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CISLUNAR TRAJECTORY DESIGN AND MANEUVER AUTONOMY FOR NASA'S MOON TO MARS ARTCHITECTURE

Abstract

NASA's Moon to Mars architecture is an ambitious roadmap of manned cislunar and deep space exploration. The extensive amount of orbital assets required will place a significant burden on ground-based resources, such as communication networks and operations facilities. Spacecraft autonomy is essential for maintaining a vast number of complex missions beyond Earth orbit. To achieve full autonomy, spacecraft must be able to employ methods of robust trajectory design and maneuvers without an explicit dependence on commands sent from the ground. This level of autonomy is needed not only for stationkeeping, but also for outbound/inbound transfers. To address the need for spacecraft autonomy, this work investigates the use of neural networks (NNs) in a supervised learning environment for trajectory design and maneuver planning. A supervised learning approach for NN training allows for a curated training data set, consisting exclusively of perturbations applied to the desired mission concept of operations (ConOps). The proposed approach allows humans on the ground to design a specific mission ConOps before flight, then employ NNs to fly the mission robustly and autonomously. This investigation numerically tests maneuver autonomy in four highly sensitive regions of flight: orbit raising, translunar injection burns, powered lunar flybys, and invariant manifold insertion burns. These straining cases are contextualized by testing them in a demo mission within the cislunar regime. The study first establishes feasibility by automating impulsive burn maneuvers. However, some guidance algorithms will need more intensive commands, such as inertial pointing and angular rates. To validate this method, supervised NN maneuver autonomy is applied to a finite burn model of the demo mission. The use of sequential, mission specific maneuvers provide an appropriate testbed to demonstrate the robustness of a NN trained on many feasible perturbed states. Moreover, these scenarios provide preliminary proof-of-concept for fully autonomous missions that execute maneuvers without dependence upon explicit command uplinks. As a result, the technological advancement proposed in this work may significantly ease the strain on ground-based mission operations. This would enable complex and autonomous mission execution in cislunar and deep space regimes, filling a technology gap required to support future manned/unmanned missions to the Moon and Mars.