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TERRAIN RELATIVE NAVIGATION FOR PRECISE PLANETARY LANDING

Abstract

Many planned planetary landing missions for the future require a pin-point landing capability. However, the current mainly applied inertial navigation method is hard to meet this requirement. Terrain relative state estimation which provides a low cost and high accuracy solution during planetary descent is suit for pin-point landing. Japan's Hayabusa detector first using the descent images for autonomous navigation successfully landed on the "Itokawa" Asteroid. During the Mars Exploration Rover landings, the Descent Image Motion Estimation System was used for horizontal velocity estimation. China's Chang E III lunar probe also used the lunar surface images in the final landing phase for landing site selection and autonomous soft landing.

This paper proposed a landmark based navigation method through a sequence of descent images for precise planetary landing. The system employed tight integration of inertial and visual feature measurements to compute accurate estimates of the lander's terrain-relative position, attitude, and velocity in real time.

Craters are the most notable terrain features on planet surface, which were chosen as landmarks in the system. Feature selection and tracking were employed to estimate the lander's position and to compute the motion between images while taking the position deviation of surface features into consideration. For crater detection, we present an edge information based crater detection algorithm, which consists of edge detection, edge selection, edge pairing and ellipse fitting. For crater matching, based on the geometric invariants of coplanar conics, the voting strategy was used to match the detected craters with the crater database. Besides, a false match and miss match revision strategy was introduced to obtain the crater's accurate global position. The bias of inertial measurements which increases with the accumulation of time is acceptable in a relatively short time. Therefore, differences of consecutive motion estimations were then compared to inertial measurements to revise the feature tracking.

All the corresponding measurement data was processed in a filter and was optimally fused with measurements from an inertial measurement unit. In order to reduce the computational burden and meets the requirements of real-time calculation, the multi-sensor information UD-EKF fusion algorithm was applied.

The key components of our terrain relative navigation approach are: (1) quick detection and tracking of landmarks in descent images taking the position deviations of surface features into consideration, (2) robust estimation of spacecraft's state is coupled with the inertial and camera measurements in a resource-adaptive way which leads to a real-time capability.