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RELATIVE NAVIGATION PROBLEM FOR RENDEZVOUS OF TWO NON-COOPERATIVE NANO-SATELLITES

Abstract

New concepts of modern space missions account for high level of autonomy. Spacecraft, including small- and nano-satellites, are required to perform operational tasks without the aid of human intervention and interaction (e.g., rendezvous, formation flying, docking). The development of hardware and software is then fundamental to address the demanding requirements that are posed by the autonomous operations of new mission concepts. This paper focuses on the identification and implementation of an onboard software to solve the problem of relative navigation of two non-cooperative nano-satellites, a target and a chaser. The mission scenario is based on a rendezvous between the chaser and target. This operation is accomplished through an accurate determination of the target orbit and maneuvering. The rendezvous is split into three main phases to account for the different guidance strategy and poses of the target: (1) phasing; (2) far-range approach; and (3) close-range approach. The determination of the target's orbit is carried out by the chaser using measurements acquired from its onboard sensor, and processing them through a recursive, nonlinear state estimation algorithm, the Unscented Kalman Filter (UKF). The algorithm has been implemented and tested through numerical simulations of the relative 6-DOF pose of the two satellites, including the perturbative effects associated with gravitational anomalies and atmospheric drag that are dominant at low Earth orbits. A thorough study on existing missions was conducted to better understand realistic limitations and capabilities of the state-of-the-art of existing devices. Visible/infrared cameras providing bearing measurements and lidar/laser for range measurements have been considered in this work. The numerical simulations will allow us to study the main requirements of the relative navigation system for this application (e.g., maximum level of noise, measurements update rate, guidance update rate, state estimation convergence time), in order to guarantee an efficient rendezvous. The main result of this study is the definition of a tool to configure the architecture of new missions. Different mission configurations will also be investigated to determine the sensors (e.g., camera and lidar) that are necessary to fulfill the stringent requirements of autonomous operations. The results of this study are validated through a Monte-Carlo campaign that will demonstrate the solidity of the proposed relative navigation architecture.