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GUIDANCE AND CONTROL IN AUTONOMOUS DEBRIS REMOVAL SPACE MISSIONS VIA ADAPTIVE NONLINEAR MODEL PREDICTIVE CONTROL

Abstract

Space debris orbiting around the Earth are becoming a major problem that could impair the future of space exploration. Among the different approaches to this problem that have been proposed in the recent years, this work focuses on a possible solution consisting in an autonomous spacecraft that performs a rendezvous maneuver, collects a debris of unknown mass and then moves to a parking orbit. When the spacecraft collects a debris of unknown mass, the dynamics of the system may change substantially and this may affect the control stability and performance of the spacecraft. In this study, a control system is designed, capable of handling situations with time-varying and uncertain parameters, as it occurs in space debris removal missions. A control strategy based on an Adaptive Nonlinear Model Predictive Control (ANMPC) is considered. The unknown mass of the debris is treated as an uncertain parameter and is estimated by means of two different methods (Recursive Average and Extended Kalman Filter (EKF)). Then, the estimated mass is used to update the internal model of the ANMPC, which later solves an on-line optimization problem providing an optimal trajectory and control action for reaching the debris and the parking orbit. Simulations shows that the proposed control system is able to effectively accomplish the requested task. The solutions coming from two different estimation methods are compared and provide similar results. If a simple NMPC startegy is employed without an estimation and adaptation process, the obtained results do not diverge significantly from the other case, meaning that NMPC is a control method that is intrinsically robust for this kind of applications. However, the mass estimation is useful in order to improve the overall performance. The adaptive algorithm has also the potential to be extended to other space missions characterized by unknown parameters.