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MONOCULAR AND LIDAR BASED DETERMINATION OF SHAPE, RELATIVE ATTITUDE AND POSITION OF A NON-COOPERATIVE, UNKNOWN SATELLITE

Abstract

The relevance of autonomy for space systems in proximity operations has been lately increasing. Growing interest has been put into autonomous rendezvous and docking operations through the use of a robust GNC architecture, which strictly relies on the navigation system's performance and must assure both high efficiency and safety. One of the most explored technologies is the optical navigation. In such a field, the aim of the present research is to investigate the docking of a chaser, equipped with a monocular camera and a LIDAR only, to a non-cooperative, unknown target. The research focuses on the development of an H-infinity filter which can estimate the shape and relative state of the target, using the measurements obtained from the real-time features' detection and matching process. One of the main contributions of the paper deals with the enrichment of the quantities that are estimated. Usually the attention is focused on the accurate estimation of the relative state between chaser and target to ensure a correct docking; the proposed approach adds a quantitative evaluation of the target's shape, which is of crucial importance to define a no-entry zone around the target, thus avoiding any chance of collision. The expedient used in the filter is to give a 3D characterization to the 2D features used as measurements by relating the latter to the corresponding physical points of the target's structure; these points' coordinates are introduced in the estimate state vector. Once known in the camera reference frame, the tracked 3D points' coordinates can be expressed in the target's body reference frame thanks to the estimated target's attitude matrix. Thus, a 3D reconstruction of the target body can be obtained, which also helps in solving the problem of image points disappearing from the set of acquired features, e.g. because of the target's rotation. The feature extraction and matching algorithms and the filter performance are analyzed with a purposely developed software tool in which the target (i.e. a detailed 3D CAD model) and the chaser move according to the relative orbital dynamics and the virtual images are taken at a given sample time; full consideration of different light conditions and measurements' noise is possible. This high-fidelity simulator is considered as a first fundamental step for preparing software-in-the-loop ground based experiments of the proposed navigation and filtering system. Some guidelines for these experiments, educated on the basis of the simulations' findings, complete the paper.