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NONLINEAR OBSERVER AND MPC-BASED ALGORITHMS FOR RENDEZVOUS MANEUVER WITH TUMBLING TARGET

Abstract

This paper investigates a combination of nonlinear observers and a robust control strategy for spacecraft rendezvous maneuver. The main objective of the paper is to design an efficient Model Predictive Control (MPC) algorithm, to obtain an optimal rendezvous trajectory by solving a quadratic programming problem subjected to linear constraints. A combination with robust navigation algorithms is provided to show the effectiveness of the chosen control strategy. Indeed, the control strategy assumes that the relative position and linear velocity of the active spacecraft cannot be measured but are estimated with a navigation system based on Sliding Mode (SM) algorithms. In details, a combination of Super-Twisting and Linear SM observers estimate respectively the relative position and linear velocity. The states estimated by the navigation system are affected by uncertainties and errors, that are taken into account for the choice of the control strategy. For this reason, a SM-based observer is designed to estimate the system uncertainties. The information, obtained by the navigation system and the uncertainties observer, allow to express the convex problem as Linear Matrix inequalities (LMI). Thanks to the knowledge of the uncertainties, the design of the MPC algorithm with a tube-based methodology can be improved, reducing also the chattering effects derived from the actuation dynamics. The solution of the LMI problem is proposed to achieve the system robustness and to provide the gain matrix, required for setup the tube-based algorithm. Moreover, the discrete output of the control algorithm is converted in on-off pulses by a Pulse Width Pulse Frequency (PWPF) modulator. This approach simulates the behaviour of the thrusters as on-off devices and reduces the fuel consumption with an efficient tuning of the parameters. Numerical simulations show that, increasing the robustness of the control channel, the spacecraft is able to perform different maneuvers and is able to satisfy the accuracy requirements for station keeping. Moreover, this work proposes a comparison between a Linear Quadratic MPC (LQ-MPC) and a Tube-based Robust MPC (TRMPC) to verify the robustness against the uncertainties and disturbances of the system.