Paper ID: 94923
student

32nd IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS (B4)
Generic Technologies for Small Satellites (1) (6A)

Author: Mr. Ric Dengel
University of Tartu, Estonia

Dr. Mihkel Pajusalu
University of Tartu, Estonia
Prof. Rene Laufer
Luleå University of Technology, Sweden

UTILISING SPACECHIPEXPLORER TO BENCHMARK DATA REDUCTION PERFORMANCE ON FPGAS IN SPACE

Abstract

As space missions become more complex the level of required autonomy and generated data increases. Especially the generating increasingly large volumes of scientific data with a limited growth in bandwidth capacity to transmit the data to Earth is a significant challenge. Thus, efficient onboard data reduction becomes essential to minimize bandwidth limitations and enable real-time decision-making. Of course, lossless data compression will always be preferred, but neural networks offer a promising solution for onboard data segmentation and compression as it allows to select the wanted data to am accuracy other methodologies may not achieve. However, selecting the optimal architecture for deployment on space-grade hardware remains challenging due to trade-offs between accuracy, computational complexity, and hardware efficiency. In this work, we leverage SpaceChipExplorer, an automated benchmarking pipeline, to systematically evaluate the performance of neural network-based data reduction techniques on FPGAs. Using the CometSet dataset and a neural network training pipeline, we trained various networks on comet data segmentation as application scenario. We investigate various CNN architectures, ranging from lightweight models such as MobileNets and EfficientNet, which prioritize energy efficiency, to more complex networks like ResNet and YOLO, which provide improved segmentation accuracy at the cost of higher computational demand. The study also includes fully convolutional architectures such as U-Net, which are commonly used for image segmentation tasks. These models are deployed and tested on different space graded FPGA platforms. For deployment various tools are compared such as AMD Xilinx's Vitis AI, Xilinx's FINN and Microchip's VectorBlox, to analyse key performance metrics such as inference throughput, power consumption, memory footprint, and real-time processing capabilities. By quantifying the trade-offs between network depth, network parameter account, computational requirements, and hardware-specific optimizations, this study provides valuable insights into the feasibility of deploying neural networks for onboard data reduction. This paper will outline the networks and preliminary results of this evaluation. The results contribute to advancing hardware-aware machine learning solutions in space applications, paving the way for more autonomous and intelligent spacecraft operations.