2nd Stardust International Conference, 7-11 November 2022, ESTEC, Noordwijk

Space Environment Management and Sustainability Symposium

Session on "In-orbit servicing, manufacturing and recycling"

Invited talk

Speaker: Roberto Opromolla

Title: EO-based pose estimation for spacecraft relative navigation to support autonomous In-Orbit Servicing missions

Abstract:

The concept of In-Orbit Servicing (IOS) is relevant to a large variety of mission scenarios involving close-proximity operations between two or more space vehicles. These operations (ranging from refueling and repair to upgrading and assembly) play a key role for future space activities from both an economic and environmental perspective. In fact, on the one side, they provide a mean to extend the operative life of active spacecraft thus representing an opportunity for satellite owners to increase the expected revenue from existing space assets; on the other side, they help limiting the generation of new debris which may pose a threat to the life of operative spacecraft.

IOS missions typically require an active spacecraft (chaser) with an advanced Guidance, Navigation and Control (GNC) system and a proper docking or berthing mechanism to safely approach and capture the target of interest, as well as to control the resulting target-chaser stack after capture. Clearly, the need to achieve high level of autonomy in these operations is considered a critical requirement to increase repeatability, robustness and reliability for this kind of missions. Relative navigation, i.e., the capability to get frequent and accurate estimates of the target-chaser relative state, is one of the most critical functionalities that the chaser GNC system must provide, especially in the final mission phases when this task must be conducted relying on active or passive electro-optical (EO) sensors.

The Aerospace Systems research team at the University of Naples "Federico II" has gathered a wide experience on this topic. Hence, this talk will present recent developments of our research activity in the frame of national and international projects. Specifically, the EO-based pose estimation solutions conceived for close-proximity relative navigation in three mission scenarios will be presented: (i) IOS of a semi-collaborative communication satellite in GEO using visual cameras and passive retroreflectors; (ii) IOS of a tumbling target (belonging to a large constellation) in LEO using visual cameras and AruCo markers; (iii) IOS of a micro-satellite (CubeSat-based) in LEO using a multi-sensor relative positioning module composed of a laser range finder (exploited for both target illumination and range estimation), a visual camera and passive retroreflectors. Extensive numerical analyses to characterize the performance of the proposed solution for the first two scenarios have been carried out in a dedicated numerical environment developed in the frame of a research study (entitled, Preparation of enabling space technology building block "GNC and robotic arm combined control") conducted by a consortium of three Italian universities (University of Padova, Polytechnic of Milan and University of Naples "Federico II") under contract with the European Space Agency. The solution developed for the third scenario in the frame of an Italian research project (FORCE, A FORmation Flying SAR Based on CubEsat Assemblies) has instead been tested by means of both numerical and experimental activities realizing an ad-hoc laboratory setup. A summary of the main results and indications about future research activities will be provided.