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RAPID AUTONOMOUS NAVIGATION METHOD FOR HOPPING MOVEMENT ON THE SURFACE OF SMALL BODIES

Abstract

The deployment of mobile rovers on the surfaces of small bodies is imperative for advancing scientific exploration of their internal structure, surface environment, and potential mineral resources. Unlike planets, small bodies exhibit characteristics such as small volume, weak gravity, and unknown surface environments, posing challenges for conventional wheeled rovers. A current solution involves a hopping method of surface movement, facilitated by a built-in reaction wheel, enabling the rover to achieve long-distance ballistic motion. The hopping rover leverages the weak gravity of small bodies, minimizes the impact of environmental uncertainties, and possesses the capability to overcome obstacles or navigate ravines.

During the hopping movement, the rover undergoes multiple collisions and rebounds on the surface of small bodies, resulting in frequent rotations of its orientation. Therefore, a suitable autonomous navigation solution is indispensable. Navigating a hopping rover presents several challenging issues. The mass constraint dictates that the navigation system must maintain the lowest possible weight, making it impractical to carry a substantial amount of navigation equipment. The hopping movement of the rover involves rotations and collisions, necessitating a navigation system capable of responding to rapid motions. Simultaneously, the environment observed by the rover during the hopping undergoes continuous and rapid changes, making it challenging to track the same features over an extended period.

To address these challenges, this study proposes an autonomous navigation method that integrates optical flow motion estimation with inertial navigation. The navigation system of the rover consists of a monocular camera and an inertial navigation system, enabling autonomous navigation in the face of rapid motion. Initially, the rover's position and orientation are estimated using inertial navigation sensors. Optical flow is calculated through continuous changes in images to track features in the camera's field of view. Considering the significant rotation scale changes before and after attitude control, the deep learning-based scale factor recovery algorithm is proposed to estimate the rover's translational and rotational motion states. Subsequently, taking into account the accumulation errors from the inertial navigation sensors during the hopping, as well as the estimation errors induced by rover maneuvers, rotations, and collisions, fusion factors are designed to establish a strategy for combining optical flow estimation with inertial navigation. Simulation results demonstrate that the proposed method accurately estimates the rover's motion states and exhibits robustness.