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VALIDATION OF CNN-BASED IMAGE PROCESSING ALGORITHM FOR THE HERA MISSION WITH MODEL-IN-THE-LOOP AND HARDWARE-IN-THE-LOOP TESTS

Abstract

The Early Characterization Phase and the Detailed Characterization Phase of the European Space Agency (ESA)'s Hera mission are two proximity operations that have the objective of performing physical and dynamical characterizations of binary asteroid system (65803) Didymos. In these phases, we have developed a keypoints-based Convolutional Neural Networks (CNNs) Image Processing (IP) algorithm to estimate the position of the Centre of Mass of both the primary and the secondary, the range from the primary, the Sun Phase angle and the pose of the secondary to enable a fully autonomous optical navigation strategy using the images captured by the on-board Asteroid Framing Camera.

The algorithm was already proved to estimate the mentioned quantities with open-loop simulations using synthetic images of Didymos generated with the software Planet and Asteroid Natural scene Generation Utility (PANGU). This work focuses on the validation of the CNN-based IP algorithm by analysing its robustness when implemented in the Model-based environment of the Guidance, Navigation and Control (GNC) system, and by analysing its performances when applied to real images. The first step of this incremental validation process is carried at ESA and it is the Model-In-the-Loop (MIL) test, which uses the Control Set-up and Simulation Environment of Hera mission and the synthetic images generated with PANGU. The second step is carried at GMV, in charge of the GNC system of Hera mission, and it is the Hardware-In-the-Loop (HIL) test, which takes into account the testing of the synthetically-trained CNN-based IP algorithm against representative images of the target body taken with the qualification model of the spacecraft camera in a laboratory environment which recreates space-like illumination conditions. For the HIL test the CNN is trained with an augmented dataset built on purely synthetic images with added randomized noise and blur to match the images conditions of the laboratory setup.

The main objectives of this work are: to bridge the gap between the stand-alone application of CNNs in space navigation and the integrated-application in a whole GNC system; to analyse the performance of the developed algorithm when the images of the target differ from the ones used for training. The MIL and the HIL tests push the validation of the CNN-based IP algorithm developed for Hera mission up to Technology Readiness Level 5/6. The performances of the algorithm are analysed by comparing the results of the MIL and HIL tests with the current IP algorithm developed for Hera mission.