Paper ID: 73937
student

50th STUDENT CONFERENCE (E2)
Educational Pico and Nano Satellites (4)

Author: Mr. Giovanni Maria Capuano
Università degli Studi di Napoli "Federico II", Italy

Mr. Mariano Severi
TECHNO SYSTEM DEV., Italy
Prof. Nicola Petra
University of Naples "Federico II", Italy

FPGA HW ACCELERATION FOR DEEP LEARNING BASED SPACECRAFT POSE ESTIMATION

Abstract

Accurate and robust relative position and attitude determination of a non-cooperative spacecraft is a key capability for proximity operations in many classes of missions such as Orbit Servicing, Active Debris Removal and Formation Flying. Several methods and approaches for spacecraft pose estimation exist, depending on the characteristics of the main and target spacecraft, the required accuracy, and the operational environment. When the main spacecraft is a very small satellite, such as a nanosatellite, with strict mass and power constraints, typically, monocular vision is the most common solution. In this context, monocular approaches for pose estimation based on Deep Learning models have been outperforming traditional ones that have proven to be less robust to harsh and variable lighting conditions.

On the other hand, real-time on-board processing of Deep Learning algorithms may result in high power consumption and require large memory resources. For ground applications, the advancement of AI was triggered by the availability of high-performance GPUs, which allows real-time execution of Deep Neural Networks. The GPUs today available are designed for consumer applications and they are characterized by very high-power consumptions, and based on architecture and HW components not tolerant to the space environment and in particular to the electromagnetic radiation and to the particle radiation. FPGAs have already been adopted in space for some decades now; moreover, although in a very limited number, nowadays rad hard space grade FPGAs are available on the market and able to tolerate space environment also in demanding missions, such as long duration in GEO and above. FPGAs contain a matrix of configurable logic blocks that can be customized to perform specific computing tasks and can be designed to run a Neural Network improving performance in terms of power consumption with the respect the one of the GPUs, without reducing the accuracy performance thanks to quantization and pruning.

The design, implementation and validation of a FPGA accelerator, based on a Convolutional Neural Network (CNN) model for satellite pose estimation is presented in this paper. The development was carried out using, the Google Colab platform for the training and model definition and the Xilinx Vitis-AI tool for hardware acceleration of the CNN on a Xilinx's Zynq UltraScale+ MPSoC's device that represents a development solution that doesn't require a huge amount of computational resources, thus allowing you to avoid having to resort to GPUs. Particular attention is posed to the porting of the model from the Colab platform to the Vitis-AI environment that requires significant efforts. Both training and validation are performed using the Spacecraft PosE Estimation Dataset (SPEED) of 15'000 synthetic and 300 real images of the Tango spacecraft from the PRISMA Formation Flying Mission as well as additional real images of the same spacecraft that better resemble the visual features and illumination variability.