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CASCADE MASK R-CNN ARCHITECTURE FOR CRATER DETECTION IN AUTONOMOUS PLANETARY NAVIGATION

Abstract

Deep Space missions require dedicated facilities to determine spacecraft's attitude and orbit, facing large operation costs, bearing the risk of signal disturbance/blockage in emergency situations, the delay caused by the roundtrip light-time, and the time required to process the data. For these reasons improving spacecraft autonomy is a crucial aspect for current and future space projects. To tackle these issues, the paper proposes a highly reliable crater detector that exploits the properties of generalizing of modern deep learning architectures. The detector is structured through a Cascade Mask R-CNN architecture, in which stages deeper into the cascade are more selective against close false positives because are trained sequentially, using the output of one stage to train the next. The backbone is ResNet-50, a 50 layers deep convolutional neural network that is able to avoid the vanishing gradient problem, which is coupled with Feature Pyramid Network, i.e. a pyramidal structure for the extraction of features at different scales to detect craters of different dimensions. In this study a database has been developed by manually labelling in COCO format using both circles and ellipsis. To train and test the Crater Detector Algorithm (CDA) 804 images have been obtained from the Wide Angle Camera global mosaic of the Lunar Reconnaissance Orbiter (LRO). Images, in orthographic projection show a resolution of 128.00 px/deg and 256.00 px/deg, respectively in latitude and longitude. From each picture a smaller squared area has been considered to avoid distortions at the edges and 134 tiles of 512x512 pixels have been obtained and manually labeled. A huge number of simulations has been performed varying the tuning parameters used to train the detector and leading to an encouraging mAP50 value of 75.26. The CDA has been tested on a wide set of images to prove the accuracy and generalization of the detector under various challenging conditions. Namely, i) images of equatorial and polar regions of the Moon (considering a brightness variation of + 50% and -50%), ii) distorted and blurred photos captured from the Narrow Angle Camera of the LRO and iii) pictures taken from missions MARS Reconneissance Orbiter and MESSENGER observing respectively Mars and Mercury. Results prove the higher detection rates against the U-Net based architecture, adopted in recent crater detection studies. This detector is thus suitable for visual-based Terrain Relative Navigation in GNSS-denied planetary applications.