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Road vehicle state estimation using low-cost GPS/INS

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ABSTRACT

Assuming known vehicle parameters, this paper proposes an innovative integrated Kalman filter (IKF) scheme to estimate vehicle dynamics, in particular the sideslip, the heading and the longitudinal velocity. The IKF is compared with the 2DoF linear bicycle model, the triple Kalman filter (KF) and a model-based KF (MKF) in a simulation environment. Simulation results show that the proposed IKF is superior to other KF designs (both Kinematic KF and MKF) on state estimation when tyre characteristics are within the linear region (i.e. manoeuvres below 55 kph).

1. Introduction

In recent years, modern automobiles have included ever more sophisticated electronics and control systems, such as the Anti-lock Braking System (ABS) and the Electronic Stability Program (ESP). With the implementation of these intelligent systems, vehicles have become safer to drive [1] with less involvement in fatal accidents [2,3]. Evidence of this can be seen in the increased demand for ABS since 1990 [2]. It is envisaged that future development of more advanced and sophisticated control systems requires accurate and 'up-to-date' vehicle dynamic information. In particular, as highlighted by Manning and Crolla [4], sideslip estimation is essential for a commercial viable sideslip stability control system.

Vehicle dynamic states measurement and estimation can be categorised into three main approaches. The indirect approach, which involves the use of existing in-car sensors such as the Inertial Navigation System (INS) and wheel speed sensor. This is the cheapest solution, yet suffers from accumulative integration errors due to sensor bias [5]. The direct approach, includes sensors such as the speed-over-ground and Global Navigation Satellite System (GNSS), in particular the Global Positioning System (GPS). These sensors can provide accurate information but are expensive in price and to maintain. The third is the Vehicle Model (VM) approach. Although this is able to produce good estimations, VM is normally non-linear and parameter dependent. For a detailed review, see Leung et al. [6].

In order to obtain more accurate vehicle dynamic information, it is natural to combine the main methods in order to utilise their respective strengths. With INS and GPS in mind, Leung et al. [6] have identified four integrated approaches: GPS/INS, GPS/VM, INS/VM, and GPS/INS/VM. A large amount of the reported research is based on the GPS/INS kinematic Kalman filter (KKF) design [7–9]. This approach is easy to implement and is able to predict biases in the sensors. Although

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