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AUTONOMOUS AND ADAPTIVE GUIDANCE FOR INTERPLANETARY TRAJECTORIES

Abstract

Low-thrust engines offer an effective and efficient means of in-space propulsion for both planetocentric and interplanetary trajectory design tasks. What distinguishes these engines from chemical rocket engines is that they have large specific impulse values but produce very small thrust. Accordingly, they are operated continuously for long durations but utilize less fuel than traditional chemical propulsion systems. This saves valuable mass and allows for longer missions and/or larger payloads. However, the trajectory design and guidance of continuous low-thrust missions is complex and computationally burdensome. This presents challenges in the development of autonomous on-board guidance capabilities.

Indirect optimization is used to develop an optimal low-thrust control scheme to guide a spacecraft towards its target. The nominal (desired/planned) optimal trajectory is found ahead of time, providing the position, velocity, costates, and control along the nominal trajectory. On board, this information is used along with estimates of the current (actual) position, velocity, and control, to determine updates to the nominal control in response to deviation from the nominal trajectory. However, rather than re-planning the entire trajectory and imposing firm terminal constraints with each update, the control is instead updated by solving an optimal control problem (OCP) with the objective of guiding the spacecraft as close to the nominal trajectory as possible while simultaneously minimizing deviations from the nominal control law. The OCP is solved via a novel method that utilizes the nominal trajectory to entirely circumvent the burden of initializing the costates. Furthermore, this is done without need to linearize the equations of motion. This method reduces the computational burden without compromising the accuracy of the dynamics, making it well-suited for autonomous on-board guidance applications.

Application and utility of the proposed guidance method is demonstrated on a number of interplanetary trajectories in which initial deviations in the relative position and velocity vectors are considered.