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UNCOOPERATIVE SPACECRAFT RELATIVE NAVIGATION VIA VISIBLE AND THERMAL-INFRARED IMAGE FUSION

Abstract

Autonomous close-proximity operations play a major role in new classes of mis- sions, such as Active Debris Removal, On-Orbit Servicing small celestial bodies exploration. In particular, missions involving non-cooperative space objects have gained increasing interest within the research community. Within this context, the onboard reconstruction of the chaser-target relative state vector is a crucial capability. The navigation architecture relies on passive imaging sensors, due to their relatively low mass and power consumption requirements and thus naviga- tion systems relying on monocular cameras operating in the visible (VIS) spectrum have been extensively investigated and successfully tested. Nevertheless, the accuracy of such cameras is linked to the illumination conditions, since the Sun incidence angle is a key factor to collect meaningful measurements. To mitigate this issue, trajectory and operational planning is required, but this could be ex- tremely challenging for targets in LEO orbits, which spend a relevant part of their orbital period in eclipse, hence the reliance on visible imaging only greatly re- duces the robustness and the flexibility of the navigation chain. Our research aims at overcoming the aforementioned limitations by performing pixel-level fusion of im- ages acquired with a VIS camera with those acquired by a thermal-infrared (TIR) camera. Thermal-infrared camera are less sensitive to the external illumination con- ditions, and they can provide meaningful measurements also during eclipses. In our work, VIS and TIR images have been synthetically generated employing dedicated rendering tools internally developed at Politecnico di Milano and successfully tested in relative navigation scenarios. Further, a performance assessment of different image fusion techniques has been presented in a previous work from the author, which is the foundation of the present work. Despite the higher information content obtainable from VIS- TIR fused images, especially in case of partial illumination, the scenario remains challenging for classical image processing techniques, such as feature detection and feature tracking. Furthermore, the signal-to-noise ratio of these images is lower with respect to VIS images. This work develops a model-based relative navigation chain for uncooperative targets, applied to the newly obtained fused vis-tir images. The navigation chain is tested in challenging illumination conditions, to hihglight the benefits of multispectral data fusion in comparison to a traditional vis-only navigation strategy. Our research is expected to make a step forward towards a more robust navigation architecture capable of operating in challening close-proximity operations.