LandSAfe: Landing Site Risk Analysis Software Framework

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Keyword: ICA and WG IV/7: Exploring the Moon!

Presentation Preference: Oral

The Lunar Lander project of the European Space Agency (ESA) targets a precision landing with hazard avoidance at the polar regions of the Moon. To ensure a safe and successful landing a careful risk analysis has to be carried out. This is comprised of identifying favorable target areas and evaluating the surface conditions in these areas. Concretely, features like craters, boulders, steep slopes and shadows have to be identified in order to assess the risk associated to a landing site in terms of a successful touchdown and subsequent surface operation of the lander. In addition, global illumination conditions at the landing site have to be simulated and analysed, and in support of optical-based navigation a landmark database has to be generated.
The Landing Site Risk Analysis software framework (LandSAfe) is a system for the analysis, selection and certification of safe landing sites on the lunar surface and is comprised of three components: 1) The User Interface component is responsible to provide the users with a web interface allowing to access and execute the different Product Generation Modules. It also allows the user to browse, to view and to download products from the LandSAfe Products Data Store. 2) The Data Store Interface component is responsible to provide all the modules with an interface allowing handling different kinds of data. This interface allows the modules to retrieve input data from either the Input Data Store or from the LandSAfe Products Data Store. 3) The Product Generation Modules are the core processes of the LandSAfe software suite for the automatic production of lunar digital terrain models (DTMs) and derived products like hazard maps, illumination maps, temperature maps and surface reflectance maps.
DTMs are generated by stereoscopic digital image matching techniques mainly using high resolution imagery of the LROC NAC (Lunar Reconnaissance Orbiter Camera Narrow-Angle Camera). The combination of DTMs derived from LROC NAC images and height data of the LOLA (Lunar Orbiter Laser Altimeter) instrument allows for an automatic quantitative evaluation of landing site hazards like craters and boulders with respect to detection, counting, sizing and distribution. The final hazard maps support decision making in visualizing potentially unsuitable landing areas by incorporating vital factors like surface roughness, shadows, slope, boulders and craters. Combined DTMs derived from LROC NAC images and height data of the LOLA are also used to simulate and analyse the illumination conditions at the potential landing sites. In fact, the Lunar Lander aims at special locations at the pole, which experience extended periods of illuminations (more than two weeks and up to several months) due to the almost vertical axis of the Moon and to the high variability of the terrain. However, these conditions are heavily

dependant on the local topography and accurate modeling of the illumination must be performed. During the descent and landing phase of the mission optical navigation is used on-board the lander to achieve precision landing. Images of the lunar surface taken by the camera on-board the lander are processed in real-time in order to extract landmarks, which are matched with landmarks stored in a database on-board the lander in order to improve the lander position estimation. The landmark database has to be built up by LandSAfe with the help of suitable feature elements like points or edges, although other features can be used (e.g. craters).
This paper describes the architecture of the LandSAfe system and the methods employed. Additionally, products like DTMs and hazard maps are shown.