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CHURINET - A DEEP LEARNING APPROACH TO OPTICAL NAVIGATION FOR MINOR BODIES

Abstract

In the context of navigating minor bodies as asteroids, comets or small moons, traditional methods for orbit estimation and navigation may encounter limitations in robustness and precision. In this framework, this paper will explore the applicability of Convolutional Neural Networks (CNN) for optical navigation of such small bodies.

Actual Neural Networks devoted to image processing (computer vision) typically require large sets for training the net. There exist some data sets of images from missions such as Rosetta, Hayabusa 1 and 2 or Osiris-Rex, nevertheless those sets are restricted by the spacecraft orbit and illumination conditions, limiting the use cases for which a Neural Network could be successfully trained. In this research work we have developed a method for systematic generation of large sets of synthetic images adequate for training the later designed CNN for a wide range of positions, illumination conditions and camera extrinsic.

The nominal case of study takes two assumptions: First, the shape model of the target is known beforehand, required for training the net. Second, the attitude of the spacecraft with respect to the target is known, in such a way that at this stage, the net only solves for position determination. Therefore the images of the generated training and testing sets fulfill the following conditions: camera positions are randomly computed as to cover the full range of latitude and longitude for random altitudes within a specified range; nadir pointing yielding target centered images; the vertical axis of the detector frame is parallel to the projection onto the detector plane of one target body fixed frame axis; illumination source is modelled as a directional light defined by a random unit vector.

Furthermore, the main result of this research work is Churinet, a set of sequential architecture CNNs, conforming a two levels global net, composed by a high level multiclass classification CNN in charge of determining the target sector (with the target divided in 45 degrees latitude and longitude sectors) and a low level set of regression CNNs, in such a way that from sector estimation the image is sent to one specific low level CNN which estimates the latitude and longitude of the spacecraft.

The process of generating the training and test sets as well as adjusting the CNN layers is presented, together with the current results in terms of accuracy in position estimation, lightweight computational cost and future work required for accounting for detector in plane rotation, target shape model variations and assessing the applicability for navigating other bodies.