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ROBUSTNESS ANALYSIS OF DATA DRIVEN IMAGE PROCESSING METHODS FOR AUTONOMOUS NAVIGATION WITH APPLICATION TO THE HERA MISSION

Abstract

The design, development, validation and verification strategy of Image Processing (IP) algorithms involved in Autonomous Visual Based Navigation (AVBN) systems of space rendezvous missions is based on a series of tests that analyze the robustness of the algorithms in different scenarios. In this work, multiple Functional Tests are carried to test two data driven methods-based IP algorithms and evaluate their performances against potential contingencies. The aim of these tests is to prove that the IP algorithms can provide the required measurements with a high level of accuracy in scenarios different from the ones seen during training. Specifically, this work focuses on the estimation of the Center of Mass (CoM) and of the range from the target from synthetic images representing the binary asteroid system (65803) Didymos, the target of the European Space Agency's Hera mission. The IP algorithms rely mainly on architectures of Convolutional Neural Networks, and they differ from each other for the complexity of the architecture and the methodology to estimate the range. The first one is built on the High Resolution Network architecture and it estimates the range geometrically, while the second one is made ad hoc for the AVBN system of Milani, one CubeSat transported on board by the Hera spacecraft. The Functional Tests are designed to analyze the robustness of the IP algorithms and their capability to generalize their solutions when facing situations such as different illumination conditions, different shape of the target body, presence of external bodies, different Signal-to-Noise Ratio and, more in general, different images than the ones generated synthetically. Furthermore, this work analyzes the robustness of the IP algorithms during Hera's Detailed Characterization Phase proximity operation, when the CoM and the range from the target are used to estimate the relative state of the spacecraft. For this analysis the IP algorithms are fine tuned using images of the Hera's previous proximity operation, the Early Characterization Phase. Planet and Asteroid Natural Scene Generation Utiliy (PANGU) and CORTO (Celestial Object Rendering TOol) are used to generate the datasets of images for training, validation and testing. The results of the Functional Tests show that while the accuracy and the robustness on estimating the CoM is similar, for the range the performances depend on the applied methodology. The tests show also that heavier network architectures have more inertia to fine tuning, therefore they require an increased number of images to adapt their solution in unseen scenarios.