EVENT-BASED NEUROMORPHIC SYSTEMS

Edited by

Shih-Chii Liu
Tobi Delbruck
Giacomo Indiveri
Adrian Whatley
Rodney Douglas
University of Zürich and ETH Zürich
Switzerland

WILEY

Foreword

The motivation for building neuromorphic systems has roots in engineering and neuroscience. On the engineering side, inspiration from how the brain solves complex problems has led to new computing algorithms; however, the goal of reverse engineering the brain is a difficult one because the brain is based on a biological technology that was evolved and not designed by human engineers. On the neuroscience side, the goal is to understand brain function, which is still at an early stage owing the extremely heterogeneous and compact nature of neural circuits. Neuromorphic systems are a bridge between these two ambitious enterprises. The lessons learned from building devices based on neural architectures are providing new engineering capabilities and new biological insights.

Building neuromorphic VLSI chips and perfecting asynchronous event-based communication between them has required a generation of talented engineering scientists. These people were inspired by Carver Mead and his 1989 landmark book on *Analog VLSI and Neural Systems*. I was a Wiersma Visiting Professor of Neurobiology at the California Institute of Technology in 1987 and attended 'Carverland' group meetings. Neuromorphic engineering was still in its infancy, but the strengths and weaknesses of the technology were already apparent. The promise of a new massively parallel, low-power, and inexpensive computing architecture was balanced by the technical challenges of working with the transistor mismatch and noise that plagued analog VLSI chips. The brain was an existence proof that these problems could be overcome, but it took much longer time than expected to find the practical solutions which are discussed in detail in *Event-Based Neuromorphic Systems*.

At about the same time that neuromorphic systems were introduced, the neural network revolution was getting underway based on simulations of simplified models of neurons. The two-volume 1986 book on *Parallel Distributed Processing*[1] had chapters on two new learning algorithms for multilayer network models, the backpropagation of errors and the Boltzmann machine. These networks were learned from examples, in contrast to engineered systems that were handcrafted. The increase in overall computing power by a factor of a million over the last 25 years and the large sizes of data sets now available on the Internet have made deep learning in hierarchies of simple model neurons both powerful and practical, at least when power is unlimited. The Neural Information Processing Systems (NIPS) meeting in 2013 had 2000 attendees and the applications of machine learning ranged from vision systems to advertisement recommender systems.

[1] Rumelhart DE and McClelland JL. 1986. *Parallel Distributed Processing*. MIT Press, Cambridge, MA.

Systems neuroscience has made progress one neuron at a time since single cortical neurons were first recorded in 1959. In the last 10 years, new optical techniques have made it possible to record simultaneously from hundreds of neurons and allowed researchers to both selectively stimulate and suppress the spikes in subtypes of neurons. Analytic tools are being developed to explore the statistical structure of brain activity in large populations of neurons, and reconstruction of the connectivity of the brain from electron micrographs, aided by machine learning, is producing intricate wiring diagrams. The goal, which is far from yet realized, is to use these new tools to understand how activity in neural circuits generates behavior.

The next 25 years could be a golden period as these three interacting areas of research in neuromorphic electronic systems, artificial neural networks, and systems neuroscience reach maturity and fulfill their potential. Each has an important role to play in achieving the ultimate goal, to understand how the properties of neurons and communications systems in brains give rise to our ability to see, hear, plan, decide, and take action. Reaching this goal would give us a better understanding of who we are and create a new neurotechnology sector of the economy with far-reaching impact on our everyday lives. *Event-Based Neuromorphic Systems* is an essential resource for neuromorphic electrical engineers pursuing this goal.

Terrence Sejnowski
La Jolla, California
December 15, 2013