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Lunar Surface Outposts and Enabling Technologies (4)

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CRATER MATCHING BASED NAVIGATION FOR PINPOINT LUNAR LANDING

Abstract

Space missions that involve landing on planets, moon, comets and asteroids are inherently challenging. Autonomous landing spacecraft on moon close to the pre-selected landing zone with high scientific value, especially in an area of rough terrain, is a rather difficulty and risky task. Because of the long communication delay induced by the large distance between the target asteroid and base station on the earth, the traditional Deep Space Network (DSN) is not suitable for pinpoint lunar landing. The current lunar landing navigation system is based on the integration of acceleration and rotational velocity measurements from an Inertial Measurement Unit (IMU). Because of the error accumulation in position estimate, it resulted in large landing error ellipse, which can not meet the required precision of pinpoint landing. Current technology does not provide the capability to land safely and precisely, so other new techniques must be investigated. This paper presents a crater landmark matching and tracking based autonomous navigation method for lunar landing. Craters are the most notable terrain features which have clear outline, and craters are the most important landmarks for spacecraft navigation. However, due to the change of spacecraft motion states and camera's visual angle, the crater image rotation, size and shape can be greatly changed, and the crater is difficulty to be matched by general image matching methods. In this paper, the craters are first detected by edge detection, edge matching and geometry fitting, and the affine invariants of craters are advanced to match the detected crater with crater database to determine crater's global position on lunar surface. For the measurements of crater landmark's line of sights, the Unscented Kalman Filter is used to estimate spacecraft position and attitude. In addition, the propagating covariance in computer vision is sued to analysis the states estimation error, and the crater landmark selecting strategys are given. Simulation results shows that the proposed crater matching method can effectively match the detected crater with crater database under large image rotation, size and shape change, it's a robust method for crater image matching during landing. Random select four crater landmarks which global positions are known, spacecraft's relative position and attitude can be determined, the position estimate error is within 10 meters, and the attitude estimate error is within 1deg, which are precise enough for pinpoint lunar landing.