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EVALUATION OF A CAMERA-BASED POSE AND SHAPE RECONSTRUCTION TECHNIQUE FOR AN UNKNOWN TUMBLING TARGET

Abstract

The field of space proximity operations is experiencing a growing interest in high-complexity mission scenarios and applications. Studies are being made regarding the technological aspects required to perform complex operations such as on-orbit repair, dismissal, inspection and refueling. Operations in proximity of an uncontrolled and possibly unknown satellite represent a hazardous scenario and require the maneuvering satellite (chaser) to be provided with a high amount of autonomy, which directly comes from complete awareness of the operating framework. Therefore, when designing the guidance, navigation and control system, attention has to be put in the system's state estimation process. In this sense, optical hardware is today's leading technology because of its capability to yield complete information about observed satellite. Specifically, passive cameras are recognized to provide the most accurate measurements among all the space-usable optical devices. In this framework, this research aims at studying the performance of a pose and shape reconstruction process of a non-cooperative and unknown target satellite by means of a passive camera mounted on board a chaser. The focus of the work is put on the design of a navigation algorithm which iteratively receives images captured by the camera, extracts and matches features, uses the acquired data as measures in a purposely built filter (based on the unscented Kalman logic), merges this information with the propagation of an orbital dynamical model and returns target's relative translational and rotational position and velocity, along with its shape. The whole estimation process runs while the chaser satellite is orbiting around the target, which in turn is tumbling on 3-axis, increasing complexity and adding generality to the relative motion, especially because features appear and disappear in time. In the simulations, the target's images are produced thanks to a CAD model imported and processed in a Matlab environment. This fictitious, yet realistic expedient allows for the selection of a specific feature extraction algorithm among the most commonly used ones (see SURF, HARRIS, KAZE) thanks to a quantitative comparison of the relevant performance (findings). The complete navigation algorithm is tested in different dynamic scenarios, both varying the shape of the target and the relative motion. The results are promising both in terms of relative pose determination and in terms of an effective shape reconstruction. An estimated CAD model is built based on the output of the filter. A comparison with the original target's model shows a sufficient degree of accuracy to perform proximity operations.