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PERFORMANCE ANALYSIS OF VARIANTS OF THE MODEL PREDICTIVE CONTROL APPROACH FOR SPACECRAFT RENDEZVOUS AND DOCKING

Abstract

The capability of spacecraft to rendezvous and dock autonomously has become a crucial technology required for space missions. One of the most studied control approaches in the development of this technology is the model predictive control (MPC) approach. Several variations of the MPC approach have been developed to fulfill specific requirements ranging from reduced on-line computational power to a truly robust and optimal control algorithm with multiple constraints. The differences in the algorithms arise at several different levels of the MPC controller design. The most basic level of variation involves changes in the constraints and cost function defined as part of the optimization problem. Further differences arise due to variations in the methodology used to solve the optimization problem. Finally, the controller designs vary based on the MPC implementation on-board the spacecraft. The objective of this paper is to compare the changes in various performance parameters as a result of variations in the MPC controller design. The parameters considered for comparison are fuel consumption, computational workload, time and robustness to external disturbances. In this paper, we have studied the problem of rendezvous and docking with a cooperative target spacecraft, in a circular orbit, from in-track and radial positions. Firstly, a comparison is made based on differences in the constraints applied and the cost function to be minimized. The constraints considered are the line of sight constraint, maximum thrust constraint, plume impingement, and passive collision avoidance, while the cost function includes penalties on fuel consumption, state errors, and attitude change. Two methods used for solving the optimization problem are mixed-integer linear programming and quadratic programming. Lastly, the effect of implementing the MPC controller conventionally, as an explicit control law or using a chance-constrained approach is studied. This research provides a detailed analysis of how these changes affect the mentioned performance parameters. These parameters are not only affected by the inclusion or exclusion of certain constraints and penalties, but also by their formulation. While it is evident that an explicit control law reduces the computational workload and a chance-constrained approach increases robustness as they are specifically designed for that purpose, their effect on other parameters is also carefully studied. This allows for a better analysis of tradeoffs among mission–critical parameters and facilitates the selection of the most suitable design of the MPC controller, based on mission requirements.