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New discrete-time robust H_2/H_∞ algorithm for vibration control of smart structures using linear matrix inequalities

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ABSTRACT

In real structural systems, such as a building structure or a mechanical system, due to inherent structural modeling approximations and errors, and changeable and unpredictable environmental loads, the structural response unavoidably involves uncertainties. These uncertainties can reduce the performance of a control algorithm significantly and possibly make it unstable. In this paper, based on the theories of the Bounded Real Lemma and the linear matrix inequalities (LMI), a novel discrete-time robust H_2/H_∞ control algorithm is presented which not only reduces the structural peak response caused by external dynamic forces but also is robust and stable in the presence of parametric uncertainties which is always the case in real-life structures. To facilitate practical implementation, the uncertainties of structural parameters are considered in the time domain as opposed to the frequency domain. Compared with traditional H_∞ control methods, the new control algorithm proposes a convenient design procedure to facilitate practical implementations of active control of complex and large structural systems through the use of a quadratic performance index and the LMI-based solution method. The effectiveness of the new discrete-time robust H_2/H_∞ adaptive control algorithm is demonstrated using a three-story frame with active bracing systems (ABS) and a ten-story frame with an active tuned mass damper (ATMD).

1. Introduction

Reducing the peak response quantities such as displacements and accelerations of structures subjected to external dynamic loads is of primary concern in design of large structures. The most recent design strategies focus on methods of structural vibration control (Adeli and Saleh, 1999; Adeli and Jiang, 2009; Adeli and Kim, 2009). These methods are divided into passive control such as the Tuned Mass Damper (TMD) (Gutierrez-Soto and Adeli, 2013a; Andersson et al., 2015), semi-active control (Fisco and Adeli, 2011a), active control (Kim and Adeli, 2005d; Gutierrez-Soto and Adeli, 2013b), and hybrid control (Kim and Adeli, 2005b, 2005c; Fisco and Adeli, 2011b) method. Compared to the passive control system, an active control system has advantages of adaptability and performance. Moreover, semi-active and hybrid control strategies which are more practical in terms of implementation are always based on active control algorithms (El-Khoury and Adeli, 2013).

Over the past few decades many active control algorithms have been developed such as the linear quadratic regulator (LQR) (Stavroulakis et al., 2006), linear quadratic Gaussian (LQG) (Wu and Yang, 2000), sliding mode control (SMC) (Alli and Yakut, 2005; Pai, 2010; Wang and Adeli, 2012, 2015a, 2015b), H_∞ control (Yang et al., 1996), proportional–integral–derivative (PID) control (Kang et al., 2009), model predictive control (Wang et al., 2015), parallel control (Li et al., 2014), and optimal control algorithm (Adeli and Saleh, 1997; Saleh and Adeli, 1997, 1998a, 1998b, Li et al., 2015). Adeli and Saleh (1998, 1999) present an integrated control and optimization strategy for design of both civil structures and control system. For solution of the integrated control and optimization Saleh and Adeli (1994) present parallel algorithms on high-performance parallel machines (Adeli and Kamal, 1993) and supercomputers (Adeli and Soegiarso, 1999). A review of recent advances on vibration control of structures under dynamic loading is presented by Khoury and Adeli (2013)

In real structures, due to inherent structural modeling approximations and errors, and changeable and unpredictable environmental loads, the structural system response unavoidably involves uncertainties. These uncertainties can reduce the performance of a control algorithm and possibly make it unstable. In the presence of structural parameters uncertainties traditional control methods do not provide the stability and robustness needed for effective reduction of the structural response under unknowable and varying external dynamic loading conditions. They can affect the structure adversely when the frequency of external

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