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NEO Characterization

POSE ESTIMATION OF HERA SPACECRAFT AROUND DIDYMOS' MOON USING CNN-BASED IMAGE PROCESSING ALGORITHM

Aurelio Kaluthantrige[(1)]**, Jinglang Feng**[(2)]**, and Jesús Gil-Fernández**[(3)]
[(1)] *University of Strathclyde, James Weir Building 75 Montrose St., G1 1XJ, Glasgow, United Kingdom, +44 07862678235, mewantha.kaluthantrige-don@strath.ac.uk*
[(2)] *University of Strathclyde, James Weir Building 75 Montrose St., G1 1XJ, Glasgow, United Kingdom, +44 01415482473, jinglang.feng@strath.ac.uk*
[(3)] *ESA/ESTEC, Keplerlaan 1, 2200 AG Noordwijk, The Netherlands, Jesus.Gil.Fernandez@esa.int*

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ABSTRACT

The Asteroid Impact and Deflection Assessment (AIDA) is an international collaboration between the European Space Agency (ESA) and the National Aeronautics and Space Administration (NASA) aiming to investigate the binary asteroid system (65803) Didymos and to demonstrate asteroid deflection technique with kinetic impact. ESA's contribution is the Hera mission that will rendezvous with Didymos and observe the impact effects closely. The Close Observation Phase (COP) is a proximity operation of Hera mission with the objective of obtaining high-resolution images of Dimorphos, the moon of the binary system, and fully characterizing the impact crater. Autonomous optical navigation system is designed during this phase based on line-of-sight and range measurements from both the primary body and Dimorphos in order to estimate the relative position of the spacecraft. The short distance between the primary and the spacecraft during the COP allows the implementation of feature tracking relative navigation in order to solve for the primary's relative attitude. Nevertheless, the relative attitude of Dimorphos remains unsolved as it requires closer distance. This paper develops a methodology to estimate the continuous six degree of freedom pose (position and attitude) of Dimorphos during the COP using a Convolutional Neural Networks (CNN)-based Image Processing (IP) algorithm. For the attitude, we implement an appearance-based method that consists of two stages. In the first stage, we use CNNs with the images captured by the spacecraft on-board camera to regress a set of keypoints segmenting Dimorphos from its background. In the second stage, we use Neural Networks (NN) to map these keypoints to the three Euler angles representing the relative rotation matrix of Dimorphos with respect to the spacecraft. The estimated keypoints are also used to estimate the position of the centroid of Dimorphos and its relative distance with respect to the spacecraft, which together provides the relative position vector. The High-Resolution Network (HRNet) is used as CNN architecture as it represents the state-of-the-art technology in keypoint

detection with its capability of maintaining high resolution representations of the input images by connecting multiple subnetworks in parallel. The appearance-based method for attitude navigation based on Dimorphos' segmentation is preferred for two main reasons. Firstly, it has the main advantage of a reduced dependency on the distance, which is the main driver for a feature tracking relative navigation technique. Secondly, other methods such as model-based ones require sufficiently regular shapes of the targets, which is not the case of near-earth objects such as asteroids. The training, validation and testing datasets consist of synthetic images generated with the software Planet and Asteroid Natural scene Generation Utility (PANGU) at different epochs of the COP trajectories. Therefore, our developed algorithm is expected to solve the overall pose estimation and improve the efficiency and the robustness of the autonomous navigation of the proximity operations of Hera mission.