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NASH EQUILIBRIUM-BASED VIBRATION CONTROL FOR LARGE FLEXIBLE SPACE STRUCTURES USING DISTRIBUTED CONTROL MOMENT GYROSCOPES

Abstract

To suppress the vibration of large flexible space structures, a novel vibration control scheme is proposed in this paper utilizing distributed control moment gyroscopes (CMGs), based on the notion of Nash equilibrium and differential game. Collocated pairs of control moment gyroscopes and angular rate sensors are adopted as the distributed actuators/sensors mounting on a large flexible space structure. Firstly, a preparatory model considering the dynamics of the CMGs and their interactions with the flexible space structures is established via the finite element method. Based on controllability and observability criterion, several constraints are formulated and integrated into covariance matrix adaptation evolution strategy algorithm to obtain the optimal quantities and positions of actuators/sensors. Secondly, a differential game controller is designed based on a non-zero-sum differential game strategy, in which each CMG is regarded as an independent player in the game. The proposed differential game controller uses the angular rates at actuator locations as input, and takes the gimbal angular rates of CMGs as output. To yield a Nash equilibrium solution, the coupled Hamilton-Jacobi equations are resolved by leveraging a hybrid approach that combines policy iteration algorithm and actor-critic network framework. Its Lyapunov function is then analyzed to guarantee closed-loop stability. Finally, numerical examples are conducted to verify the effectiveness and feasibility of the proposed differential game-based strategy method. The simulation results demonstrate that the designed controller can noticeably suppress the vibration of flexible structures, outperforming conventional PID and positive position feedback (PPF) controllers in settling time as well as in robustness to external disturbances.