A novel approach for Video-based Absolute Navigation in space exploration missions

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I. Poster Abstract

Nowadays, space agencies have increased their research efforts in order to enhance the success rate of space exploration missions. The guided landing is becoming an hot topic and future space missions will increasingly adopt Video Based Navigation (VBN) systems to assist the entry, descent and landing (EDL) phase of space modules, enhancing the precision of automatic EDL systems.

Video-based navigation (VBN) is a well-studied area of computer vision spanning several application fields, including robotics, unmanned vehicles, and avionics.

VBN is also gaining importance in space applications where Image Processing (IP) is becoming more and more important to enhance the on-board advanced avionics functionalities.

Different mission types will benefit of the IP outputs to increase the reliability and the accuracy of the navigation system. Typical applications are RdV, Debris Removal, In Orbit Servicing, Rovers/Robots and Descent & Landing on planets.

As example, for in orbit operations the identification and the relative position determination of the target from images are essential for supporting the docking or capture of collaborative and in particular non-collaborative objects. Instead, for Rovers and Robots, vision is necessary to support the reconstruction of the terrain maps, the determination of the safe path planning, and the identification of scientific targets. For Descent and Landing on remote planets, where the autonomy is a critical factor, cameras have already been used on past missions but with limited on board capabilities, whereas IP is deemed a key feature to be integrated in the GNC in order to improve the reliability and precision (in particular during the absolute/relative navigation and hazard mapping/avoidance).

The usage of a VBN system will allow to design an autonomously guided EDL system able not only to reduce the landing ellipse, but also to avoid the landing in dangerous area of the planet surface (e.g., huge craters or big stones), that could lead to the mission failure.

A VBN system executes very computationally intensive image processing algorithms. Since real-time performances are mandatory, it must be able to compute these algorithms at high speed. A software implementation of the complete image processing chain cannot reach the required performances, thus the emerging trend is to accelerate portions of the image processing algorithms via hardware.

In space-applications, Field Programmable Gate Arrays (FPGAs) are increasingly replacing Application Specific Integrated Circuits (ASICs). They are highly versatile, featuring dedicated carry structures to support adders, accumulators and counters, and offer cheaper cost per logic gate.

The presented poster will focus on the concept of Video-based *Absolute Navigation*, i.e., the ability to compute the position of a spacecraft, during the EDL phase, referred to a general coordinate system. The basic approach consists in extracting some kind of information (e.g., landmarks), characterizing the landing zone, from the images taken by the spacecraft, and trying to match these information with the ones stored in a reference database, created at design time. In order to ensure the proper definition of the absolute position, the database stores the information related to a planetary surface portion wider than the target landing area.

Existing approaches for Video-Based Absolute Navigation can be classified in three main groups: (i) *Orbiter-assisted*, (ii) *Shape-based*, and (iii) *Crater-based*.

However, they have common drawbacks concerning the database size in terms of required memory. Moreover, they could lead to fake matchings, and so to a wrong absolute position estimation, if landmarks with similar shape are present in the landing zone.

This poster will show a preliminary work on a novel approach for Video-based *Absolute Navigation*. Moreover, the poster depicts how a Video-based *Absolute Navigation* processing chain can exploit FPGA devices to achieve high throughput, in terms of frames-per-seconds.

The proposed approach aims at identifying each landmark (i.e., craters) through a characterizing point, and then applying the same approach used in Planar triangle-based (PT) Star trackers. PT Star trackers are used to define the attitude of a satellite depending on which stars are within the satellite camera's field of view. In our approach the characterizing points associated with landmarks act as stars.

The presented poster will detail the proposed algorithm operations and show how this approach can strongly reduce the database size, w.r.t. existing methods. Moreover, the FPGA-based hardware architecture implementing the proposed approach will be presented. The proposed FPGA-based system is mainly composed of a processor supported by a hardware implemented image processing core which accelerates some image processing tasks.

The performances of the system and several visual results will be shown to highlight the peculiarities of the proposed approach.