Modified Fast-SLAM For 2D Mapping And 3D Localization

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***Abstract*— Fast Simultaneous Localization and Mapping (SLAM) algorithm is capable of real-time implementation due to logarithmic time complexity which results in decrease of computational cost. In this algorithm state vector of a robot merely includes planar location of the robot and its angle to the horizontal plane. It has fewer components comparing to state vector in extended Kalman filter method which consists of location of all environmental features. In existing methods for implementing this algorithm, robot movement is considered to be totally in planar movement; while if moving on a slope changes the pitch angle of the robot, it causes errors in the algorithm. Correcting these errors will lead to a precise 2D mapping and 3D localization. This paper details the modification added to conventional Fast-Slam algorithm to accommodate this requirement by using an IMU. Simulation and experimental results shows the effectiveness of such modification.**

Keywords— Fast-SLAM, 2D localization, 3D Mapping, pitch angle, mobile robot.

I. Introduction

SLAM problem deals with robot excavation in unknown environment or localization and simultaneous map building. The difficulty of this method is related to the dependency of localization and mapping. To address localization issue, it is necessary to have maps of the environment so that observations could be matched to it and an estimation of robot location could be achieved. On the other hand, to build a map of the robot's environment one must has information about its location at each moment. Putting this information together the robot would be able to complete the map and localize itself.

Various frameworks have been considered to address SLAM problem. As an instance for implementation of SLAM in indoor environments, outdoor environments, submarine environment and air operations might be mentioned. SLAM problem can be solved for two types of environments; 3D and 2D. Algorithms for SLAM solutions are different considering temporal priority and response quality. The main methods may be listed as Extended Kalman filter method, 2. Fast-SLAM and 3. Iterative smoothing and mapping (iSAM). The first efforts regarding SLAM problem were made by Smith, Leonard and Durrant in a probabilistic framework [1], [2], [3]. They considered state vector of the robot and environment in the form of random variables. These studies aimed to estimate Gaussian probability density distribution for each random variable at each time and to describe the environment map using estimated variables. For this purpose previous observations and estimations are exploited.

In 2001 Dissanayake et al proposed a solution for SLAM problem based on Extended Kalman filter [4]. In this article primary estimation was performed based on kinematics of the problem and issues such as map convergence were investigated. Since state space equations for motion and observation models are considered to be nonlinear, Kalman filter cannot be used directly. At each step linear models approximated by first term of Tailor expansion are substituted in equations. This modeling error may result in inconsistency and divergence of the solution after a while.

Another problem associated with EKF-SLAM algorithm is that size of the state vector and number of state parameters increase when the number of robot observations increases. It, in turn, results in larger covariance state matrix with $O(N2)$ complexity degree. In recent decades several efforts have been made to address this problem. One of these solutions was introduced by Thrun et al [5] in 2004. They presented a method for solving SLAM problem using extended information filter called SEIF. Baily et al investigated solution convergence for EKF method in 2006 [6]. At the same year Castellanos et al pointed out some facts regarding convergence improvement and convergence speed in estimation problem using Extended Kalman filter [7].

In Extended Kalman Filter algorithm motion and observation models' equations are considered nonlinear and noises are introduced by Gaussian distributions. In this method, problem would be solved analytically. Fast-SLAM employs particle filter for estimating variables. In contrast to Kalman filters, in particle filters nonlinear models and non-Gaussian noises could be described pretty well and equations are solved numerically. Another issue that EKF encounters is data