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A HIGH THROUGHPUT SOFTWARE ACCELERATION TO ON-BOARD ARTIFICIAL INTELLIGENCE FOR EARTH OBSERVATION

Abstract

The next generation of spacecraft is compelled to undertake increasingly intricate tasks with heightened autonomy. Space exploration, Earth Observation (EO), and space robotics are burgeoning fields that demand a surge in sensor capabilities and computational power to effectively execute these missions. In the realm of EO satellites, the introduction of cutting-edge sensors to the market are yielding data of superior quality and in larger volumes at accelerated rates. Multi-spectral and hyper-spectral imagers, as well as Synthetic Aperture Radar (SAR) sensors, stand as exemples of this trend. However, the timely transmission of this abundant sensor data to Earth presents a formidable challenge, often impractical. Conversely, advancements in processor technologies have resulted in increased computational power, empowering on-board data processing to achieve tasks such as 1) pre-processing sensor data to reduce the volume for transmission (e.g., on-board cloud segmentation and AI-based compression) or 2) processing sensor data to generate preliminary information for near-real-time transmission (e.g., early detection of natural disasters like wildfires, as well as identification of ships or objects). This new landscape of advanced space applications, characterized by a surge in data volume and processing power, brings forth new challenges: low determinism, heightened power requirements, data losses, and substantial response latency.

This article introduces a novel approach to on-board artificial intelligence (AI) grounded in cutting-edge academic research on the well-established technique of software data pipeline. Algorithm pipelining has experienced a resurgence in high-performance computing due to its advantageous combination of low power consumption and high throughput capabilities. The approach presented here employs a sophisticated threading model that combines pipeline and parallelization techniques, specifically applied to deep neural networks (DNN). This integration enhances the efficiency and reliability of AI applications, particularly in the context of EO applications.

The validation of this innovative approach was initially done within an European Space Agency (ESA) contract and involving multiple DNN models, including cloud segmentation and ship detection, across various computer architectures, demonstrating substantial increases in data processing rates and power efficiency compared to conventional AI solutions. The article outlines current and future research efforts within ESA further initiatives. These include adapting the novel inference engine software for deployment on space-qualified hardware systems such as the GR740 and GR765 processors, as well as radiation hardened accelerators like ISD's HPDP co-processor, Xilinx FPGAs, NVIDIA GPU and Ramon's RC64, proving the significant contribution of this technology to the ongoing evolution of AI capabilities for EO in Space.