From:	Andrew Dienstfrey
To:	Shainline, Jeff (Fed)
Cc:	Liu, Yi-Kai (Fed)
Subject:	a few thoughts for the "theory" component of the neuromorphic work
Date:	Thursday, March 9, 2017 11:51:26 AM

Hi Jeff,

Yi-Kai and I are working on developing research ideas/goals/language to support the neuromorphic proposal. A few thoughts:

Neuromorphic SI

What are the fundamental units of a neuromorphic computer? Traditional computers have computational units of bits on which one performs arithmetic, and information storage units of bytes. These appear to be the same thing but this is a symptom of our upbringing. Distinctions arise in physical models of computation. Think, for example, of differences in the use of quantum systems to encode information for key exchange vs. using quantum systems to factor. Running with this further, to spec a classical computer one talks: numerical precision, memory size, floating-point operations per second, and memory bandwith. To get NIST-y, SI units for computers are: b, B, b/s (or flops), and B/s. What are analogous concepts for neuromorphic architectures?

Neuro-Thermo

Can we construct an ensemble theory for the operation of a full-scale neuromorphic computer? What we are thinking here is something like a "statistical mechanics/thermodynamics for a neuromorphic computer". In more detail, this project proposes to build systems of interconnected neurons. At a fundamental level, one requires models of (1) individual neuron states, and (2) neuron-neuron interaction dynamics. Developing models for each physical platform will require iteration between measurement and theory. With validated models in hand, one can consider large ensembles and search for average response characteristics: small degrees of freedom average out, the system evolves on a lower-dimensional manifold, etc... Think of the passage from Netwonian mechanics of minimally interacting atoms, to the ideal gas law. Because the neuromorphic computer is dynamical system, some analog to this might exist.

Note: Whereas a full-blown thermodynamic theory represents a "grand challenge", model construction of the atomistic building blocks is both more assured and nicely ties together measurement and theory.

Computational Complexity

Questions of computational complexity, as in, "What class of problems are solved efficiently by neuromorphic computers?" are interesting but too hard for now. You and I discussed this in the hallway the other day and decided the same. However, as you suggested, we could consider gathering collections of trained neural networks of different types and measure their success on problems of different classes. The idea is to build an empirical dataset which could be used to validate the complexity theories of the future.

These are our thoughts for now. Yi-Kai and I exchanged a few references. We plan to think on it some more and circle back next week.

--Andrew

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