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MACHINE LEARNING BASED GUIDANCE FOR OPTIMAL SPACECRAFT DE-ORBITING

Abstract

In recent years, Artificial Neural Networks (ANNs) are showing excellent performances in approximating solutions to optimal control problems, where the goal is the definition of a control law minimizing or maximizing a cost function. Successful outcomes of this approach have been achieved in the Space Engineering field, in the case of interplanetary transfers and landing, where the increasingly stringent requirements demand more precise control systems to ensure high precision. Different architectures are tested, united by the ability to approximate the optimal state-feedback maps with high precision. The current work proposes a novel application of this approach to a spacecraft de-orbiting, playing a crucial role in any manned and unmanned space mission. High precision is required to ensure the satellite or capsule landing in a desired location for a prompt and safe recovery. The main solutions to achieve the necessary orbital energy reduction include de-orbit burn, based on a propulsion system, and ballistic de-orbiting, exploiting drag modulation. The latter is the object of interest of this work, proposing a Machine Learning solution to get a closed-loop control for a satellite's optimal de-orbiting from a Low-Earth Orbit (LEO). The objective is to learn a policy able to achieve optimal control to ensure a desired de-orbiting point in terms of latitude, longitude, and altitude. For this purpose, an Artificial Neural Network (ANN) is trained with the state-action pairs, resulting from the optimal control problem resolution. In particular, the training set relies on several open-loop minimum-time optimal de-orbiting trajectories, exploiting the exposed surface variation to ensure a desired de-orbiting point. They have been generated with an algorithm previously developed by the authors, based on the MATLAB software GPOPS-II, involving the hp adaptive Gaussian quadrature orthogonal collocation method. The implementation of an optimal closed-loop controller for a satellite ballistic de-orbiting can find a wide application in the current scenario, which sees an increasing number of CubeSats, and other satellites not equipped with a propulsion system.