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HARDWARE-IN-THE-LOOP TEST OF A CNN-BASED IMAGE PROCESSING ALGORITHM FOR AUTONOMOUS VISUAL-BASED NAVIGATION APPLIED TO THE HERA MISSION

Abstract

The Early Chracterization Phase (ECP), the Detailed Characterization Phase (DCP) and the Close Observation Phase (COP) of the European Space Agency (ESA)'s Hera mission are three proximity operations that have the objective of conducting physical and dynamical characterizations of binary asteroid system (65803) Didymos. A keypoints-based Convolutional Neural Networks (CNNs) Image Processing (IP) algorithm has been developed and applied to these phases to estimate the position of the Center of Mass of both the primary and the secondary and the range from the primary to enable a fully autonomous optical navigation strategy using the images captured by the on-board Asteroid Framing Camera (AFC). 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 Natual scene Generation Utility (PANGU). This work presents the Hardware-in-the-Loop (HIL) tests of the developed algorithm using the Functional Model of the AFC, courtesy of ESA. With these tests it is possible to anlyze the robustness of the developed algorithm to the electro-optical effects introduced by a spaceborn camera. The tests are run in the GMV Optical Laboratory, where space-like illumination conditions are recreated. Apart from the AFC FUMO, the HIL test setup features a monitor with 4k resolution where images of PANGU are projected, a rail where the camera and the monitor are mounted, and the Hera Avionics Test Bench, that runs PANGU and controls the acquisition of images by the AFC FUMO. A complete calibration of the HIL setup is performed prior to the tests, in order to correct parameters such as point spread function, alignment and gamma correction, to minimize the difference between the images taken with the AFC FUMO and the synthetic ones generated with PANGU. The HIL tests show that the developed algorithm is robust to the electro-optical effects introduced by the camera, increasing, if applied, the autonomy of the navigation strategy of the Hera mission.