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ABSTRACT
VIRTUAL CONTROL WITH APPLICATION TO VIBRATION SUPPRESSION
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The saturation problem was and still a challenging research topic in the control community. For many decades it has attracted and still attracts many researchers and scientists to investigate and trials to give a resolution to the problem. There are many recent methods and techniques introduced in the literature as a solutions for the problem, but most of them are introducing an ad hoc methods, nonlinear or anti-windup schemes were in most, these methods are either incompetent in the sense of applicability to the broad control problems and/or they are computationally expensive. This study presents novel solutions modeling and control as a remedy for the saturation problem with applications. These novel proposed methods are systematic, numerically sounds and are applicable for a wide range of Linear Time Invariant (LTI), Linear Parameter Varying (LPV), discrete and continuous systems.

The first novel idea introduced in this dissertation is for LPV systems. The idea of scaling scheduling parameters is introduced and synthesized. Two novel Linear Parameter Varying (LPV) modeling and control techniques are proposed for active flutter suppression of a smart airfoil model. The smart airfoil model is instrumented with a moving mass that can be used to actively control the airfoil pitching and plunging motions. The first LPV modeling approach makes use of the moving mass position as a scheduling parameter, and the hard constraint at the boundaries is imposed by proper selection of the parameter varying function. The second modeling technique
utilizes nonlinear springs and dampers, which are added to both ends of the airfoil groove to confine the motion of the moving mass. A state-feedback based LPV gain-scheduling controller with the guaranteed $H_\infty$ performance is proposed by utilizing the dynamics of the moving mass. In this novel idea, both the position of the moving mass and the free stream airspeed are considered as the scheduling parameters.

The second novel idea is the virtual hard constraints control approach. The proposed idea is introduced to deal with saturation control problems for linear time invariant (LTI) systems using virtual nonlinear springs and dampers for the optimal control design and then incorporates the virtual dynamics into the control input for real-time control. The basic idea is to increase the control cost when these state(s) move close to the hard constraint(s) and saturation limit(s), and the designed optimal control strategy will avoid moving these state(s) close to the hard constraint area. The proposed method is applied to a ball and beam system to demonstrate its feasibility and effectiveness, where virtual spring and damper are introduced during the control design. The performance of conventional LQR state feedback control and the associated virtual LQR-based MPC control are compared.

The third novel idea is the LPV virtual control (LPVVC) scheme with hard constraints for LPV system is proposed. The main idea of virtual control and virtual mechanism is introduced here to the LPV systems to form LPVVC. The proposed control scheme is applied to the flutter suppression of a smart airfoil to demonstrate its effectiveness and ability of performance enhancement. The state-feedback LPV (gain-scheduling) control with guaranteed $H_\infty$ performance is used for designing controller based on the model with virtual mechanisms. The virtual mechanisms used in this paper are in terms of springs and dampers located at both ends of the airfoil groove to prevent the control mass from moving outside of the groove. Noticing that the virtual mechanisms are not limited to springs and dampers and can be choosing to be in any other form. The performance of the designed LPVVC controller is compared with the conventional LPV control with hard constraints (LPVN), nonlinear control (NLC), and regular LPV control (LPVR) and showed significant improvement.