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Robust fault tolerant tracking controller design for vehicle dynamics: A descriptor approach

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ABSTRACT

In this paper, an active Fault Tolerant Tracking Controller (FTTC) scheme dedicated to vehicle dynamics system is proposed. To address the challenging problem, an uncertain dynamic model of the vehicle is firstly developed, by considering the lateral forces nonlinearities as a Takagi–Sugeno (TS) representation, the sideslip angle as unmeasurable premise variables and the road bank angle as an unknown input. Subsequently, the vehicle dynamic states with the sensor faults are jointly estimated by a descriptor observer on the basis of the roll rate and the steering angle measures. Then a fault tolerant tracking controller is synthesized and solutions are proposed in terms of Linear Matrix Inequalities (LMIs). Simulation results show that the proposed FT control approach can effectively improve tracking performance of the vehicle motion.

1. Introduction

In recent years, driver assistance and safety systems have attracted increasing research efforts in automotive industry. Indeed, the number of road deaths decreases since the introduction of safety systems with significant improvements taken into account driven conditions (tire/road adhesion variation, speed variation, steering abrupt change of driver, load transfer, wind, etc.). Moreover, considerable work has been carried out on collision warning, collision avoidance, adaptive cruise control and automated lane-keeping systems. Nowadays, more and more cars are equipped with Traction Control System (TCS), anti-lock brake system (ABS) or many variants of the Electronic Stability Program (ESP) [1–3].

As such systems increasingly depend on accurate information about vehicle states which are obtained by direct measurement; the appropriate sensors may be unreliable, inaccurate, or even faulty. More practically, breaking control, lane departure avoidance and rollover detection generally make use of the lateral vehicle dynamics which are impossible or hard to measure accurately with cost sensors [1–3].

These challenges have been addressed in some previous works based on estimation and/or observation techniques of these dynamic parameters using available measurement [2,4,5]. In this context, several research works involving various methods have been conducted for vehicle dynamics, road bank angle and unknown inputs estimation [6–8,41–45]. In [6], lateral vehicle dynamics are estimated based on a descriptor approach for a proportional-integral (PI) observer. In [7], the authors proposed a road bank angle estimation algorithm based on a proportional-integral H_∞ filter for a modified bicycle model to improve robustness against modeling errors and uncertainties. Furthermore, the lateral control system must have fault tolerant ability such that the system maintains stability and acceptable performance despite of the failure situation [4]. Many work dealing with FTC design has been developed where significant results have been proposed in [10,11] and references therein. Recently, FTC strategies allow the adaptation of the control law on the basis of the estimation of faults affecting the system components (as sensors or actuators) [9,20,30–38]. The success of these methods mainly depends on the model complexity [12–14]. Accordingly, numerous FTC approaches for nonlinear systems approximated by Takagi–Sugeno representation have been developed [39,40], and some useful results for the trajectory tracking problem are proposed in [17–20,25,26,31].

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