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HUMAN AGENT PLANNING FOR SPACECRAFT MOTION SUBJECT TO CHAOTIC DYNAMICS, SMALL RANDOM PERTURBATIONS AND UNKNOWN PARAMETERS

Abstract

Increasing the autonomy of spacecraft requires the development of algorithms to plan a vehicle's route when subject to coupled interactions of chaotic dynamics, small random perturbations and unknown system parameters (CD-SRP-UP). Numerous algorithms have been developed to steer spacecraft along deterministic baseline trajectories within chaotic systems (including asteroid, ocean-world and cislunar environments) that are subject to small, random perturbations. However, application of baseline tracking solutions may lead to infeasible or highly inefficient solutions within chaotic dynamics, if the selected baseline is not representative of the natural flow. That may occur when the baseline is constructed upon a dynamical model with poorly known parameters, such as during exploration of uncharted destinations. Currently, the process of designing natural-flow-compliant baselines is largely dependent on human insight and expertise, and the extension of human involvement renders the autonomous search of natural-flow-compliant baselines highly complicated and inefficient. In addition, the existence of chaos and bifurcations within spacecraft dynamics is an obstacle to mapping existing point-design baselines to new applications, where the equations of motion are still valid but the system parameters change. Rather than automatizing the identification process of natural-flow-compliant baselines, autonomous spacecraft guidance within CD-SRP-UP environments could be implemented via baseline-free strategies for trajectory planning. Baseline-free planning strategies can be learned from demonstration by observing human agents controlling spacecraft motion within real-time flight simulators. In this work, a flight simulator reproduces spacecraft motion for different binary asteroid systems using an Elliptic Restricted Three-Body Problem (ER3BP) model, which includes solar radiation pressure and irregular gravity. Spacecraft dynamics within ER3BP models are well-known to be chaotic. Small random perturbations are applied in the form of orbit determination errors. For each run of the simulation, random system parameters are assigned to the ER3BP model and mimic poorly known asteroid system properties; continuous runs of the simulation will allow for baseline-free planning strategies to emerge. A previous numerical experiment demonstrated that a human agent may learn path-planning strategies for spacecraft motion in the context of CD-SRP-UP applications. In this work, we have redesigned the simulation interface to facilitate data collection. The database was also expanded by considering a larger range of asteroid systems and additional human agents. This investigation is important for collecting documented evidence of human ability to pilot a spacecraft within CD-SRP-UP environments. If such ability is demonstrated, the resulting database of simulations could allow for development of autonomous spacecraft guidance via offline learning.