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AUTONOMOUS GUIDANCE USING NONLINEAR MODEL PREDICTIVE CONTROL FOR RENDEZVOUS AND DOCKING WITH NON-COOPERATIVE TARGETS

Abstract

In this paper, a Nonlinear Model Predictive Controller (NMPC) for autonomous non-cooperative Rendezvous and Docking (RVD) operations is presented. This project has been carried out for a rendezvous and docking mission with two micro satellites of mass 150 kg each in Low Earth Orbit. Autonomous RVD operations of spacecraft require the capability of on board planning and execution of highly constrained trajectories without ground support for cooperative/non-cooperative targets. The aim is to develop a controller that performs RVD operations in real time, in particular obstacle avoidance, while providing optimal performance in a constrained environment. In this project, obstacles are approximated and bounded by ellipsoids for the purpose of estimation without loss of obstacle nature. These ellipsoid models are constructed around obstacles as constraints and applied in NMPC in rotating hyperplane method. The NMPC controller performance has been compared with traditional real time trajectory planning techniques, such as the potential field method. In addition, port constraints, terminal constraints for soft docking, and plume constraints have been modeled as linear equality/inequality constraints. Fuel minimization with above constraints is presented as a convex optimization problem. A vision-based navigation sensor has been applied to determine the position and velocity of the target satellite. The vision sensor processing involves feature detection and feature tracking using computer vision algorithms. Optical flow and SIFT algorithms and have been applied to derive the relative position and velocity. The NMPC controller has been implemented using a 6-DOF Robotic arm as the chaser and a three axis motion simulator as the target. This setup works analogous to docking with non-cooperative targets.