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ATTITUDE CONTROL DESIGN OF SPACE LAUNCH VEHICLES USING MODEL PREDICTIVE CONTROL

Abstract

The idea of the model predictive control MPC is applied to launch vehicle attitude control. Successful application of automatic control depends on the accuracy in modeling the system. Attitude control of the launch vehicle is no different. The rocket's parameters such as the mass and the stiffness are constantly changing with time. Additionally, there is uncertainty in these parameters because it is not possible to test a flight model. This study is focused on attitude control of the launch vehicle during its ascent stage. At this stage, the environmental condition is also changing with time, and there is uncertainty in local wind and atmospheric conditions. Rapidly changing wind disturbances make the vehicle unstable, thus response performance is demanded. Furthermore, dynamics is composed of rigid body attitude motion and elastic vibration, and both are highly coupled. Elastic vibration greatly affects the response of attitude motion, thus leads to destabilizing the vehicle. These conditions of the dynamics and the environment demand not only robust stability but also response performance for flight safety, but they are in a trade-off relationship. The latest designs, including a combination of H-infinity control and gain scheduling control, have been successfully applied to real systems. The gain scheduling control approach divides the entire flight time into multiple blocks. This approach requires significant time and labor because each block must have its own controller design. To simplify this design procedure, the goal of the study is to design a robust control algorithm that can directly respond to the time-varying characteristics of the system. In this paper, two controllers are designed: one for the time-varying system and the other for the uncertain system. The one has been designed with adaptive model predictive control (AMPC). AMPC can predict future behavior of the system more precisely than conventional MPC. This paper demonstrates that the AMPC controller provides better control performance for the time-varying system than the conventional controller. The other controller uses the idea of linear matrix inequality (LMI)for robust MPC. The robust stability of the system is guaranteed with the Lyapunov stability theory. The robust stability is demonstrated through simulations of the models with uncertain parameters. The direction of further study will be discussed for the combined algorithm which can deal with both the uncertainty and the time-varying characteristics. This work can be considered essential to improve the performance and safety of future launch vehicle flights.