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EXPERIMENTATION OF NONLINEAR SPACECRAFT ATTITUDE MOTION CONTROL VIA SUCCESSIVE LINEARIZATION BASED MODEL PREDICTIVE CONTROL

Abstract

In space applications, reliability and real-time implementation capability of control algorithms are two key requirements. In this paper, we propose Successive Linearization based Model Predictive Control (SL-MPC) paradigm to control the nonlinear dynamics of the satellite attitude motion and meet the aforementioned requirements, by performing Hardware-In-The-Loop tests to verify the proposed approach. SL technique is known as an approximation of the highly nonlinear plants in the literature. SL technique provides a convex optimization problem and benefits from the mature and reliable linear systems theory. In the current literature, the SL technique has never been used to address the attitude control problem of space systems. First, the SL-MPC approach is compared with Linear-MPC (L-MPC) in which the plant is linearized around the nadir pointing attitude and corresponding angular rate. It has been shown that given a small angle initial condition, the SL-MPC approach points to the nadir with a lower settling time and torque inputs. The proposed approach is also compared with the traditional PD controller designed for the pointing problem. It is demonstrated that both PD and SL-MPC approach can follow continuously changing attitude references whereas the L-MPC approach fails to track as Linear Time Invariant (LTI) models cannot completely represent the nonlinear model. In the comparison with PD like controller, it was shown that SL-MPC can save up to 30% of torque input, and thus fuel or energy consumption, in order to track the same reference while both approaches show a similar and satisfactory tracking error. In addition, the SL-MPC approach can also have the distinct feature of explicitly handling the input and output constraints (e.g. saturation of the reaction wheels). Lastly, the proposed approach has a preview capability such that given reference can be tracked without undesirable overshoot. It is shown that sensitive sensors such as cameras or LIDAR can perform healthier and longer orbit life when avoiding overshoots on their mechanisms. Eventually, it is acknowledged that Nonlinear MPC approach can have a slightly better representation of the attitude plant but the computational time may violate real-time implementation capability, and possibly solves the non-convex optimization problem for which globally optimal solutions may be difficult to ensure. In summary, having real-time implementation capability, ability to explicitly handling constraints, coverage of complete nonlinear plant without compromising tracking error and finally the experimental results show that the proposed SL-MPC strategy is a promising approach for future satellite missions.