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FPGA-BASED MULTI-SENSOR RELATIVE NAVIGATION IN SPACE: PRELIMINARY ANALYSIS IN THE FRAMEWORK OF THE I3DS H2020 PROJECT

Abstract

Orbital applications encompass activities such as on-orbit servicing and repair, space rendezvous and docking, collision avoidance and active debris removal (ADR). Simultaneous localisation and surface mapping (SLAM) for planetary exploration and general navigation in an unknown environment for scientific purposes can be considered in planetary applications. These envisaged space applications can be tackled by exploiting the flexibility, high performance and long product life of FPGAs. Conventional FPGAs are subject to Single Event Upsets (SEU) due to space radiation, causing their failure. Therefore, space-graded FPGAs, such as those developed by Xilinx, are targeted within the I3DS project. Currently, the main use of the FPGA within the development of this robust end-to-end multi-sensor suite is for navigation and data preprocessing. The aim of this paper is to assess the capabilities of FPGAs to carry out complex operations, such as running navigation algorithms for space applications. The motivation for the development of the on-board software architecture is as follows: raw data, acquired from the various sensors – including, among others, a High Resolution camera, a stereo camera and a LiDAR – is pre-processed to ensure the provision of robust and optimised inputs to 3D navigation algorithms. Noise reduction and conversion into suitable formats for the successful application of navigation algorithms are therefore the main aims of the data pre-processing. Some techniques adopted in this phase include outlier rejection and data dimensionality reduction for large point clouds, e.g. from LiDAR, and geometric and radiometric correction of the images from the cameras. The pre-processed data will then feed state-of-the-art relative navigation algorithms. Some of the proposed navigation algorithms include Generalised Iterative Closest Point (GICP) for dense 3D point clouds, relative positioning with fiducial markers, and visual odometry. The system environment for the preliminary operation is a test-bench setup formed by a standard desktop computer and a non-space-graded FPGA (Xilinx UltraZed-EG FPGA). The choice of FPGA was based on the similarity of this board to other spacegraded ones also provided by Xilinx. Experimental tests on the algorithms are being performed in the framework of the validation campaign for the I3DS project. Preliminary results indicate that the data pre-processing can be efficiently carried out on the FPGA board.