Paper ID: 38705
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ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (3) (5)

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ANGLES-ONLY-BASED NONCOOPERATIVE PROXIMITY OPERATION FOR TETHERED SPACE ROBOT

Abstract

Noncooperative proximity operation is not trivial because the spacecraft is assisted solely by its own onboard sensors in implementing relative navigation. This is more challenging for micro spacecrafts such as tethered space robot (TSR) due to their limited payload capability. Vision sensors such as cameras are better suited to micro spacecraft as they are low-cost and light-weight but provide rich information. Although the use of camera is attractive, vision-only-based proximity operation is however extremely challenging because camera can only measure line-of-sight direction of noncooperative targets and has the well-known limitation of determining distances. Despite the achievements in angles-only navigation in the aerospace field, most of the existing studies focus on the theoretical aspects of observability conditions and optimal maneuvers. There have been few studies dedicated to any real-time integrated navigation and control framework in a specific proximity operation scenario. In this paper, we propose a real-time angles-only navigation and control framework for proximity operation with application to the TSR. Under this framework, the spacecraft not only estimates its current orbital position precisely using simple angles-only measurements, but also approaches to the noncooperative target following desired motions for both attitude and orbit.

The study is motivated by a realistic problem that arose during our design of TSR. The proposed angles-only navigation framework combines off-line motion planning and on-line navigation and control scheme. The off-line motion planning predicts optimal profiles for both orbit and attitude motions that follow the dynamics of TSR and integrate observability condition. In on-line navigation and control scheme, time delay control (TDC) is then used to follow the desired attitudes. Meanwhile, model predictive control (MPC) is adopted to track the orbital trajectories while ensuring the performance of extended Kalman filter (EKF) for orbital position estimation. The main contribution of this work lies in twofolds. First, the paper proposes a real-time systematic angles-only navigation and control framework for proximity operation. To the best of authors' knowledge, there is no such systematic framework that has been reported in orbital rendezvous and proximity operation. Secondly, the paper provides TSR with a feasible relative navigation means for approaching to noncooperative target. Extensive simulations illustrate the effectiveness of the proposed framework, which can be readily extended to other angles-only navigation applications.