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AUTONOMOUS HAZARD DETECTION AND AVOIDANCE SYSTEM BASED ON THE FUSION OF LIDAR AND CAMERA SENSORS FOR THE LUNAR LANDER MISSION

Abstract

The next generation of space exploration missions to the Moon, Mars and small bodies will require the ability to navigate and land safely in close proximity to potential hazards on the surface. These applications require the capability to identify surface constraints such as boulders, rocks, slopes and shadowed areas on the surface of the celestial body and react rapidly in order to guide the spacecraft toward the safest regions. This capability is known as Hazard Detection and Avoidance (HDA).

In the context of the ESA Lunar Lander phase B1 program, aiming at landing a spacecraft at the South Pole of the Moon, NGC Aerospace has developed a HDA system capable of detecting and avoiding autonomously such surface constraints. The HDA system is composed of image processing, navigation, guidance and control algorithms. These algorithms are implemented on an onboard computer interfacing with a scanning Lidar, a camera sensor, an IMU, a distance-to-ground sensor and the Lander propulsion system. The Lidar is used for the detection of slopes and roughness while the camera is used for shadow and texture detection. This information is also fused with constraints on fuel consumption, distance to nominal target and distance to the nearest hazards in order to ensure that the selected landing site is the safest one and will remain safe despite control dispersions during the avoidance manoeuvres. The architecture of the HDA system also enables the management of sensor failures. Camera sensors are redundant and sensor validity check is performed at fusion function level, such that if the Lidar fails, the HDA relies only on the camera instead of using both sensors.

The lunar landing trajectory is designed in order to optimise the performance of the HDA system (spatial resolution and coverage) while minimising the impacts at Lander/sensor system-level (fuel and sensor mass/power requirements). To assess the robustness of the HDA system, Monte Carlo software simulations is performed using a high-fidelity simulator of the mission, of the spacecraft and of the targeted landing area topography.

This paper reports the main requirements of the ESA Lunar Lander phase B1, the main features of the HDA system design, the validation methodology and the most significant results. It concludes that the proposed HDA system architecture meets the mission requirements and is applicable to missions other than those to the Moon, including missions to other celestial bodies such as Mars and small bodies.