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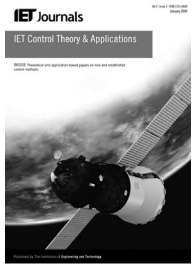

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Robust static output-feedback controller design against sensor failure for vehicle dynamics

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Abstract: This study deals with the design of a robust fault estimation and fault-tolerant control for vehicle lateral dynamics subject to external disturbance and unknown sensor faults. Firstly, a descriptor state and fault observer is designed to achieve the system state and sensor fault estimates simultaneously. Secondly, based on the information of on-line fault estimates, a robust fault-tolerant controller based on static output-feedback controller (SOFC) design approach is developed. To provide linear matrix inequalities of less conservatism, the results are conducted in the non-quadratic framework dealing with unmeasurable premise variables case. Simulation results show the effectiveness of the proposed control approach when the vehicle road adhesion conditions change and the sideslip angle is unavailable for measurement.

1 Introduction

In the last decades, enormous efforts have been devoted in developing intelligent systems for road vehicles. Thus, a Q2 trend was the application of active safety systems to improve vehicle handling characteristics like stability and comfort. Various works have been carried on collision warning, collision avoidance, adaptive cruise control and automated lane-keeping systems. Furthermore, majority of cars are nowadays equipped with traction control system, anti-lock braking system and many variants of electronic stability program [1]. However, the development of effective control systems in more challenging operating conditions and systems failure is still the objective of intense research from both academic and industrial perspectives. In terms of the translation vehicle motion, three types of control systems for vehicle dynamics can be distinguished: lateral, longitudinal and vertical control system. The presented work focuses on fault-tolerant control of vehicle lateral dynamics. Hence, an occurring fault must not only be detected and isolated but also accommodated by a so-called fault-tolerant control law, to preserve satisfactory system performances.

Over the past decades, fault diagnosis and fault-tolerant control strategies (FTC) have been proposed especially for sensor and/or actuator faults for vehicle lateral dynamics [2–4]. Two classes of the existing strategies have been distinguished. The first one is the so-called passive FTC or robust control where faults are treated as non-structural bounded uncertainties [5–7]. However, the issues of fault detection and estimation are not involved either. Contrarily to the passive FTC, active FTC requires the knowledge of the faults to reconfigure the controller law to maintain system stability, thus ensuring a smooth operation (see e.g. [8–12] and references therein). The success of the previous methods mainly depends on the model complexity. Indeed, most studies have considered simple models and generally linear. The reality is far from these assumptions and systems are extremely non-linear [10]. Moreover, a large class of non-linear systems can be well approximated by Takagi–Sugeno (T–S) models [10, 11, 13]. This later is described by a set of linear time invariant (LTI) models and an interpolation mechanism between these models based on non-linear weighting functions. Indeed, the T–S models can be cast into two main classes depending on whether the decision variables are measurable or not [14]. Furthermore, the T–S models with unmeasurable premise variables may be more interesting [14, 15]. Recently, it has been demonstrated that the multiple model approach is suitable for observer and/or controller design, because it allows avoiding the need of Lipschitz hypothesis like [16, 17] does.

Observers design for the non-linear T–S systems has been studied using a quadratic Lyapunov functions (see e.g. [18, 19] and references therein). These approaches remain conservative since a common Lyapunov matrix must be Q3 found for a set of linear matrix inequalities (LMIs) [20]. To leave the quadratic framework, some works deal with poly-quadratic and non-quadratic approaches [21–24] for control and observer or filter design [14, 21, 25–27]. In this context, relaxation schemes have been proposed for fault diagnosis and fault-tolerant control [6, 11, 15, 28–31], and even for Markovian jump systems with sensor saturation [32] and network sensors [33–35].

Among control theory, regarding to output stabilisation of T–S models, several techniques have been proposed for