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Author: Mr. Jean-Sébastien Ardaens
German Aerospace Center (DLR), Germany, jean-sebastien.ardaens@dlr.de

Dr. Gabriella Gaias
German Aerospace Center (DLR), Germany, gabriella.gaias@dlr.de

SPACEBORNE AUTONOMOUS VISION-BASED NAVIGATION SYSTEM FOR AVANTI

Abstract

AVANTI (Autonomous Vision Approach Navigation and Target Identification) is an experiment currently in development at the German Space Operations Center and aiming at demonstrating the capability to perform autonomously far- to mid-range noncooperative rendezvous approaches by making use of angles-only measurements. AVANTI will be implemented onboard the DLR's Biros satellite, scheduled for launch in 2015, and takes advantage from the fact that Biros embarks a third-party pico-satellite to be ejected in-orbit prior to the start of AVANTI, which will thus serve as noncooperative target for the sake of the experiment. AVANTI will use star-trackers of the satellite to track the pico-satellite without any direct range measurement. As part of the experiment, a vision-based navigation filter is designed to provide an estimate of the target relative state to an onboard autonomous maneuver planner which produces the required guidance profile in order to perform a rendezvous in a safe, fuel efficient manner. The resulting maneuvers are in turn improving the observability of the angles-only navigation and thus the knowledge of the relative state. The paper focuses on the vision-based navigation of system AVANTI, which comprises two main functionalities. First, the pictures from the star tracker are processed by a target identification algorithm, which provides the angle measurements of the line-of-sight to the target. The reliable recognition of the target spacecraft among all the luminous spots comprised in the picture is a delicate task because the target is at a first glance not distinguishable from the surrounding stars and from the non-celestial objects that might appear in the picture. The paper describes the strategy adopted for the robust target identification, relying on the fact that the apparent motions of the objects imaged by the camera are fairly different. By combining several images, it becomes possible to recognize unambiguously the peculiar trajectory followed by the target. In a second step, the line-of-sight measurements feed a Kalman navigation filter which provides the relative state estimate of the target to the onboard maneuver planner. The filtering is done using a simple analytical model of the relative motion, parameterized in relative orbit elements, which includes the mean effects due to the Earth oblateness. The vision-based navigation filter has been tested and validated in a highly realistic simulation environment and using flight data from the PRISMA formation flying mission. Overall, the results show that reliable target recognition (more than 95% success) and accurate navigation performance can be achieved.