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APPLYING MACHINE LEARNING TECHNIQUES FOR OPTICAL NAVIGATION IN LUNAR MISSIONS

Abstract

Artificial Intelligence (AI) algorithms can be used on-board to enhance spacecraft operations, helping to autonomously navigate, improve scientific observations and optimise the amount of downlink data sent to Earth. Showing promising performance and accuracy, these algorithms can be applied to Solar System Exploration missions with sometimes high precision requirements, offering alternative navigation solutions in the absence of GNSS positioning. This contribution proposes the use of machine learning techniques to provide real-time in-orbit determination even with adverse illumination conditions. The method relies on the training with synthetic Lunar images and on-board deployment of Convolutional Neural Networks (CNNs).

A method for synthetically generating photo-realistic image data sets with user defined conditions has been implemented. The Moon polar regions are of special interest for future human and robotic exploration missions, however, the illumination phase angle close to 90 degrees results in long projected shadows extending hundreds of kilometres and causing some areas to be in permanent darkness. This condition makes shadows much more relevant in the images captured by optical navigation systems, leading to the need of combining surface albedo and terrain elevation data. The combination of these data sets, available from different sources at multiple spatial resolutions, allows for the proper generation of synthetic images accounting for surface illumination incidence, terrain projected shadows and surface reflectance.

The presented CNNs have been trained at different altitude ranges and Lunar regions, evaluating the performance of the networks during the orbital and descent phases of a mission. The neural networks trained only with synthetic data, are capable of directly estimating the camera position and attitude taking a single image as input, mapping the 2D space (grayscale image) to the 6D space (3 coordinates for position vector and 3 Euler angles). Moreover, they have been tested and validated with real images from actual Lunar missions. Showing its potential to be used as a lightweight onboard autonomous navigation solution for future Lunar missions.