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IMPLEMENTATION OF MACHINE LEARNING METHODS ON FPGA FOR ONBOARD SATELLITE OPERATION

Abstract

Machine learning techniques are increasingly being applied in terrestrial day-to-day activities. They have also been proposed for various space applications such as for onboard data processing, space bodies explorations, autonomous operations and various mission-specific applications. Terrestrial application of machine learning is facilitated by shared resources such as cloud services, powerful desktop computers and machine learning framework APIs. However, these enablers are limited in the space environment.

To take advantage of the progress in machine learning, space applications will need to have onboard implementation of the various methods. Two of the main platforms suitable for machine learning computations are Graphical Processing Units (GPUs) and Field Programmable Gate Arrays (FPGAs). However, GPUs are power hungry compared to FPGAs for similar operation and accuracy. Therefore, FPGAs are more suitable in space applications. More so, FPGAs are already being applied in space operations in mission-specific and satellite subsystem operations. They are also reconfigurable, and therefore can be adopted for different tasks on the fly.

Most satellites rely on telemetry data received by ground stations to monitor the health of satellites. This requires that massive telemetry data is downlinked as frequent as possible. With more sensors being incorporated on the satellite, the amount of data generated is increasingly becoming difficult to efficiently downlink. The possibility of incorporating some artificial intelligence onboard the satellite would help in freeing up the downlink budget for actual mission data. This will ensure only the critical data is downloaded and not all the raw data. More so, this would introduce a level of autonomous satellite operation that augments ground operators.

This paper presents the implementation of two machine learning algorithms on an FPGA. Inherently, most of the satellite and telemetry data have the property of time series. One of the machine learning algorithms suitable for time series data is the Long Short-Term Memory (LSTM) networks. Towards this, this paper implements an LSTM and an ANN network on the FPGA, both simulation and on the real hardware. The Xilinx Kintex-7 FPGA has been used in the implementation and evaluation of the networks. The network is implemented at the RTL level using Verilog hardware description language. Due to the time series property of most satellite data, the two networks will be tested on time series data sets such as state of charge estimation for lithium ion batteries. Their accuracy and resource utilization will be evaluated.