



Fault tolerant tracking control using unmeasurable premise variables for vehicle dynamics subject to time varying faults

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Abstract

This paper deals with fault tolerant tracking controller (FTTC) design for vehicle dynamics system represented by an uncertain continuous time Takagi–Sugeno (T–S) model with unmeasurable premise variables. The goal is to ensure both state and fault estimations and the state trajectory reference tracking even if faults occur. To do this, a Proportional Integer Observer (PIO) with unknown inputs is then designed on the basis of the measure of the roll rate, the steering angle and the lateral offset given by the distance between the road centerline and the vehicle axle at a look-ahead distance. In this study, the faults affecting the system behavior are considered as time varying functions modeled by exponential functions or first order polynomials. Based on descriptor redundancy property solution are proposed in terms of Linear Matrix Inequalities (LMIs). Simulation results illustrate the applicability and the effectiveness of the proposed approaches on the vehicle system.

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1. Introduction

Driver assistance and safety are becoming increasingly common in automotive industries applications in order to fight against the problems relative to road security. Indeed, the number of

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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, vehicle stabilization systems such as Electronic Stability Program (ESP), Dynamic Stability control (DSC), and Anti-lock Brake Systems (ABS) have now become almost standard in new vehicles [1–3]. However, these solutions often repressive have been shown their limits and so, improvements using an advanced estimation and control design methods is needed [4–6].

Estimating vehicle dynamics and road geometry are of primary importance for the implementation of warning and active safety systems. 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]. Indeed, value of the sideslip is required to detect a lane departure, while vehicle roll and road bank angle are needed to detect a rollover. However, direct measurement of these values is not available or very expensive as for lateral speed. 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]. In [6], lateral vehicle dynamics are estimated using a descriptor system based approach for a PI observer. In [7], the authors propose 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 the failure situation [4]. Many works dealing with FTC design have been developed where significant results have been proposed in [10,11] and reference 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)[20,30–33]. The success of these methods mainly depends on the model complexity. Indeed, most studies have considered simple models and generally linear. The reality is far from this assumptions and systems are extremely nonlinear [12]. Moreover, a large class of nonlinear systems can be well approximated by T–S fuzzy models whether the premise variables are measurable or not [9,13,14]. It is clear that the choice of measurable premise variables eases the extension of the methods already developed for linear systems. In the field of diagnosis, this assumption forces to design observers with weighting functions depending on the input $u(t)$, for the detection of the sensors faults, and on the output $y(t)$, for the detection of actuator faults. Indeed, if the decision variables are the inputs, for example in a bank of observer, even if the i th observer is not controlled by the input u_i , this input appears indirectly in the weighting function and it cannot be eliminated [19]. For this reason, it is interesting to consider the case of weighting functions depending on unmeasurable premise variables, like the state of the system. This case makes it possible to handle a large class of physical systems [19,32]. Accordingly, numerous FTC approaches for this class of systems have been developed and some useful results for the tracking trajectory problem are proposed in [17–20,31]. In [30], an FT controller for T–S Models with unmeasurable premise variables is proposed. The estimation of the constant faults was obtained by using proportional–integral observers, while time varying faults are obtained using proportional multiple integral observers. Nevertheless, unknown inputs, parametric uncertainties and time varying faults are not considered in this work. Therefore the purpose of the proposed work is to integrate all of these issues.

In this paper, an uncertain T–S fuzzy representation is considered to describe the vehicle dynamics in large domains [15,16]. A model based unknown input observer is designed in order to estimate both vehicle dynamics and road geometry (road curvature and road bank angle).

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