NASA SBIR 2019 Phase I Solicitation

H6.22 Deep Neural Net and Neuromorphic Processors for In-Space Autonomy and Cognition

Lead Center: GRC

Participating Center(s): ARC

Technology Area: TA11 Modeling, Simulation, Information Technology and Processing

Machine Inferencing and Neuromorphic Capabilities

The Deep Neural Net and Neuromorphic Processors for In-Space Autonomy and Cognition subtopic is focused on computing advances for the space environment based on neurological models in contrast to von Neumann architectures. Deep neural net and neuromorphic processors can enable a spacecraft to sense, adapt, act and potentially learn from its experiences and from the unknown environment without needing a ground mission operations team. Neuromorphic processing will enable NASA to meet growing demands for applying artificial intelligence and machine inferencing and learning algorithms on board a spacecraft that is energy efficient. These demands include enabling on-board cognitive systems to improve mission communication and data processing capabilities, provide sensory processing onboard to optimize communication bandwidth and latency, enhance computing performance, and reduce memory requirements. Additionally, deep neural net and neuromorphic processors show promise for minimizing power requirements that traditional computing architectures now struggle to meet in space applications.

The goal of this subtopic is to develop deep neural net and neuromorphic processing hardware, software, algorithms, architectures, simulators, and techniques as an enabling capability for autonomy in the space environment. Additional areas of interest for research and/or technology development include:

- Deep neural net and neuromorphic processing approaches to enhance data processing, computing performance, and memory conservation.
- Spiking neural net algorithms that learn from the environment and improve operations.
- New brain-inspired chips and breakthroughs in machine understanding and intelligence.
- Novel memristor, MRAM, and other radiation tolerant devices that can be incorporated in neuromorphic processors which show promise for space applications.

This subtopic seeks innovations focusing on low size, weight, and power (SWaP) processing suitable for CubeSat operations or direct integration with sensors in the harsh space environment. Focusing on SWaP-constrained platforms opens the potential for applying neuromorphic processors in spacecraft control situations traditionally reserved for power-hungry general-purpose processors. This technology will allow for increased speed, energy efficiency, and higher performance for computing in unknown and uncharacterized space environments.

Phase I will emphasize research aspects for technical feasibility and show a path towards a Phase II proposal. Phase I deliverables include concept of operations of the research topic, simulations and preliminary results. Early development and delivery of prototype hardware/software is encouraged.

Phase II will emphasize hardware and/or software development with delivery of specific hardware and/or software products for NASA targeting demonstration operations on a CubeSat platform. Phase II deliverables include a working prototype of the proposed product and/or software, along with documentation and tools necessary for NASA to use the product and/or modify and use the software. Hardware products should include both layout and simulation. Sample chips – from device level on up – are encouraged. Software products shall include source for government use. Proposed prototypes shall demonstrate a path towards a CubeSat mission. Proposals should include a strategy for tolerance to radiation and other adverse aspects of the space environment.

Background, State of the Art, and References

The current state-of-the-art (SOA) for in-space processing is the High-Performance Spaceflight Computing (HPSC) processor being developed by Boeing for NASA Goddard Space Flight Center (GSFC). The HPSC, called the Chiplet, contains 8 general purpose processing cores in a dual quad-core configuration; initial hardware delivery is expected by December 2020. In a submission to the Space Technology Mission Directorate (STMD) Game Changing Development (GCD) program, the highest computational capability required by current typical space mission is 35-70 GFLOPS (billion floating-point operations per second).

The current SOA does not address the capabilities required for artificial intelligence and machine inferencing and learning applications in the space environment. These applications require significant amounts of multiply and accumulate operations, in addition to a substantial amount of memory to store data and retain intermediate states in a neural network computation. Terrestrially, these operations require general-purpose graphics processing units (GP-GPUs), which are capable of TFLOPS (10^{12}) -- approximately 3 orders of magnitude above the anticipated capabilities of the HPSC.

Neuromorphic processing offers the potential to bridge this gap through novel hardware approaches. Existing research in the area shows neuromorphic processors to be up to 1000 times more energy efficient than GP-GPUs in artificial intelligence applications. Obviously, the true performance depends on the application, but nevertheless neuromorphic processing has demonstrated characteristics that make it well adapted to the power-constrained space environment.

Neuromorphic computing is a technology to tackle the explosion in computing performance and memory requirements to meet growing demands for artificial intelligence and machine learning. While the commercial market for these processors is in its infancy, there is a growing community of small businesses that have been funded by Air Force and Department of Energy grants toward development of neuromorphic capabilities. These companies continue to make great strides in neuromorphic processor technology including new devices such as memristors. This subtopic would put NASA in a position to join its partners in the DoD and DoE to enable a research area that shows tremendous application for space.

The Cognitive Communications Project, through the Human Exploration and Operations Mission Directorate (HEOMD) Space Communications and Navigation (SCaN) Program, is one potential customer of work from this subtopic area. Neuromorphic processors are a key enabler to the cognitive radio and system architecture envisioned by this project. As communications become more complex, cognition and automation will play a larger role to mitigate complexity and reduce operations costs. Machine learning will choose radio configurations, adjust for impairments and failures. Neuromorphic processors will address the power requirements that traditional computing architectures now struggle to meet.

The expected TRL for proposals is 4-6.

References:

- Several reference papers that have been published at the Cognitive Communications for Aerospace Applications (CCAA) workshop are available at: http://ieee-ccaa.com.
- A survey paper on neuromorphic computing and neural networks in hardware: https://arxiv.org/pdf/1705.06963
- References for deep neural network and neuromorphic computing can be found in IEEE, ACM, and conference archives such as NIPS and ICONS (International Conference on Neuromorphic Systems).