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ARTIFICIAL NEURAL NETWORK FOR PRELIMINARY MULTIPLE NEA RENDEZVOUS MISSION USING LOW THRUST

Abstract

Since the 1960s the study of near-Earth asteroids (NEAs) has become extremely interesting for science, Earth protection, and future exploitation of their resources. Recently, researchers have been attracted by the possibility of multiple NEAs rendezvous missions because of the cost reduction for each observation and the increased range of opportunities to visit NEAs of interest, given the lack of information that makes the choice of a single asteroid difficult. Low-thrust propulsion system is especially suited to perform this kind of interplanetary transfers otherwise very expensive in propellant mass. Evaluating the feasibility of a low-thrust transfer and, ultimately, its time of flight and cost requires to solve an optimal control problem, which is generally computationally demanding. According to the NASA's database, almost 20,000 NEAs have been discovered until now, of which almost 2,000 are classified as Potentially Hazardous Objects (PHO). Thus, it becomes paramount to develop a method for quick identification of the transfer time and cost. This work develops a methodology based on Artificial Neural Networks (ANN) to identify a preliminary multiple NEAs rendezvous trajectory using low-thrust propulsion. It takes advantage of the ANN capability to map the transfer time and cost starting from parameters that can describe the initial and final orbits and boundary conditions of the transfer. The ANN is trained, and its reliability is analysed under different conditions. Specifically, training sets obtained with direct optimisation method and shape-based method, whose solutions are characterised by a different degree of accuracy and varied speed and ease of convergence, are used to investigate how they affect the network performance in identifying cost and time of flight, compared to the real optimum. Also, the influence of different input parameters and network settings on the outputs will be examined. The outcome of the network is used as input in a combinatorial problem to search for the asteroid sequence to visit, where a tree-search method is employed. Once the multiple rendezvous sequence is identified, the feasibility of the transfer with the given propulsion system is studied. Thus, an optimal control problem is solved for each leg by means of an optimisation solver based on pseudospectral method. The performance of the presented method is assessed by conducting analyses of different sequences of asteroids of interest. This methodology is applicable to different low-thrust options, such as solar electric propulsion and solar sailing.