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AUTONOMOUS SMALL BODY MAPPING AND SPACECRAFT NAVIGATION VIA REAL-TIME SPC-SLAM

Abstract

Current methods for small body shape modeling require significant time on the Deep Space Network as well as extensive ground support. The Stereo-Photoclinometry (SPC) technique is currently used to provide topological information about asteroids and comets, such as Ceres, Vesta, and Churyumov-Gerasimenko. This technique estimates the topography and albedo of a small body using surface images obtained from various spacecraft perspectives and under multiple lighting conditions. Weighted least-squares are used sequentially to solve for map control points (landmark vectors), spacecraft position, and camera orientation. While this technique is powerful, it is also very complex and requires a team of scientists on the ground who must communicate with the spacecraft in order to oversee SPC operations. Autonomous on-board navigation addresses these limitations by eliminating the need for human oversight. In this paper, we propose an estimation algorithm for navigation that would be an important step toward an autonomous approach of small bodies, which will help reduce the reliance on ground-in-the-loop operations. The estimation algorithm allows the spacecraft to autonomously approach and maneuver around an unknown small body by mapping its geometric shape and albedo, estimating its orientation, spin rate, and mass distribution, and simultaneously determining the spacecraft's orbit. This algorithm combines Simultaneous Localization and Mapping (SLAM) techniques with cutting-edge computer vision tools and SPC. The current SPC framework is highly sensitive to initial conditions. Our goal is to increase the robustness of SPC by defining the initial conditions according to SLAM and computer vision-derived features algorithms. We investigate the performance of our algorithm using simulated data from previous missions.