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# CNN-BASED VISUAL NAVIGATION: OPTIMIZATION STRATEGIES FOR MONOCULAR POSE ESTIMATION IN PROXIMITY OPERATIONS

**Abstract**

On-orbit proximity operations are becoming increasingly more important for current and future missions, particularly On-Orbit-Servicing (OOS) and Active-Debris Removal (ADR) ones. In this framework, a high-accuracy estimation of the relative pose (position and attitude) between spacecraft is required to successfully and safely achieve inspection/observation, rendezvous, and docking phases.

Visual navigation has recently become one of the most popular techniques for this purpose, thanks to the availability of increasingly compact, precise, and reliable monocular cameras, ideally suited for this application due to their minimal system resource demands. Traditional approaches relied on hand-engineered feature matching, that do not guarantee robustness and a sufficient generalization. In contrast, Convolutional Neural Network (CNN)-based architectures have demonstrated to improve robustness and rejection of noise and resilience to unseen scenarios. Despite their potential, these algorithms do not frequently reach the desired accuracy. This is due, among others, to the employment of a heuristic approach in the choice of hyperparameters and the unavailability of an adequate large dataset.

This work aims at overcoming these limits by proposing a CNN-based architecture for non-cooperative spacecraft monocular pose estimation exploiting optimization techniques to improve performances and to reduce the computational effort. This is achieved through the development of a robust analytical method to select the best set of hyperparameters to minimize the pose loss function and the enhancement of the dataset for better feature learning. The study analyses the most significant hyperparameters to be tuned and their correlations, as it can be demonstrated that only a few of them can explain most of the performance variation. Moreover, the relationship between hyperparameters and the objective function (pose loss) is investigated, as well as the impact of different sets of hyperparameters on the CNN performance. A Blender®-based synthetic dataset of approximately 25,000 synthetic images of an uncooperative target is generated to train the CNN. Such images are used to emulate representative proximity scenarios to validate the proposed approach.

The results of the simulation campaign show that the proposed algorithm allows to achieve centimeter-level position accuracy and near-degree-level attitude accuracy, maintaining, at the same time, high robustness against changes of illumination conditions and background textures. These results are shown and discussed in the paper, where computational time and performances are also compared with existing algorithms compatible with the use on low-power hardware.