Key Technologies (7)
General, Guidance & Control (3)

Author: Mr. Carlos Paulete
Universidad Carlos III de Madrid, Spain, 100333352@alumnos.uc3m.es

Mr. Alfredo Escalante
ESA - European Space Agency, Spain, alfredoescalante95@gmail.com
Dr. Manuel Sanjurjo-Rivo
Universidad Carlos III de Madrid, Spain, manuel.sanjurjo@uc3m.es

OPTICAL NAVIGATION IN CLOSE-PROXIMITY OPERATIONS AROUND SMALL CELESTIAL BODIES USING CONVOLUTIONAL NEURAL NETWORKS

Abstract

Exploration of asteroids and comets are key to increase our understanding of the origin and formation of our Solar System. Moreover, they rise interest not only for scientific but also for commercial reasons. Missions to these small celestial bodies were conducted recently or are planned to be launched soon. One key enabling technology of this kind of missions is an autonomous GNC system. It would allow for real-time generation of trajectory planning and manoeuvre control; and has been identified as a required step in the GNC roadmap for future space exploration. Among the possible navigation solutions, optical sensors are especially well suited. However, there are plenty of open challenges to be solved before having an operational optical navigation technology.

In this work, an optical navigation solution for asteroid and comet missions is proposed based on the utilization of Convolutional Neural Networks. CNNs has been recently applied to a similar problem of rendezvous with non-cooperative targets. CNNs represent a subset of the broader term Deep Neural Network which are particularly suited to image data processing. The size and scale of the required network makes their training impractical, however, by using transfer learning techniques, a pre-trained network is adapted to the problem at hand reducing significantly computational costs. The method has two phases: training and predictive phase. The former is key to obtain the required performances and needs large datasets to do so. Therefore, a method has been developed to generate realistic images allowing us an adequate training of the network.

SPICE is an information system which uses ancillary data to provide Solar System geometry information in order to analyze scientific observations from space-born instruments as cameras. SPICE is used for creating a highly accurate scenario containing ephemeris and attitude (SPK and CK) of the spacecraft (observer); with a camera defined by field-of-view aperture and number of pixels (IK); and the asteroid (target) with reproduced illumination conditions. With this, geometric quantities can be efficiently derived and integrated with OpenGL renderers in order to create high resolution images of the simulated instrument. Moreover, these images can then be systematically generated for operational or planned missions, creating a bank of images devoted to train the algorithm.

For testing the algorithm, an intensive training has been carried out using fundamentally images from Rosetta mission. The predictive phase has been tested in a descent to an asteroid not contained in the training dataset