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DEEP LEARNING BASED RELATIVE NAVIGATION ABOUT UNCOOPERATIVE SPACE OBJECTS

Abstract

Nowadays the space sector is experiencing an increase in the demand for missions involving proximity operations. This trend can be partially attributed to the raised awareness of the space debris problem, as more and more Active Debris Removal (ADR) and on-orbit servicing missions are being planned. Consequently, the need for an accurate onboard relative navigation system is more and more present in the industry.
This work proposes a pipeline for relative navigation based on Deep Learning techniques to obtain the relative pose measurements and Kalman Filtering to reconstruct the relative dynamics and add robustness to the pipeline. Furthermore, a testing procedure involving a Blender-based spaceborne image generator has been devised and applied to validate the results in the case of a realistic image sequence.

The overall pipeline is based on a pre-existing Neural Network pipeline that participated in ESA Pose Estimation Challenge with excellent results. This network achieved a centimeter-level position accuracy and degree-level attitude accuracy, along with considerable robustness to changes in background and lighting conditions.

To reconstruct the state during navigation, a set of Kalman filters have been implemented to tackle attitude and position separately.

For the relative distance, an Extended Kalman Filter has been applied, as the underlying relative dynamics are represented by a linearized dynamical model. Instead, for the more complicated attitude problem, the choice fell on the Unscented Kalman Filter thanks to its superior robustness in highly non-linear dynamics.

In addition, robustness was taken as a priority with thousands of tests aimed at identifying and counteracting the most common failure modes. Moreover, some techniques were also developed for the detection and rejection of measurement outliers.

The whole navigation pipeline was then tested on a simulated set of image sequences of the TANGO spacecraft in free tumbling conditions. The frames were obtained from a Blender-based spaceborne image generation platform exploiting a 3D model of the target and relying on an accurate propagation of the relative dynamics.

Finally, this work also presents the preliminary results coming from the implementation of the pipeline on a Raspberry Pi 4 single-board computer for a preliminary evaluation of its performance on more representative hardware. The results, although not directly applicable for real-time navigation, proved to be very promising.

Overall the pipeline managed to leverage the predictions of the Neural Network it was based on, adding robustness and precision with a minor addition of computational time."