IAF SPACE SYSTEMS SYMPOSIUM (D1)
Technologies to Enable Space Systems (3)

Author: Mr. Ric Dengel
Luleå University of Technology, Germany, ric.dengel@outlook.com

Mr. Christophe Honvault
European Space Research and Technology Centre, ESA-ESTEC, The Netherlands,
christophe.honvault@esa.int
Mr. Luis Mansilla
European Space Research and Technology Centre, ESA-ESTEC, The Netherlands, Luis.Mansilla@esa.int
Ms. Diane Magnin
ESTEC-European Space Agency Technology and Research Centre, The Netherlands,
dianemagnin@yahoo.com
Mr. Hugo Marques
ESTEC-European Space Agency Technology and Research Centre, The Netherlands,
hugomm.marques1@gmail.com
Mr. David Steenari
European Space Research and Technology Centre, ESA-ESTEC, The Netherlands, David.Steenari@esa.int
Ms. Kyra Foerster
European Space Research and Technology Centre, ESA-ESTEC, The Netherlands, Kyra.Foerster@esa.int
Prof. Marcus Liwicki
Luleå University of Technology, Sweden, marcus.liwicki@ltu.se
Prof. Rene Laufer
Luleå University of Technology, Sweden, rene.laufer@ltu.se

HARDWARE ACCELERATED MACHINE LEARNING ON EMBEDDED SYSTEMS FOR SPACE APPLICATIONS

Abstract

As spacecraft missions continue to increase in complexity, the system operation and gathered data amount demand more complex spacecraft systems than ever before. Currently, mission capabilities are constrained by the link bandwidth as well as on-board processing capacity and depend on a high number of commands and complex ground station systems to allow operations of the spacecraft. Thus, efficient use of the bandwidth, computing capacity and increased autonomous capabilities are of utmost importance.

Artificial intelligence with its vast areas of application scenarios allows tackling these and more challenges in spacecraft designs. Particularly the flexibility of neural networks as machine learning technology provides many possibilities. For example, neural networks can be used for object detection and classification tasks. This field is constantly evolving, as on-board data processing, perception and path planning continue to become more advanced in space applications. Generally, application scenarios of artificial intelligence are vast and even more usage scenarios are evolving. Unfortunately, the execution of current machine learning algorithms is consuming a high amount of power and memory resources as well as their qualification remains challenging which limits their possible applications in space systems.

Thus, an increase in efficiency is a major enabling factor for these technologies. The optimisation of the algorithm for System-on-Chip platforms to benefit from the best of a generic processor and hardware

acceleration shall allow broader applications of these technologies with a minimum increase of power consumption. Additionally, COTS embedded systems are commonly used in space application, due to the possibility to add fault mitigation on the user side. For this, machine learning techniques in form of a neural network are optimised on a workstation. By utilising automatic code generation tools as well as pruning and quantization the network is optimised for embedded system and initially ported on an embedded system including a powerful generic processor and the hardware programming capabilities of an FPGA. This result is then evaluated based on relevant performance and efficiency parameters. Furthermore, the auto-generated code is investigated to adapt manually parts of the implementation towards optimisation of the relevant parameters. These changes are also evaluated and compared to the previous implementations.

This paper aims to contribute to increasing the efficiency of artificial intelligence in space. Specifically, the performance of machine learning algorithms is evaluated on embedded systems which are the heart of most current space missions.