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OPTIMAL CONTROL OF SPACECRAFT ATTITUDE MOTION USING PORT-HAMILTONIAN SYSTEMS

Abstract

In this study, a concept of optimality is introduced into a Port-Hamilton system for attitude control of spacecraft. Port-Hamiltonian systems make it possible to design asymptotically stable controllers in a uniform procedure for a wide variety of physical systems. By introducing optimality to the Port-Hamilton system, more efficient control becomes possible. A conventional error system of a Port-Hamilton system for attitude motion of spacecraft is expanded to minimize a quadratic form of evaluation function by the proposed procedure.

In previous studies, attitude control of a spacecraft has been proposed for a time-varying error system using Port-Hamiltonian systems. This error system can be derived through generalized canonical transformation, which is a generalization of canonical transformation widely used for analysis of dynamics of mechanical systems. This generalized canonical transformation can yield robustly stable controllers because it is a natural extension of the passivity-based control for conventional mechanical systems. However, optimal control based on Port-Hamilton systems has not been discussed yet, although the importance of fuel consumption is widely approved in space missions.

Based on the above problem, we consider the optimal control of the Port-Hamiltonian system from the approach using Hamilton-Jacobi-Bellman (HJB) equation. A condition for generalized canonical transformation to satisfy passivity of systems has been stated in a previous study. In this study, the stated condition is replaced with the HJB equation to obtain generalized canonical transformation and control input that minimizes an evaluation function in quadratic form of the error system. The HJB equation can be easily solved by utilizing the structural features of the Port-Hamiltonian system, and the minimum evaluation function is expressed as an initial value of a transformed Hamiltonian through the generalized canonical transformation. This method can also be used for a conventional time-varying error system. In the presentation, by applying the proposed method to a trajectory tracking control of the spacecraft, an optimum control input to follow an arbitrary trajectory is obtained.