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AUTONOMOUS MOTION PLANNING FOR SPACECRAFTS NEAR SMALL SOLAR SYSTEM BODIES: SIMULTANEOUSLY REFINING THE GRAVITATIONAL FIELD MODEL AND RE-PLANING GRAVITY DEPENDENT MANEUVERS

Abstract

Dynamic path planning near small celestial bodies has the potential to improve asteroid study, landing strategies, and scouting for in-situ resources, as well as autonomous missions for comet interception and deep space exploration. Strategic missions to orbit celestial bodies have primarily considered spacecraft trajectories as a two step process: capture of the vehicle within the gravitational influence of the body, followed by in-orbit maneuvers. While maneuver planning in the gravitational field of larger solar system bodies (with near-uniform gravity fields) is relatively straightforward, planning similar maneuvers around smaller bodies such as asteroids and comets is more challenging. Moreover, a priori maneuver planning approaches that use earth-based measurements will tend to generate motion plans that have a monolithic profile. Fine grained motion plans that respond to mission conditions require a detailed understanding of the gravitational forces around the body—which can be obtained once a craft is in orbit, assuming the craft has sufficient on-board sensors. For example, the gravity model can be analyzed to provide information about the mass, density, and material distribution across the body. We propose a method for autonomous motion planning around small bodies that simultaneously refines the gravitational model of the body, while using the model to perform more and more accurate orbital maneuvers. Our research focuses on a problem variant where the orbital maneuvers are designed to refine the gravity map as quickly as possible. However, the basic idea of simultaneous gravity model refinement and motion planning is relevant to a variety of space exploration and scientific missions. We use a receding horizon approach. During each planning epoch, the planner considers the gravitational influence over a tree of orbital maneuver sequences (between discrete points around the celestial body). Starting with the (low fidelity) gravity model created from earth-based observations, the gravity model is continually updated during the mission as the spacecraft experiences varying gravitational forces. On-board instruments measure the force observed by the craft and the gravity model is updated with each maneuver, eventually providing a high fidelity gravity field model of the body. The updated model is simultaneously and continually used to re-plan the craft's trajectory during the mission, ensuring that each maneuver respects the most up-to-date model of the body's gravity field (that is, respects the gravity data observed during the mission so far). Such an approach has the potential to expand to autonomous spacecraft missions to perform maneuvers near small celestial bodies.