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A CNN-BASED RELATIVE NAVIGATION ARCHITECTURE FOR PROXIMITY OPERATIONS IN ACTIVE DEBRIS REMOVAL MISSIONS

Abstract

Over the last years, the increasing risk of collisions among inactive satellites or debris in the Earth orbit has pushed research efforts for the development of key enabling technologies for active debris removal missions. In this framework, visual sensors can represent a valid asset to support relative navigation during the final close proximity operations, but several technical challenges must still be addressed to guarantee accurate measurements despite operating with uncooperative targets, which represent the majority of the inactive spacecraft population. In this regard, convolutional neural networks have shown promising results to achieve both adequate pose estimation accuracy and high robustness to variable illumination conditions. This work, developed in the framework of the Autonomous Navigation up to High Earth Orbits (ANHEO) project funded by the Italian Space Agency (ASI), describes a relative navigation architecture for proximity operations towards an uncooperative inactive satellite, employing convolutional neural networks for monocular-based pose estimation. Specifically, the relative navigation architecture envisages a monocular RGB camera to acquire images of the uncooperative target. Pose estimation is performed following an indirect approach, in which neural networks are employed for image processing, aimed at extracting the position of natural features on the target surface, while the estimate of pose parameters is successively determined through a numerical least-square solver. The image processing step is composed of two tasks accomplished by two different neural networks: in the former, object detection is performed to determine the position of the target within the image, while in the latter features' position is extracted from the corresponding cropped image. Pose estimates are finally integrated within a filtering scheme to retrieve the relative navigation state. In order to train the proposed target detection and features' extraction networks, a new dataset of 20000 synthetic images of the Envisat satellite has been developed in the open-source software Blender, accounting for variable relative position, attitude, illumination and presence of the Earth in the background. From an analysis of target geometry, a set of features is identified as reference keypoints to train the features' extraction network. An assessment of relative navigation performance is conducted on a reference monitoring trajectory around Envisat; to this aim, a sequence of images reproducing this operative scenario is generated to assess the inference

performance of the networks. The testing sequence also allows evaluating the effect of motion blur, of image noise and of defocus-related aberration on pose estimation and relative navigation accuracy.