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OPTIMAL PATH PLANNING OF SWARM OF CUBESATS TO ASTEROID DETUMBLING USING ARTIFICIAL INTELLIGENCE

Abstract

The human breakthroughs in interplanetary missions to explore deep space led to the ambitions to control and mining space objects. Asteroids as rich sources of organic matter and minerals are suitable candidates for these purposes. This paper aims to design a precise and robust soft-landing of a swarm of CubeSats on an irregular asteroid to detumble in the context of online agents' collaboration. One of the major issues in such sensitive space missions is optimal fuel consumption. Furthermore, several uncertainties are caused by the imprecise gravity field model, environmental perturbations, the shortage of asteroid surface geophysics information, etc. Therefore, optimal low-thrust trajectories for the swarm of CubeSats in a 3D high perturbed asteroid environment while maintaining a safe distance from each other, i.e., collision avoidance, would be designed through the optimization algorithm. The location of landing points and orientation of CubeSats are determined by designing optimal configuration with respect to the minimum number of required CubeSats, which means minimized fuel consumption in asteroid detumbling. In this way, the reconfiguration of landing locations and optimal paths replanning are realized through optimization algorithms when a failure emerges throughout the mission. In this paper, it is assumed that a mothership first takes CubeSats' carriers to the equilibrium points of the asteroid. The 216-Kleopatra asteroid is considered a target with relatively large dimensions and an irregular shape. To reduce the computational burden of gravitational field equations, which is considered polyhedron as the most suitable model for asymmetric objects such as asteroids, a Deep Neural Network (DNN) is presented to estimate real-time and onboard gravity accelerations. In this regard, we attempted to predict the gravitational field gradient by DNN regression with a large dataset that contains 6000 data points. It is found that a pre-trained and fine-tuned DNN shows faster responses besides better generalization performance over the conventional methods. To achieve high performance, real asteroid data is used in the simulation. Examining the proposed approach through a simulation reveals admissible accuracy in path planning for a swarm of CubeSats' in uncertain and perturbed environments. Concerning the DNN results, effectiveness and accuracy in prediction are verified. The feasibility of adopted methods is demonstrated by comparing the deviation from the optimal results.