Single Camera Absolute Structure from Motion using H_∞ Data Fusion for a Next Generation Planetary Lander

Luke Feetham[1] and Nabil Aouf[2]
Cranfield University, Shrivenham, Oxfordshire, SN6 8LA

Clement Bourdarias[3]
Astrium ST, 66 route de Verneuil - 78133 Les Mureaux Cedex (France)

Thomas Voirin[4]
ESA-ESTEC, Postbus 299 - 2200 AG Noordwijk (The Netherlands)

Abstract

Planetary surface exploration missions are becoming ever more ambitious in their science goals as they attempt to answer bigger and bigger questions relating to the possibility of life elsewhere in our solar system. This inevitably leads to larger, more expensive robotic craft carrying large suites of complex scientific instruments, which in turn places greater emphasis on the need to land the spacecraft safely and in a location where the science goals can be met effectively and efficiently. These ambitions are leading to a growing need to extend the capabilities of current entry decent and landing technology in order to provide a means for delivering a sophisticated robotic craft to precise points of scientific interest. Truly interesting landing sites are rarely found in hazard free and easily accessible locations. Therefore next generation entry descent and landing systems must possess sophisticated autonomy in order to negotiate hazards and steer the lander towards its intended landing site with high precision.

The primary focus of this paper is on accurate real-time estimation of the spacecraft's absolute motion parameters during descent towards the surface, with future goals aimed at constructing an accurate and dense 3D digital elevation model of the terrain in the vicinity of the landing site that could form the foundation of a sophisticated hazard detection system. Hence we have chosen a recursive structure from motion technique as a first step towards achieving these goals. Specifically, we present a multi-source, multi-rate data fusion algorithm to combine the results of a single camera recursive feature based structure from motion algorithm with measurements from an inertial measurement unit, as a means to directly estimate the unknown scale factor present in such single camera systems. Direct estimation of the scale factor allows for absolute measurements to be obtained from the single camera structure from motion algorithm, which leads to greater overall accuracy and robustness compared to other vision and inertial measurement data fusion techniques presented in the literature. We focus specifically on techniques that enable robust feature tracking that is adaptive to sudden disturbing impulses in the spacecrafts motion, which are likely to be common during descent, by utilising measurements from an inertial measurement unit to assist in tracking the features. Additionally we also focus on a robust state estimation technique for estimating the spacecraft's absolute 3D parameters, based on the extended H_∞ filter, due to the highly non-linear measurement model employed in this work, and the potential for sudden large disturbances.

Results are presented from a test using synthetic but representative images of a descent towards a planetary surface, created using the Planet and Asteroid Natural Scene Generation Utility (PANGU). These results demonstrate that highly accurate estimates can be obtained for the 3D motion parameters, even in challenging situations such as from an altitude of 2km, where errors of only a fraction of a degree for the orientation and only a few meters for the absolute translation are observed. Consequently it is believed that the proposed method has great potential as the foundation on which to develop the other key capabilities for a next generation entry descent and landing system.

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[1] PhD Research Student, Department of Informatics and Systems Engineering, Cranfield University, Shrivenham, Oxfordshire, SN6 8LA.
[2] Senior Lecturer, Department of Informatics and Systems Engineering, Cranfield University, Shrivenham, Oxfordshire, SN6 8LA.
[3] Project Manager, Sensors Engineering and Image Processing, Astrium ST, 66 route de Verneuil - 78133 Les Mureaux Cedex (France)
[4] Space Systems Engineer, Control Systems Division, ESA-ESTEC, Postbus 299 - 2200 AG Noordwijk (The Netherlands)