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KAMNET – APPLYING MACHINE LEARNING TECHNIQUES FOR OPTICAL NAVIGATION IN EARTH OBSERVATION MISSIONS

Abstract

Artificial Intelligence (AI) algorithms are increasingly used onboard to enhance Earth Observation applications, helping to autonomously improve the observations and optimize the amount of downlink data sent to Earth (e.g., not relevant or low quality data). This contribution proposes the use of machine learning techniques to train and deploy on-board Convolutional Neural Networks (CNNs), trained with synthetic Earth images. These CNNs provide real-time, enhanced in-orbit determination of a Sun-synchronous orbiting spacecraft as well as to tag the captured images with geo-localisation information.

A method for systematically generating image data sets with user defined conditions has been implemented, combining the required features for dawn-dusk orbit pose estimation use case and extending the available data for training. Equatorial passes for a dawn-dusk orbit imply that the local mean solar time is around sunrise or sunset at zero latitudes. This condition makes shadows much more relevant in the images captured by the satellite, leading to the need of combining Earth albedo, like provided by Sentinel surface reflectance data and terrain elevation data obtained from radar measurements as the Shuttle Radar Topography Mission (SRTM) products. The combination of these diverse data sets, available at multiple spatial resolutions and obtained at different time periods, allows for the proper generation of synthetic images accounting for surface illumination incidence, terrain projected shadows and surface time-variations.

The presented work is a follow on activity of a previous study which set the basis for training pose-CNNs in the Earth orbit scenario. Automated Machine learning (AutoML) has been introduced in the workflow to more efficiently explore the Neural Architecture Space (NAS), improving the accuracy in the pose estimation and optimizing the hyperparameters set-up of the trained networks for each study case. Furthermore, architectures implementing Time Distributed layers have also been explored, taking advantage of the orbit dynamic pattern underlying in the actual image sets and enabling the estimation of time-derived quantities. The achieved accuracy in the position estimation is of the order of tens of kilometers, equivalent to less than half of the camera footprint on the Earth surface, outperforming the accuracy of the available propagated orbit determined from ground observations. The estimated position is suitable to be used by conventional navigation filters, enabling an efficient navigation solution which can be applied not only to the Earth case, but to navigate other planets as well.