International Journal of Automotive Technology, Vol. 21, No. 1, pp. 259−268 (2020)
DOI 10.1007/s12239−020−0025−8

pISSN 1229−9138/ eISSN 1976−3832

DISTRIBUTED H_∞ CONTROL OF PLATOON INTERACTED BY SWITCHING AND UNDIRECTED TOPOLOGY

Feng Gao*, Fan-xia Lin and Bao Liu

School of Automotive Engineering, Chongqing University, Chongqing 400044, China

(Received 24 January 2018; Revised 22 May 2019; Accepted 22 May 2019)

ABSTRACT−To deal with the challenges caused by the weakness of wireless communication, this paper presents a distributed $\boldsymbol{H_\infty}$ control strategy for platooning of automatic vehicles (AVs) connected by switching and undirected topologies. With the compensation of the powertrain nonlinearities by an inverse model, the node dynamics is described by a linear system with bounded uncertainty. Then the platoon system controlled by a distributed state-feedback controller is decomposed into multiple low order subsystems by applying the eigenvalue decomposition and linear transformation. The open gain of these subsystems dependends on the eigenvalues of the topological matrix. The sufficient condition for the $\boldsymbol{H_\infty}$ performance of platoon is proved by using the invariant of signal amplitude of the linear transformation. A numerical way is further provided to solve the distributed controller by using the LMI approach. For this new synthesis method, only the bounds of the topological eigenvalues are necessary. And the designed state-feedback can control the platoon composed of disturbed nodes and interacted by uncertain even switching topologies in a satisfactory way. The effectiveness of this distributed $\boldsymbol{H_\infty}$ control strategy is validated by comparative bench tests between nominal and disturbed conditions.

KEY WORDS : Vehicular platoon, Robust performance, Distributed control, System decoupling

1. INTRODUCTION

Many such traffic performances as driving safety and fuel consumption can be greatly improved by platooning, which has attracted extensive interests since the PATH program in 1980's (Shladover *et al*., 1991; Zhang *et al*., 2011). Recently some practical demos have also been carried out in the real world, e.g., the SARTRE in Europe (Chan *et al*., 2012). In the past years, many issues about platooning have been extensively studied, such as how to deal with the nonlinearities of powertrain (Li *et al*., 2016), the influences of clearance policy (Swaroop *et al*., 1994; Swaroop and Hedrick, 1999), homogeneity and heterogeneity (Shaw and Hedrick, 2007) of nodes, asymptotical and string stability (Xiao and Cao, 2011). Many advanced control methods have been applied to platoon control to achieve better control performances (Liang and Peng, 1999; Shladover *et al*., 1991).

These earlier studies mainly consider the radar-based or centralized control systems, whose interaction topologies are simple and quite limited. Recently because of the rapid development of wireless communication, it is a trend to apply such vehicle-to-vehicle communication (V2V) technologies as dedicated short range communication (DSRC) to automated vehicles (AVs) (Willke *et al*., 2009). The application of V2V generates a variety of new interaction topologies such as multiple-predecessor following type. Comparing with the earlier systems, new challenges arise because of the topological variety including the robustness of information connections, the dimension and structure of interaction topologies, etc. It becomes even critical if there exist packet loss and time delay in wireless communication (Liu *et al*., 2019).

From the perspective of multi-agent control system, a platoon connected by V2V can be considered as a dynamical network with one dimension, in which each node only uses its neighboring information. When the nodes are interacted by a symmetrical information flow called "undirected topology", the network can be decoupled to multi-systems with lower order, whose open loop gain depends on the topological eigenvalues. With this approach, Zheng *et al*. (2016a) gave out the asymptotic stability condition of homogeneous platoons and introduced a method to improve the stability margin via topological selection and control adjustment. To overcome the drawback of homogeneous state-feedback controller, a heterogeneous feedback controller is further designed to ensure string stability of platoons interacted by bi-directional topology in (Ghasemi *et al*., 2013; Zheng *et al*., 2016b). In practice, node dynamics may be affected by many factors such as vehicle type, environmental resistance and working condition. To deal with such uncertainties, Wang *et al*. (2015) proposed a linear matrix inequality (LMI) method to optimize the state-feedback controller for multi-AVs interacted by pre-know and fixed topologies. Gao *et al*. (2017a) further presented a robust

**Corresponding author.* e-mail: gaofeng1@cqu.edu.cn