A NEW SURVEY ON SELF-TUNING INTEGRATED LOW-COST GPS/INS VEHICLE NAVIGATION SYSTEM IN HARSH ENVIRONMENT

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ABSTRACT:

Nowadays, Global Positioning System (GPS) receivers are aided by some complementary radio navigation systems and Inertial Navigation Systems (INS) to obtain more accuracy and robustness in land vehicular navigation. Extended Kalman Filter (EKF) is an acceptable conventional method to estimate the position, the velocity, and the attitude of the navigation system when INS measurements are fused with GPS data. However, the usage of the low-cost Inertial Measurement Units (IMUs) based on the Micro-Electro-Mechanical Systems (MEMS), for the land navigation systems, reduces the precision and stability of the navigation system due to their inherent errors. The main goal of this paper is to provide a new model for fusing low-cost IMU and GPS measurements. The proposed model is based on EKF aided by Fuzzy Inference Systems (FIS) as a promising method to solve the mentioned problems. This model considers the parameters of the measurement noise to adjust the measurement and noise process covariance. The simulation results show the efficiency of the proposed method to reduce the navigation system errors compared with EKF.

INTRODUCTION

Accuracy requirement of Location-Based Telematics Services (LBTS) for land navigation mostly depends on Global Positioning System (GPS) and Global Navigation Satellite Systems (GNSS) to obtain a useful navigational solution. GNSS receivers require proper operating conditions for providing a valid and precise solution. Whereas GNSS operation is affected by Line of Sight (LOS) signal propagation and condition, resulting in a non-effective GNSS solution while driving in harsh environments, such as in urban canyons, under dense foliage or other so-called GPS-denied environment (i.e. indoor parking, tunnel, etc.). As a matter of fact, these harsh environments significantly reduce the efficiency of GNSS [1, 2].

Advanced commercial vehicle services, such as car insurance companies and car assistance services (OnStar, Car-net, etc.), need to overcome the mentioned GNSS problems to provide higher customer supports and quality of services. An encouraging solution to achieve a high-precision navigation system, at all time, is to fuse the GPS data with low-cost Micro-Electro-Mechanical Systems (MEMS)-based Inertial Measurement Units (IMUs), which are self-governing navigation devices. In fact, an GPS/INS integrated system can provide a state-of-the-art land navigation system with a better efficiency compared with GPS or INS alone.

The conventional Extended Kalman Filter (EKF) has been extensively employed for the integration of INS with GPS, as it can determine the optimal estimation of the system state vector with minimum mean and square errors [3-6]. For good results, an EKF needs to perform under appropriate defined errors and dynamic models notably for its initialization process, which requires the knowledge and adequate noise modeling. Also and to provide a continuous efficient estimation, EKF requires a good background on the dynamic process of the system and measurement model based on white Gaussian noises. In addition, the accuracy of MEMS-based IMUs is greatly damaged by their long and short terms drift and bias errors. This problem impacts the navigation systems' performance, when exploiting the traditional EKF in land vehicular navigation [7]. Moreover, the main problem of the EKF is the covariance divergence due to modeling error in EKF, which makes infinite or very large the bound of the actual estimate error covariance [8].

To solve the covariance divergence in EKF, two solutions are mainly considered. The first one is employing the un-modeled state which increases the complexity of the system for its computation [8]. The second is employing the process noise to improve the confidence when using white Gaussian noise so that it can prevent the EKF to reject new measurements for estimating the state vector [7, 9, 10]. This paper suggests using Fuzzy Inference System (FIS) based on the second solution, which is employed for self-tuning the EKF parameters by observing the covariance measurements.

The proposed hybrid FIS-EKF model is exploited to develop a low-cost and low-processing power GPS/INS integrated navigation system for modern land vehicular navigation systems efficient in challenging environments. This new technique will open the door to new navigation capabilities to expand the markets of automotive navigation services. FIS is exploited to predict the error states of the EKF based on a Covariance Matching Estimation Technique (COMET). The paper is organized as follows: Section 2 presents the GPS/INS integration process used in this paper. Section 3 explains the proposed model to fuse the INS and GPS measurements in detail. Sections 4 and 5 present the simulation results and the conclusion of this paper, respectively.

2. GPS/INS INTEGRATION PROCESS

A. Loosely coupled GPS/INS integration

It is well known that integration of INS and GPS through loosely coupled structure, not only maintains independency and redundancy of stand-alone GPS and INS solutions; but it can also provide more robustness for the navigation solution [11]. Loosely coupled integration presents a closed-loop