NASA SBIR 2020 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

Scope Title

Neuromorphic Capabilities

Scope Description

The Neuromorphic Processors for In-Space Autonomy and Cognition subtopic specifically focuses on advances in signal and data processing. Neuromorphic processing will enable NASA to meet growing demands for applying artificial intelligence and machine learning algorithms on-board a spacecraft to optimize and automate operations. This includes enabling cognitive systems to improve mission communication and data processing capabilities, enhance computing performance, and reduce memory requirements. Neuromorphic processors can enable a spacecraft to sense, adapt, act and learn from its experiences and from the unknown environment without necessitating involvement from a mission operations team. Additionally, this processing architecture shows promise for addressing the power requirements that traditional computing architectures now struggle to meet in space applications.

The goal of this program is to develop neuromorphic processing software, hardware, algorithms, architectures, simulators and techniques as enabling capability for autonomous space operations. Emerging memristor and other radiation-tolerant devices, which shows potential for addressing the need for energy efficient neuromorphic processors and improved signal processing capability, is of particular interest due to its resistance to the effects of radiation.

Additional areas of interest for research and/or technology development include: a) spiking algorithms that learn from the environment and improve operations, b) neuromorphic processing approaches to enhance data processing, computing performance, and memory conservation, and c) new brain-inspired chips and breakthroughs in machine understanding/intelligence. Novel memristor approaches which show promise for space applications are also sought.

This subtopic seeks innovations focusing on low size, weight and power (SWaP) applications suitable lunar orbital or surface operations, enabling efficient on-board processing at lunar distances. Focusing on SWaP-constrained platforms opens up the potential for applying neuromorphic processors in spacecraft or robotic 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 un-characterized space environments including the Moon and Mars.

Phase I will emphasize research aspects for technical feasibility and show a path toward 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 low-SWaP 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. In order to enable mission deployment, proposed prototypes should include a path, preferably demonstrated, for fault tolerance and mission tolerance.

References

Several reference papers that have been published at the Cognitive Communications for Aerospace Applications (CCAA) workshop are available at: http://ieee-ccaa.com.

Expected TRL or TRL range at completion of the project 4 to 6

Desired Deliverables of Phase II

Prototype, Hardware, Software

Desired Deliverables Description

Phase 2 deliverables should include hardware/software necessary to show how the advances made in the development can be applied to a cubesat, small sat, and rover flight demonstration.

State of the Art and Critical Gaps

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 GSFC. The HPSC, called the Chiplet, contains 8 general purpose processing cores in a dual quad-core configuration. Delivery is expected by December 2022. In a submission to the STMD Game Changing Development (GCD) program, the highest computational capability required by a typical space mission is 35-70 GFLOPS (million fast logical operations per second).

The current SOA does not address the capabilities required for artificial intelligence and machine-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 teraflops (TFLOPS) each -- approximately 3 orders of magnitude above the anticipated capabilities of the HPSC.

Neuromorphic processing offers the potential to bridge this gap through a novel hardware approach. 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 the architecture has demonstrated characteristics that make it well-adapted to the space environment.

Relevance / Science Traceability

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 and are of relevance to lunar return and Mars for autonomous operations, as well as of interest to HEOMD and SMD for in-situ avionics capabilities.