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PROCESSOR-IN-THE-LOOP TESTING OF AI-AIDED ALGORITHMS FOR SPACECRAFT GNC

Abstract

Artificial Intelligence represents the new frontier for autonomous robotics algorithms, thanks to the outstanding capability of adapting and generalizing responses to unforeseen events. In the space domain, the implementation of AI-based is still in the early phases. This is due to the fact that AI-based algorithm are seldom considered as unpredictable, especially when working outside the training domain. In addition, limited computational resources available on-board require sophisticated design of the algorithm to prevent heavy computational loads without losing the benefit of AI. This paper presents a set of neural-aided algorithms employed for on-board spacecraft GNC, which present hybrid architectures between classical approaches and novel AI-based techniques developed at Politecnico di Milano - ASTRA research group. The goal of such algorithms is to support the traditional GNC algorithms, solving the identified shortcomings using neural-based structures. It has been demonstrated that hybrid architectures often present superior performance with respect to both traditional approaches and full AI-based algorithm. In particular, a GNC algorithm for autonomous operations is developed. The Navigation algorithm uses an Extended Kalman Filter, where the prediction step is performed using a neural-reconstructed dynamics. This dynamical model comprises two terms: an analytical expression leveraging on physical understanding of the equations of motions and an additional term learnt and estimated by a Radial-Basis-Function Neural Network. The latter term entails all the unmodelled perturbations, which can be completely unknown before the spacecraft departure. The Guidance and Control is worked out using a neural-Model Predictive Control which utilizes the neural reconstructed dynamical model to predict and optimize the receding horizon on-board. As previously mentioned, it is critical to proceed with the hardware implementation of such algorithms to test the feasibility of on-board execution. The paper presents an effective procedure for fast algorithm prototyping. The AI-aided GNC system is deployed to an MCU processor, whose specifications are comparable to flight hardware. The Processor-in-the-Loop test by simulating the orbital environment on a dedicated PC, leaving the GNC execution to the MCU. Execution times and numerical accuracy are assessed and compared with on-board requirements, paving the way to extensive testing campaign to increase the TRL of the presented architectures.