ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (2) (4)

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DESIGN AND VALIDATION OF GEOMETRIC OPTIMISATION SOFTWARE FOR THE ATTITUDE CONTROL OF MICROSATELLITES

Abstract

The capabilities of microsatellite attitude control hardware have considerably evolved during the last two decades. However, three axis attitude control software is still predominantly based on the conservative use of standard flight proven PD type controllers, which are known to be limited in terms of rapidity for a prescribed level of energy consumption. Microsatellites are therefore typically not as agile as they could be. This conservatism is due to the complexity of implementing and validating globally stable numerical optimisation techniques to the attitude control of satellites.

In this paper, we consider the model of a low earth orbiting microsatellite with a four wheel configuration, where the speed of one of the wheels is kept constant to provide a momentum bias and guarantee gyroscopic stiffness to disturbances. A new geometric optimal control approach is presented, which circumvents the tedious tasks of numerically solving online the nonlinear optimisation problem. The approach is based on the design of suboptimal phase space trajectories. The phase space trajectory of a standard linear controller, typically a PD law, is used as a benchmark. The proposed inverse optimal control technique is then used to enforce higher convergence rate constraints than the PD benchmark, without increasing the total energy consumption. The convergence rate of a Lyapunov function under the effect of the controller typically outperforms the convergence rate of the same function under PD control and keeps increasing until a design convergence rate limit is reached. Guidelines are given for the optimal tuning of the controller.

The optimal attitude control algorithms are validated on a microsatellite software simulator in collaboration with the space company Surrey Satellite Technology Limited (SSTL). The software simulator incorporates a precise model of the effects of estimation errors, noise, external disturbances, sampling and actuator dynamics. The software is very similar to the flight software of typical Surrey microsatellites.

The proposed techniques are characterized by low implementation complexity because the difficulty is confined to the theoretical design stage. The rapidity in terms of settling time is enhanced by forty percent for the same level of energy consumed as the standard flight proven PD law, which was used as a benchmark without loss of generality. Low computational demand also makes the approach particularly suitable for implementation onboard microsatellites.