High Performance Computing Success Stories

PROGRAMMING APPROACHES FOR NEUROMORPHIC COGNITIVE COMPUTING

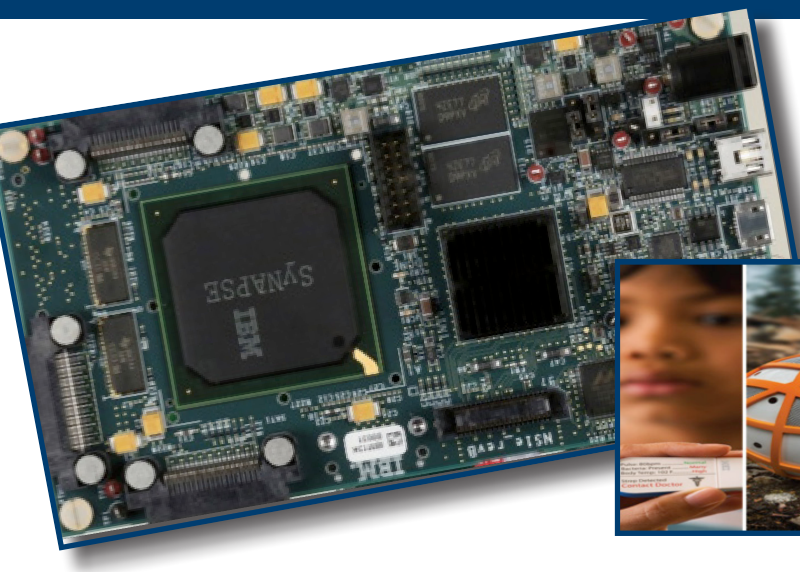

Figure 1: (left) ARL's neuromorphic computing program utilizes the IBM TrueNorth neuromorphic chip.

Figure 2: (below) The low-power real-time computing capabilities of neuromorphic computing will enable devices capable of intelligent data-driven behaviors in power-constrained environments.

Project Description

Neuromorphic computing is an emerging technology that promises intelligent real-time computing at extremely low power, less than 1 watt. Our research focuses on discovering new neuromorphic programming techniques, and computing paradigms that will enable the development of future low-power adaptable cognitive computing systems. Neuromorphic systems are fundamentally incompatible with most of the computing theory, techniques, and infrastructure that have emerged over the last 50 years. Reasonably efficient mechanisms for representing and storing data using neuronal computing principles remain to be identified. The best methods for designing and implementing efficient algorithms are yet to be discovered. We are seeking fundamental approaches for integrating neuromorphic and classical computing

Relevance of Work to DOD

Neuromorphic hardware (Figure 1), holds promise in mobile, autonomous and stationary systems that have complex, intelligent processing requirements in low power applications; however, the programming models for this hardware are underdeveloped. We have a framework for integrating two methods of programming neuromorphic hardware. It will greatly expand the class of problems that can run on neuromorphic hardware and provide a path to more advanced cognitive computing (Figure 2). Our one-of-a-kind research platform with 16 IBM NS1E TrueNorth neuromorphic computing systems (Figure 3) is capable of performing real-time tasks on a low power mobile computing platform. We now have a state-of-the-art facility for training and testing deep neural networks for vision, audio, multi-modal integration, and other classification problems. Examples are object identification, facial recognition, and iris recognition.

Computational Approach

Our approach for writing neuromorphic programs builds on the Integrated Connectionist/Symbolic architecture and the Neuro Engineering Framework. These approaches have developed a method of encoding data structures and procedures in a neural based spiking framework. Neuro Engineering Framework has shown success at capturing a wide range of psychological tasks from picture copying to analogical reasoning. We are integrating this framework with the IBM TrueNorth neuromorphic hardware and are developing a cognitive computing program for simple tasks, such as playing blackjack, to allow us to integrate learning from data with programming by construction to solve a task. The system will learn to recognize the cards on the table and encode player and dealer hands. A hardcoded strategy uses the hand information to make a decision. We also store observed cards in neuromorphic memory to enable better decision making as the game progresses.

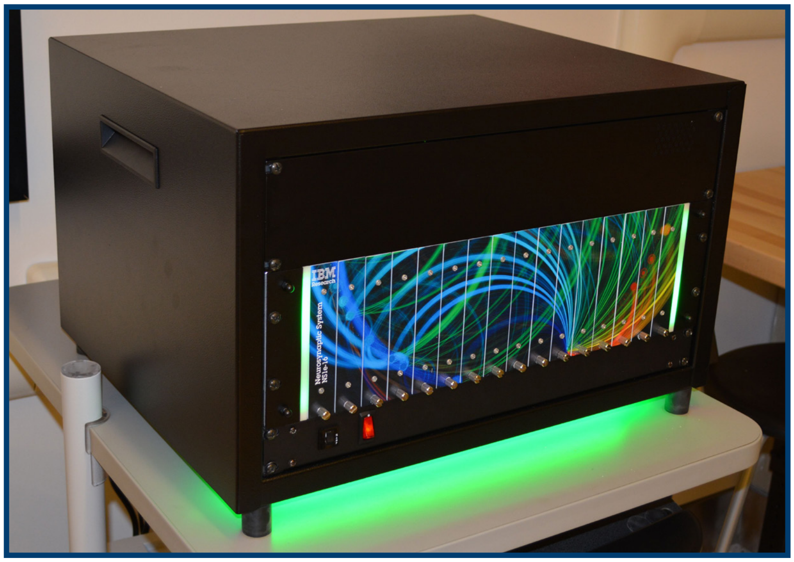

Figure 3: IBM 16 System TrueNorth Cluster

Figure 4:
Data flow for machine learning handwriting analysis.

Results

- Successfully trained a network to classify cards and deployed it on a TrueNorth chip, performing with approximately 90% accuracy (Figure 4)
- A framework was created to integrate the trained network with a strategy to produce a subsequent decision.
- Methodologies were developed to code and test cognitive computing programs that can be reused in other applications.
- Successfully demonstrated an end-to-end solution based on neuromorphic samples for recognizing handwritten numbers (this will be jointly published with IBM co-authors).

Future

We continue collaborating with Lawrence Livermore National Laboratory to benefit from their advancements in deploying neural networks on neuromorphic hardware. We are beginning work with the University of Tennessee-Knoxville and Oak Ridge National Laboratory in exploring a simpler yet more flexible neuron structure, and in using evolutional algorithms for programming the systems. We are collaborating with researchers from Purdue University to utilize neuromorphic computing with mobile sensors to discover different agents within an environment. We are seeking collaborations to apply our expertise and systems to intelligent sensors that reduce power and bandwidth requirements by utilizing neuromorphic computing to perform intelligent real-time processing directly at the sensor. We are also interested in applications to adaptive autonomous systems that receive and integrate information from a distributed array of deployed intelligent sensors. We are exploring ways to create a more flexible framework to expand the number of applications.

Contact Information

Dr. Manny Vindiola
Army Research Laboratory
Computational and Information Sciences Directorate
manuel.m.vindiola.civ@mail.mil 410.278.9151

Co-Investigators

Dr. John Monaco, Jamie Infantolino & Brian Dawson
Army Research Laboratory
Computational and Information Sciences Directorate

Professor Kaushik Roy
Purdue University