ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (2) (2)

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AUTONOMOUS NAVIGATION AND GUIDANCE FOR TERMINAL MANEUVER FOR DOCKING USING MODEL PREDICTIVE STATIC PROGRAMMING (MPSP) AND UNSCENTED KALMAN FILTER (UKF)

Abstract

ISRO is planning to demonstrate the space docking experiment (SPADEX) using two mini satellites IMS bus of 100kg in Low Earth Orbit. Traditionally rendezvous and proximity maneuvers have been performed using open-loop maneuver planning techniques and visual based error correction in semi-autonomous mode. Lately, in order to improve the performance (robustness, fuel efficiency, speed, safety, and reliability) feedback controllers are applied in Autonomous Docking. Recently, Model Predictive Static Programming (MPSP) based guidance algorithms are effectively used for aerospace applications. MPSP is based on the concept of Approximated Dynamic Programming (ADP) and Model Predictive Control (MPC) basically optimizes the problem considered and formulated in such a way that control history is updated to reduce the target error. In ADP, the dynamics is discrete form and the co-state is propagated from final time to current position i.e. backward direction. Where as in MPSP, dynamics is formulated in discrete form and the output error is propagated in backward direction to optimize the control inputs.

MPSP based relative motion control is developed for rendezvous of a target spacecraft with a chaser spacecraft. In this approach, the optimal control sequence is generated over finite time by considering the measurement of the state in every guidance step. Terminal hard constraints (equality state constraints) are included for soft docking. These constraints are under thrust magnitude limit, chaser spacecraft positioning with in Line-of-Sight (LOS) while approaching the target spacecraft, and chaser spacecraft terminal velocity limit for soft-docking with target spacecraft. Full optimal problem of a non-linear system with closed form solution as well as with minimum computational time is achieved in this. The robustness of this control has been verified using nonlinear dynamics with J2 perturbation model. The MPSP Controller is validated on nonlinear and elliptical orbit model by simulations. In this paper, the estimation of relative position and relative velocity for a terminal maneuver for docking application using Unscented Kalman Filter (UKF) has been presented. In order to achieve the highly precise navigation information, Unscented Kalman Filter has been designed for terminal phase low impact docking. Even though, Extended Kalman Filter is a good nonlinear estimation technique, because of some limitations

like handling too much of non-linearity, higher time intervals, filter instability, etc. cannot give the expected results and also computationally it is complex, whereas Unscented Kalman Filter can provide better results without compromising accuracy and it is computationally efficient.