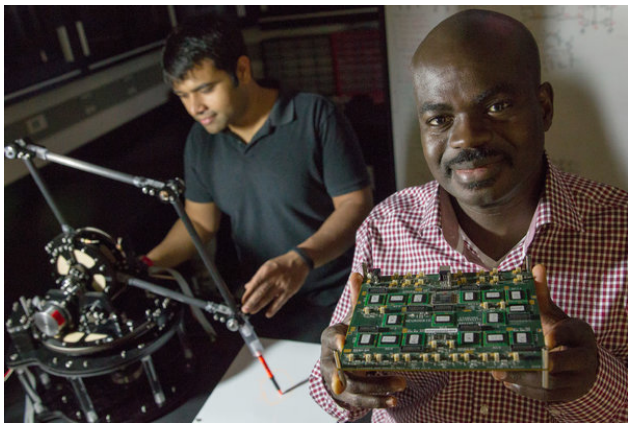
Institute for Neural Computation

2015 ROCKWOOD MEMORIAL LECTURE



Dr. Kwabena Boahen
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Neuromorphic Chips: Combining Analog Computation with Digital Communication

Location: San Diego Supercomputer Center Auditorium, Floor B-2, 10100 Hopkins Dr., La Jolla, CA 92093
Date/Time: Friday, April 24, 4:00-5:30pm

I'll argue that combining analog computation with digital communication can effectively combat increased heterogeneity (a.k.a., mismatch) and stochasticity (a.k.a., noise) as transistors scale down to a few nanometers. Intriguingly, the brain adopts precisely such a hybrid approach to combat the heterogeneity and stochasticity that arise from its nanoscale ion-channels' probabilistic expression and operation. Neurons' dendritic trees combine thousands of graded potentials to produce an output (c.f., analog computation) that their axonal arbors transmit to thousands of other neurons in the form of all-or-none action potentials (c.f., digital communication).

To support my argument, I'll present a Kalman-filter-based brain-machine interface and a three-degree-of-freedom robot-arm controller implemented on a neuromorphic chip that combines analog computation with digital communication much like the brain does. The neuromorphic chip's spiking-neuron network was configured to perform these operations using the Neural Engineering Framework (NEF), a formal method for approximating arbitrary nonlinear dynamical systems with networks of spiking neurons. Using NEF, you can, for example, get a spiking-neuron network to perform temporal integration or rotate an n-dimensional vector by a given angle. NEF proved robust to heterogeneity introduced by transistor mismatch as well as stochasticity introduced by probabilistic spike delivery. As an added bonus, NEF produced interconnection-weight matrix with low-rank—it could be stored using an order-of-magnitude less memory.

Kwabena Boahen received the B.S. and M.S.E. degrees in electrical and computer engineering from the Johns Hopkins University, Baltimore, MD, both in 1989 and the Ph.D. degree in computation and neural systems from the California Institute of Technology, Pasadena, CA, in 1997. He was on the bioengineering faculty of the University of Pennsylvania from 1997 to 2005, where he held the first Skirkanich Term Junior Chair. He is presently a Professor in the Bioengineering Department of Stanford University, with a courtesy appointment in Electrical Engineering. He directs Stanford's *Brains in Silicon* Laboratory, which develops silicon integrated circuits that emulate the way neurons compute, linking the seemingly disparate fields of electronics and computer science with neurobiology and medicine.

Prof. Boahen's contributions to the field of neuromorphic engineering include a silicon retina that could be used to give the blind sight, a self-organizing chip that emulates the way the developing brain wires itself up, and a specialized hardware platform (*Neurogrid*) that simulates a million cortical neurons in real-time—rivaling a supercomputer while consuming only a few watts. He has received several distinguished honors, including a Fellowship from the Packard Foundation (1999), a CAREER award from the National Science Foundation (2001), a Young Investigator Award from the Office of Naval Research (2002), a Pioneer Award from the National Institutes of Health (2006), and a Transformative Research Award from the National Institutes of Health (2011). His 2007 TED talk, "A computer that works like the brain", has been viewed half-a-million times.

The Rockwood Memorial Lectures are endowed by Mr. and Mrs. Jerome Rockwood in memory of their late son, Paul, who received a B.S. in Computer Science from UCSD in 1980 and then obtained a second degree B.A. in Psychology in 1981. In 1983 he started a company, Integral Solutions, to develop a universal language translation, but died tragically in a mountaineering accident before he could fulfill his promise.