IAF SPACE EXPLORATION SYMPOSIUM (A3)
Moon Exploration – Part 3 (2C)

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RELATIVE NAVIGATION AND HAZARD DETECTION & AVOIDANCE INTEGRATION FOR AUTONOMOUS MOON LANDING APPLICATIONS

Abstract

Future Lander systems need to be equipped with high-accuracy navigation systems to accurately reach the target and Hazard Detection and Avoidance (HDA) systems to detect and avoid any surface hazards at touchdown. High-accuracy navigation and HDA have been identified as key enabling technologies by private and governmental organisations willing to explore or commercially exploit the Moon.

High-accuracy navigation in such applications typically relies on optical systems and serves two purposes: absolute navigation (to locate the Lander in an absolute sense with respect to a Moon-fixed reference frame) and relative navigation (to estimate the Lander motion relative to the local terrain). Relative navigation and HDA work hand-in-hand during the last phase of landing operations. HDA determines the best landing site, while relative navigation is key in determining the landing-site-relative position and velocity in order to achieve accurate and safe touchdown at the intended location.

The HDA function commands the sensors (Lidar and camera), processes the sensor data, generates surface hazard maps for slope, roughness and shadow, and combines this information to recommend a safe landing site meeting all the safety and Lander manoeuvrability constraints. The HDA function thus relies on the outputs of the navigation system for processing the sensor measurements and to actively command the Lidar scan coverage and resolution. The integration of optical navigation and HDA components is thus key to achieve the required hazard detection reliability, to enable accurate retargeting toward the identified target and to ensure suitable touchdown conditions.

An important technological unknown is the achievable system performance when considering affordable technologies available for deployment in space within the next years. The system performance depends on sensor accuracy, resolution and scan time, on the quality of the navigation solution (based on optical navigation) but also on the capabilities of the processing platform.

Development activities are on-going to develop a fully integrated and affordable navigation and HDA system composed of a scanning Lidar sensor, a camera sensor, an inertial measurement unit and an embedded processing unit where optical navigation and HDA functions are integrated and operating in real time. The paper will present the latest hardware-in-the-loop demonstration results of this integrated system in a dynamic environment. It will demonstrate the integration of relative navigation and HDA and discuss overall performance compared with the required hazard detection reliability requirements, the landing accuracy requirements and the desired touchdown conditions. The paper will conclude with recommendations for future developments.