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FEASIBILITY ASSESSMENT OF AUTONOMOUS OPTICAL NAVIGATION IN LUMIO MISSION

Abstract

Autonomous optical navigation is one of the main key enabling technologies for the Lunar Meteoroid Impacts Observer (LUMIO) mission, as well as for other deep-space science and exploration CubeSat missions.

Traditional navigation techniques for spacecraft rely on radiometric tracking from ground stations, which perform ranging and range-rate to feed a state estimation filter. The accuracy of radiometric navigation is very high, but a flight dynamics team must be allocated for every mission and mission phase like in a conventional spacecraft mission, thus increasing the ground segment costs and the overall CubeSat mission cost.

The challenge of granting autonomy in navigation and operations to deep-space CubeSats is faced by LUMIO, acknowledged by ESA as winner of SysNova Lunar CubeSats for Exploration competition, and currently under consideration for future implementation by the Agency. LUMIO envisages a 12U CubeSat form-factor placed in a halo orbit at Earth-Moon L2 to characterise the lunar meteoroid flux by detecting the impact flashes produced on the far-side of the Moon. LUMIO CubeSat performs autonomous on-board optical navigation by processing resolved images of the Moon, where its full-disk is visible. The distance to the Moon is estimated by linking its apparent size in an image with the real one, and the relative position vector is obtained if both the spacecraft attitude and the Moon ephemeris are known.

The LUMIO navigation performances assessment is performed following a clear and structured work-flow as follows. A rendering software (POV-Ray) is used to generate synthetic images of the Moon as function of LUMIO, Moon and Sun positions, LUMIO attitude, and optical camera properties (Field-of-view, resolution, focal length, etc.). The raw images, properly cleaned from background noise, are converted into black and white according to a certain threshold on each pixel illumination, and processed to detect the light direction and the Moon edge. Then, the Moon lit horizon pixels are extracted and a circle is fitted. This circle represents the Moon disk size in pixels, which is linked to the real one to estimate the camera-to-Moon distance and position, provided that attitude and Moon ephemeris are known. The outputs feed an extended Kalman filter to estimate the spacecraft full state and increase the estimation accuracy.

In this work we show the performances of the full-disk autonomous navigation in LUMIO, and discuss possible improvements in view of the mission implementation.