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MONOCULAR VISION BASED SIMULTANEOUS LOCALIZATION AND MAPPING FOR CLOSE PROXIMITY NAVIGATION NEAR AN ASTEROID

Abstract

In the past, exploration missions to small celestial bodies have been limited to scientific studies and sample return. With the recent surge in interest, future missions are expected to have more complex mission scenarios and thus autonomous on-board guidance and navigation will play a key role to achieve success and to lower mission cost. Autonomous on-board navigation will reduce the need to process the navigational data in the ground control center. The main challenge is close proximity navigation near an asteroid. Missions to asteroids offer enough time to process navigation information on-board compared to the other scenarios such as planetary approach and landing. To achieve autonomous navigation, knowledge of the spacecraft's state and the asteroid's state, geometry and dynamic characteristics are important. The problem of relative navigation with respect to the orbiting body and mapping the geometry of the body are interdependent and can be solved through the Simultaneous Localization and Mapping (SLAM) approach.

While most SLAM approaches in robotics use a wide array of sensors (GPS, IMU, LIDAR and camera) to find the position of the robot, deep space missions are limited to the camera, star sensor and, in some missions, laser altimeter. The proposed visual SLAM framework for asteroid navigation is based on monocular vision and uses registered images of the asteroid. The image is processed and distinct features on the surface of the asteroid are extracted and initialized through inverse depth parametrization and with the subsequent images, the Lucas-Kanade differential method for optical flow estimation is used to track the features through series of images. Considering the rigid body dynamics of the asteroid and the spacecraft's motion, the filter estimates the spacecraft's attitude and position relative to the asteroid and the asteroid geometry, and also other dynamic characteristics of the asteroid. Simulated experiments are carried out and the results suggest that the proposed method can estimate the unknown parameters using the images from a monocular camera.