Filter based Simultaneous Localization and Mapping problem. Finite escape time has been one of the obstacle that holding the realization of H_∞ Filter in many application. For this reason, a method of decorrelating some of the updated state covariance of the filter is suggested to avoid the finite escape time from occurred during mobile robot estimation. Two main cases are investigated in this paper to observe the filter performances. The simulation results have shown convincing outcomes to the overall estimation which can prevent the finite escape time in the estimation.**

***Index Terms*— H_∞ Filter, Kalman Filter, SLAM, Decorrelation**

I. Introduction

A. Robotic Mapping

Nowadays, the development of autonomous robot in various applications can be notably recognized. Especially, in the task of exploration and navigation, the role of autonomous robot is very important in order to explore, observe and plan for its movement. One of the task which attempt to continuously observing landmarks and collecting information while moving through an unknown environment is referred as the SLAM(Simultaneous Localization and Mapping) problem or alternatively known as CML(Concurrent Mapping and Localization) problem. The problem became famous after a series of influential seminal papers introduced in 1990's such as Smith and Cheeseman et.al[1] introduced the relationship between mobile robot and landmarks. Due to its capability in realizing a truly autonomous robot behavior, the SLAM problem has gained researcher's attention over some past decades. Unfortunately, even though a lot of discussion and development efforts have been continuously conducted, the problem still facing a lot of unsolved issues such as the condition of data association, effects of dynamic environment and uncertainties.

Human limitations to work in hazardous areas is one of the key factor making the SLAM becomes the ultimate way to solve the problem. Hence, the application can be found widely not only in space exploration, but also can be identify to be useful in underwater navigation, mining operations and military. As the application can be applied in such cases, the system is also well-designed to consider both 2D and 3D configurations[3], [4], [5]. See Figs.1 for further explanation of SLAM. Further explanation about SLAM can be found in [6].

With regards to uncertainties, it is a wise decision to model a system that is able to take into account for a worst case of noise or when the noise statistics is unknown. Hence, H_∞ Filter could be the best to tolerate with such robust system. H_∞ Filter theoretically assumes that the noises are bounded in a level of energy. The approach is recommended to be applied in a system where the worst-case estimation is considered. The development of H_∞ Filter for SLAM is proposed in this paper for estimation to consider about its finite escape time problem. Even though this approach is a family of Kalman Filter approach[7][8], Kalman Filter do not exhibit such issue that affects the overall estimation.

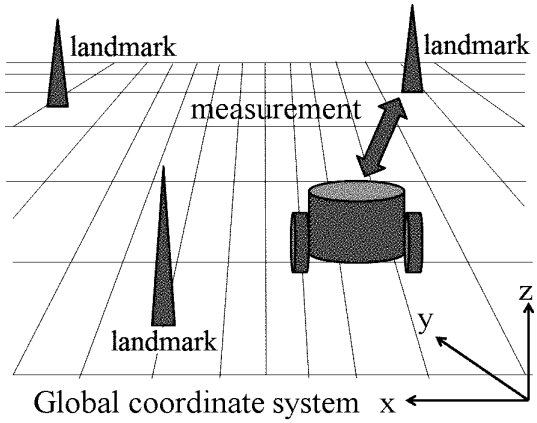

Fig. 1. Illustration for SLAM problem

Throughout this paper, H_∞ Filter based SLAM performance in nonlinear SLAM problem under two partially observable SLAM cases is examined; Unstable Partially Observable SLAM and Stable Partially Observable SLAM. Simulation analysis is carried which considers a planar and small environment that consists of some stationary landmarks. Kalman Filter and Extended Kalman filter(EKF) have been studied immensely in the SLAM problem using various approaches[9][10]. However due to the limitation of incapabilities or incompetency in non-gaussian noise environment, others methods are also welcomed such as the Particle Filter, and the Uncented Kalman Filter. Unfortunately, those two methods suffers in terms of computational cost and for online application. Hence, H_∞ Filter is chosen as a solution to SLAM problem.

Despite of current papers that has been published regarding the observability of SLAM using Kalman Filter and H_∞ Filter[13] already exists, more analysis still expected. The reason is due to complexity of correlation of the state covariance. The two cases stated above needs proper analysis especially for H_∞ Filter where the finite escape time

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