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Author: Mr. Renato Volpe
Sapienza University of Rome, Italy, renato.volpe@uniroma1.it

Dr. Christian Circi
Sapienza University of Rome, Italy, christian.circi@uniroma1.it
Dr. Marco Sabatini
Sapienza University of Rome, Italy, marco.sabatini@uniroma1.it
Prof. Giovanni B. Palmerini
Sapienza University of Rome, Italy, giovanni.palmerini@uniroma1.it

GNC ARCHITECTURE FOR AN OPTIMAL RENDEZVOUS TO AN UNCOOPERATIVE TUMBLING TARGET USING PASSIVE MONOCULAR CAMERA

Abstract

Many recent researches have been studying techniques to handle the problem of pose and shape reconstruction in the framework of space proximity operations. The most challenging scenario is when the target satellite is uncooperative, i.e., out of control and possibly of unknown shape because of damages occurred to its structure. In such a situation, complete awareness of the target's configuration is mandatory and can be achieved through optical hardware. Moreover, recent studies have shown how passive optical sensors are so far the best choice when limitations of mass and power consumption on board the chaser satellite are considered. Monocular cameras, if complemented with a single depth information (e.g., provided by a range-finder), can be used to extract meaningful information of the observed satellite. When paired with purposely built filtering algorithms, the accuracy reached by such systems can increase considerably. In this work, a navigation algorithm exploiting images acquired by a camera is included in a GNC architecture, aimed to perform a rendezvous to the target satellite. The navigation algorithm consists of the following blocks: an image features extraction and matching block, tuned to track features for as long as possible; a features sorting and storing routine, used to rearrange features in a usable way; a UKF filter, which is fed up with matched features and range distance, and returns the estimates of relative position, velocity, attitude, angular velocity and shape. From the operational point of view, firstly the possible docking area is identified from the acquired images, then the reference approaching trajectory is computed through an optimization procedure carried out by means of an inverse method. The trajectory is parameterized through a polynomial basis and a gradient method is applied to seek for a minimum of the fuel consumption, under constraints such as collision avoidance and continuous visibility. The main contribution of this research resides in the integration of visual navigation with optimal guidance. In fact, iterative successful calculation of the optimal trajectory is exclusively possible if an accurate estimate of target satellite's relative pose and shape is available. The GNC architecture is tested with a co-simulation approach, in which the orbital dynamics, navigation filtering and control laws are developed in MATLAB, while the images rendered from a realistic 3D CAD model are iteratively imported from Blender software. Different dynamical states of the target are considered to analyze the robustness of the proposed architecture and to highlight its operational limitations.