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APPLICATION AND ANALYSIS OF NEURAL NETWORKS FOR UNMODELED DYNAMICS IN THE CIRCULAR RESTRICTED THREE BODY PROBLEM

Abstract

The work done has been motivated by the Artemis mission which utilizes the Earth Moon system's Lagrange points. Since orbits around these points rotate with the Earth Moon system, they are desirable for use as outposts between the Earth and Moon or for gateways for future manned missions beyond the Moon. For cislunar mission designs, solar electric propulsion can be used to raise a spacecraft from an Earth centered orbit to a cislunar transfer trajectory. The challenge when using solar electric propulsion is that much of the orbit raising process will be perturbed by the Moon's gravitational force. To account for this, the circular restricted three body model can be used for analytical approximations. Since the circular restricted model utilizes multiple assumptions, the trajectory must then be converted to a high-fidelity ephemeris model to determine any additional trajectory correction maneuvers required to account for the unmodeled dynamics. This process can be aided by, or entirely bypassed, by applying artificial neural networks.

What is new and useful about this work is the application of neural networks to capture the space environmental factors which are not incorporated within the circular restricted model. Rigorous training of the network is done by generating numerous families of halo orbits around the colinear Lagrange points in the circular restricted three body reference frame. From these families, stable manifolds are determined which pass near the Earth to allow the satellite to coast into the designated orbit. These trajectories are then implemented in the high-fidelity model and the difference attributed to unmodeled dynamics is used for the training of the neural network. Using the network, a mission designer can assign a halo orbit with desired distances from the Lagrange points and receive an associated trajectory in the ephemeris model which can be fuel or time optimized. Once the trajectory is autonomously generated, the end-to-end transfer can be completed by determining the transfer from a near Earth orbit to the coasting manifold using impulsive maneuvers or a low thrust transfer. In simulations, both thrusting methods are tested. Ongoing studies for this work also include analysis of the robustness of the neural network as the halo orbit amplitudes and their corresponding manifold distances move away from the Earth Moon line.