Angles-Only Relative Orbit Determination during the AVANTI experiment

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This paper presents the key results of the angles-only relative orbit determination activities performed during the AVANTI (Autonomous Vision Approach Navigation and Target Identification) experiment. This in-orbit endeavour has been conducted by DLR in autumn 2016 [1] and aimed at demonstrating spaceborne autonomous rendezvous to a noncooperative target using solely optical measurements [2]. AVANTI is implemented on the German BIROS satellite and uses a picosatellite (which had been previously released in orbit by BIROS) for the sake of the experiment.

AVANTI capitalizes the experience already collected in 2012 using the PRISMA formation flying testbed. At that time, the so-called ARGON (Advanced Rendezvous demonstration using GPS and Optical Navigation [3]) experiment had already tackled the problem of angle-only relative navigation by making a ground-in-the-loop approach to a target using optical methods. With respect to such achievements, AVANTI presents an increased level of complexity to cope with a more realistic scenario, in view of the future possible applications of such a technological know-how: rendezvous to space debris or to a noncooperative satellite to be serviced [4].

One of the major differences with respect to ARGON (in addition to the fact that AVANTI is now fully autonomous) lies in the fact that, during AVANTI, the target object is really noncooperative. Thus, the vision-based precise relative orbit determination done on ground becomes the only means to derive precisely the state of the formation and the unique reference to evaluate the performance of the algorithms implemented onboard.
Contrary to ARGON which, thanks to the dusk-dawn orbit of PRISMA, benefited from optimal illumination conditions, AVANTI is meant for target objects flying on any kind of low-Earth orbits. This has dramatic impacts in terms of visibility, since on the one hand the target object is eclipsed during a large part of the orbit and on the other hand the camera becomes blinded by the Sun during another large part of the orbit. In addition, BIROS flies at a low altitude (500 km) inducing a strong unknown differential drag which has to be estimated as part of the orbit determination.
Combined with the fact that the picosatellite is a tiny object and that the problem is weakly observable, these constraints make the angles-only relative orbit determination very challenging.

AVANTI could demonstrate that the angles-only relative orbit determination task can still be successfully conducted at a distance up to 50 km. In order to assess independently the performance of the resulting relative positioning products, a ground-based radar campaign has also been organized during the experiment, within a separation range where the radar signatures could still be separated from each other. Results confirmed the overall consistency of the angles-only relative determination products.

References

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