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ON THE INTEGRATION OF HAZARD DETECTION AND AVOIDANCE SYSTEMS WITH AUTONOMOUS NAVIGATION SYSTEMS FOR PLANETARY LANDING APPLICATIONS

Abstract

In order to reduce mission landing risk, many upcoming planetary exploration missions require the use of an autonomous Hazard Detection and Avoidance (HDA) system. HDA provides the capability to identify landing hazards such as roughness, slope and shadowed areas on the surface and to autonomously identify the safest landing site considering Lander manoeuvrability constraints. To achieve these objectives, HDA systems typically rely on a combination of measurements from camera and active Lidar sensors. Amongst the various Lidar technologies, scanning Lidar technologies show many advantages for missions which have tight mass and power constraints.

However, a scanning Lidar takes time (typically several seconds) to scan a complete landing area. In order to mitigate the impact of the system on the overall propellant budget, it is not desirable to maintain static hovering conditions with the Lander during terrain assessment. The Lander keeps descending while the scanning and the processing takes place. The measurements provided to the HDA system are thus taken from different surface-relative conditions. The HDA system needs to do “motion compensation” to remove from the measurements the distortion caused by Lander motion to accurately reconstruct surface topography, a process which heavily relies on surface-relative navigation estimates.

There is a strong interaction between HDA and navigation which occurs at four levels. Firstly, in order to maintain optimal surface coverage, the Lidar scan pattern is dynamically adapted to the estimated Lander motion. Secondly, the HDA reconstructs from relative motion compensation small-scale features on the surface to assess surface roughness and slope. Thirdly, hazards are referenced on the ground such that information from all sources can be combined and positioned with respect to the Lander trajectory estimate. Finally, the navigation estimates are used by the Lander to track the reference trajectory and reach the HDA-designated safe landing site. In most cases, the HDA is impacted not only by the absolute estimation error value itself, but also by the variation of this error over various timescales. This leads to unconventional performance requirements for the associated navigation system.

The paper will thus discuss the interaction between the HDA and the navigation system at the various levels and will discuss the type of requirements this imposes on navigation. High-fidelity closed-loop simulation examples will demonstrate how HDA performance is affected by navigation errors in an autonomous Moon landing reference scenario and recommendations will be provided on how to mitigate or reduce their negative effects.