LOCALIZATION OF CHANG'E-3 LANDER AND ROVER USING MULTI-SOURCE DATA

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ABSTRACT:

High precision localization of Chang'E-3 (CE-3) lander and rover is of great importance for CE-3 mission operations and relevant scientific investigations. This paper presents a overview of the methods and results of lander and rover localization using multi-source data in different stages of the CE-3 mission.

CE-3 was landed in December 14, 2013 in Mare Imbrium. The initial location of the lander (44.12°N, 19.51°W) was determined through radio tracking. Image based lander localization was also carried out immediately after landing. A localization method of CE-3 lander based on descent sequence images and Chang'E-2 (CE-2) DOM (Digital Orthoimage Map) was developed and performed. First, the landing position of CE-3 was manually determined on the descent image with the highest resolution, and then transferred to other descent images by the geometric relationship established through SIFT matching among descent images. Next, lunar crater extraction method, implemented by mean-shift image segmentation, was applied to the registration of lower resolution descent images and CE-2 DOM. Consequently, the landing position is transferred to CE-2 DOM, and the lander location was determined to be (44.1188° N, 19.5126° W). The relative localization accuracy is better than one pixel (1.5m) of CE-2 DOM, and was verified by the landing position observed by a Lunar Reconnaissance Orbiter (LRO) narrow angle camera (NAC) image acquired on December 25, 2013. This image-based localization of CE-3 lander was achieved in less than 1 hour after landing, which successfully supported the subsequent surface operation tasks.

Along with the mission, more precise localization of the CE-3 lander and rover were necessary for making strategic decisions. High-precision topographic products of the landing site with extremely high resolutions (up to 0.05 m) were generated from descent images and registered to CE-2 DOM. Local DEM and DOM with 0.02 m resolution were produced routinely at each waypoint along the rover traverse using rover stereo images. The lander location was then determined to be (44.11884° N, 19.51256°) W using a method of DOM matching. In order to reduce error accumulation caused by wheel slippage and IMU drift in dead reckoning, cross-site visual localization and DOM matching localization methods were developed to localize the rover at every waypoints. The result has been verified using a LRO NAC image where the rover trajectory was directly identifiable. During CE-3 mission operations, landing site mapping and rover localization products including DEMs and DOMs, traverse maps, vertical traverse profiles were generated timely to support teleoperation tasks such as obstacle avoidance and rover path planning.

At the later period of the mission, the location of CE-3 lander was calculated by using multiple LRO (NAC) images and the precision was validated with the Lunar Ranging Retro Reflectors (LRRRs). First, the CE-3 lander and other landmarks (LRRR etc.) were pinpointed on multiple LRO NAC images by manual interpretation and high-precision image matching. Then the geodetic coordinates were derived from the image coordinates with the rigorous sensor models established with the refined orbiter positions and attitudes from NAIF SPICE kernels. Finally, the average geodetic coordinates were calculated and considered as the locations of CE-3 and other landmarks. As a result, the location of CE-3 lander was determined to be (44.1219° N, 19.5113°W) using 14 LRO NAC images. The five LRRRs with high-precision absolute locations available were used as check points to evaluate the poisoning errors. The results show that the absolute location accuracy can reach 20 m with a single LRO NAC image, and localization of the lander using multiple images reduce random errors and provides better accuracy than that using a single image.

The localization methods and results of CE-3 lander and rover using multi-source data greatly supported the surface operations of mission in different stages. The results confirmed each other and refined step by step during the mission. These localization data are valuable for post-mission scientific investigations. The localization methods can be applied in future planetary lander/rover missions.

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