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SLAM-BASED AUTONOMOUS ORBITAL NAVIGATION OF DISTRIBUTED SPACECRAFT FOR SMALL CELESTIAL BODY MISSIONS

Abstract

Small celestial bodies (SCB) like asteroids have recently gained significant attention as potential destinations in future space missions for both scientific exploration and space resource utilization with the goal of facilitating a sustainable human presence beyond the cislunar space. Autonomous navigation and distributed spacecraft architectures are amongst the key technologies identified as essential for the type of missions envisioned for the future. In this regard, the ability of distributed spacecraft to navigate cooperatively and autonomously near a SCB is an invaluable capability to accomplish sophisticated mission goals in the proximity of these bodies. Unfavorable illumination conditions and complex dynamics near SCBs have rendered many conventional navigation techniques unusable, making proximity navigation extremely challenging.

Most past missions to SCBs have utilized Stereophotoclinometry (SPC) as the algorithm for autonomous proximity navigation of monolithic spacecraft. Spacecraft employing SPC for navigation typically have an initial surveying phase for developing maps and models necessary for navigation. Although SPC is renowned for its robustness and precision under challenging illumination conditions, it requires an initial mapping phase that constitutes a considerable share of mission timeline and also demands ground intervention for the development of navigation models from downlinked mapping data. This paper investigates a technique based on Simultaneous Localization and Mapping (SLAM) to perform both mapping and localization simultaneously with the objective of developing a completely autonomous method for the proximity navigation of distributed spacecraft in SCB orbits. SLAM is ideal for this purpose as a well explored topic in terrestrial robotics with established frameworks for cooperative navigation. The availability of a shared map and the knowledge of trajectories resulting from cooperative SLAM is also beneficial in terms of autonomous mission planning. Results from the simulations on the accuracy of navigation suggest that the proposed SLAM based algorithm is a viable method for the autonomous proximity navigation of distributed spacecraft.