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A NOVEL NONLINEAR CONTROL APPROACH FOR RENDEZVOUS AND DOCKING MANEUVERING

Abstract

Nowadays autonomous rendezvous and docking (ARD) operations represent a crucial technique for several space missions which involve either in orbit assembly of numerous modules or serving/refueling operations; both around Earth and interplanetary scenarios, manned and unmanned vehicles may ask for such a technique. In order to obtain the final docking interface conditions, translational and attitude constraints must be satisfied during a rendezvous and docking maneuver; therefore, the control scheme has to simultaneously tune the relative position and velocity between the two satellites and adjust the chaser spacecraft's orientation with respect to the target port. Since dynamic equations which describe the relative satellites pose are nonlinear, many nonlinear control methodologies have been investigated during last decade: Terui has shown the effectiveness of the sliding mode control technique to control both position and attitude for proximity flight around a tumbling target; Kim et al. have proposed nonlinear backstepping control method to solve the spacecraft slew manoeuvre problem. One of the highly promising and rapidly emerging methodologies for designing nonlinear controllers is the state-dependent Riccati equation (SDRE) approach, originally proposed by Pearson and Burghart and then described in details by Cloutier, Hammett and Beeler. This approach manipulates the governing dynamic equations into a pseudo-linear non-unique (SDC parameterization) form in which system matrices are given as a function of the current state and minimizes a quadratic-like performance index. Then, a sub-optimal control law is obtained by online solution of Algebraic Riccati Equation (ARE). Even if the SDRE method represents a valid option to solve the nonlinear control problem related to ARD manoeuvring, it is prone to high computational costs due to the online solution of ARE. In this paper, a new approximated SDRE solution to solve ARD manoeuvring problem based on the differential algebra (DA) exploitation is proposed. Differential algebraic techniques allow for the efficient computation of the arbitrary order Taylor expansion of a sufficiently continuous multivariate function in a computer environment with a fixed resource demand. A DA-based algorithm is here presented to compute a high order Taylor expansion of the SDRE solution with respect to the state vectors around a reference trajectory. The computation of the next SDRE solution is then reduced to the mere evaluation of polynomials, substantially reducing the associated computational effort due to the ARE solution, main gap to the online/on-board technique exploitation.