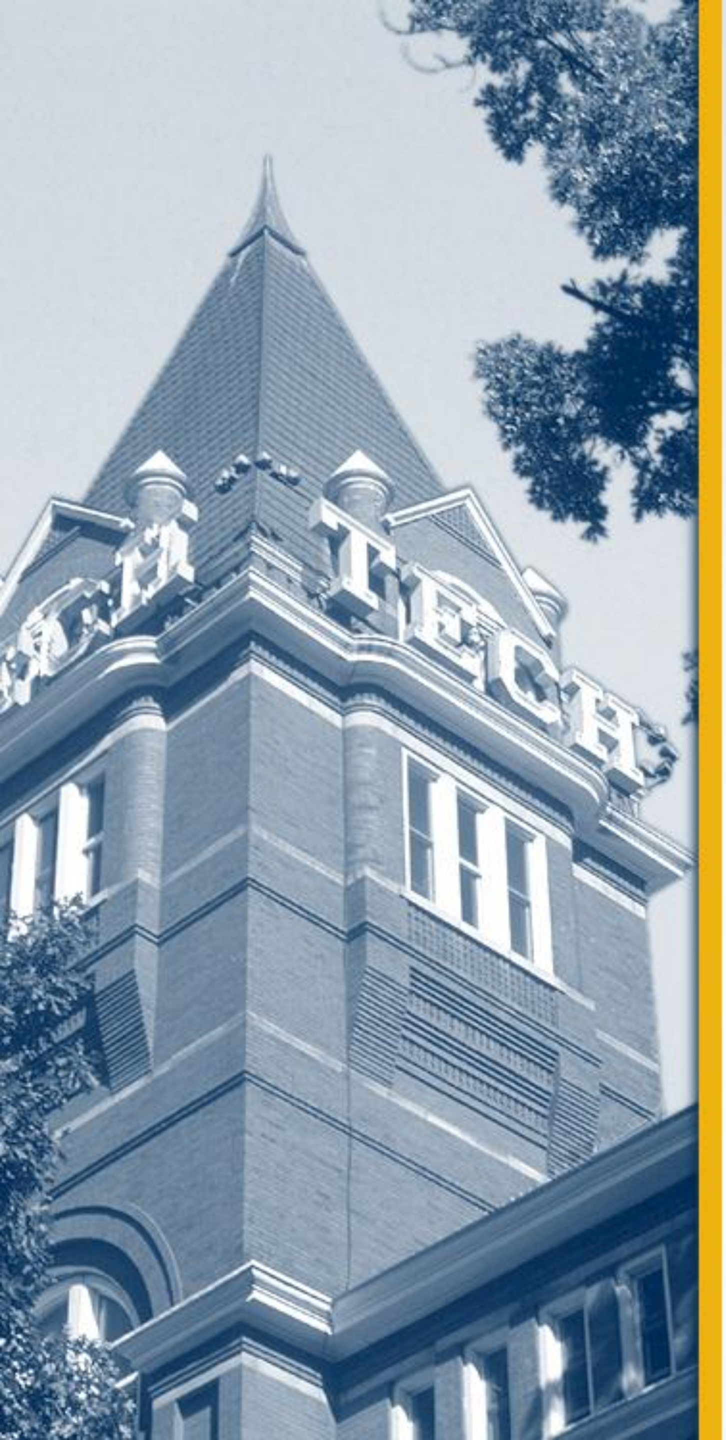


Neuromorphic Computing

Mario Quispe

Georgia Institute of Technology

ECE 3080

April 12, 2011

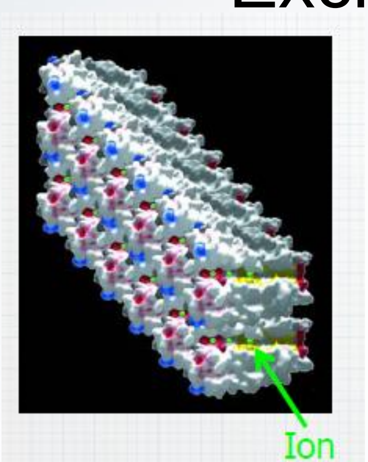
We Will Be Looking at…

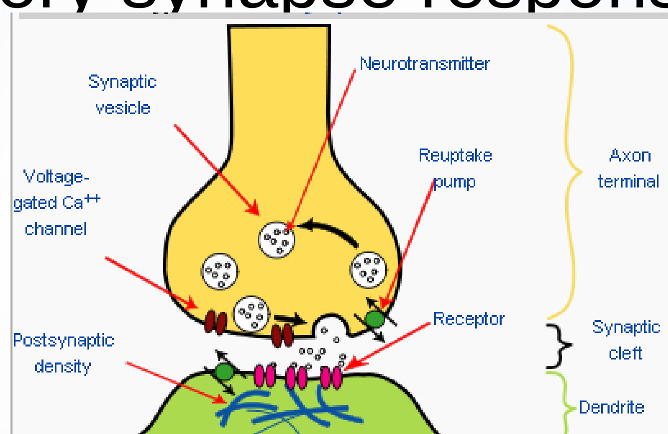
- Basic concept of neuromorphic computing
- Incentive behind neuromorphic computing
- Facilitation of technology
  - Architecture of Neurogrid
  - Neuromorphic vision chips
  - Complementary Oxide Memristor
- Barriers preventing advancement

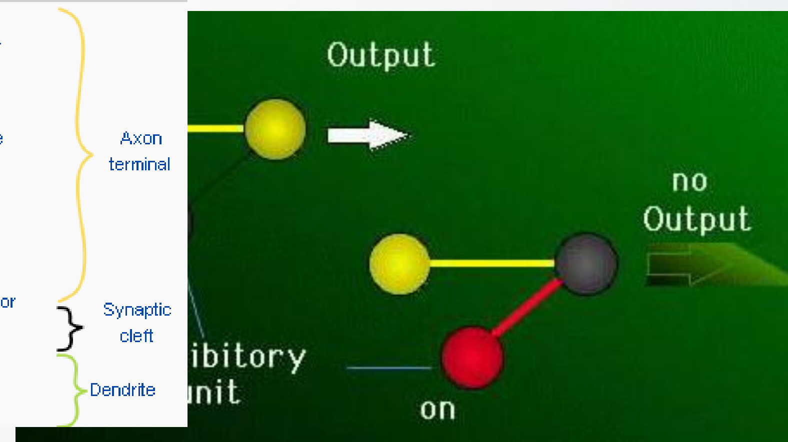
Georgia Tech

First…

- Neuron - axon and dendrite
- Synapses:
  - Chemical/Electrical
    - Inhibitory synapse response
    - Excitatory synapse response







What is neuromorphic computing?

- How information is transferred in the brain:
  - Neurons
  - Ion Channel
  - Neural Networks
- Parallel neural networks

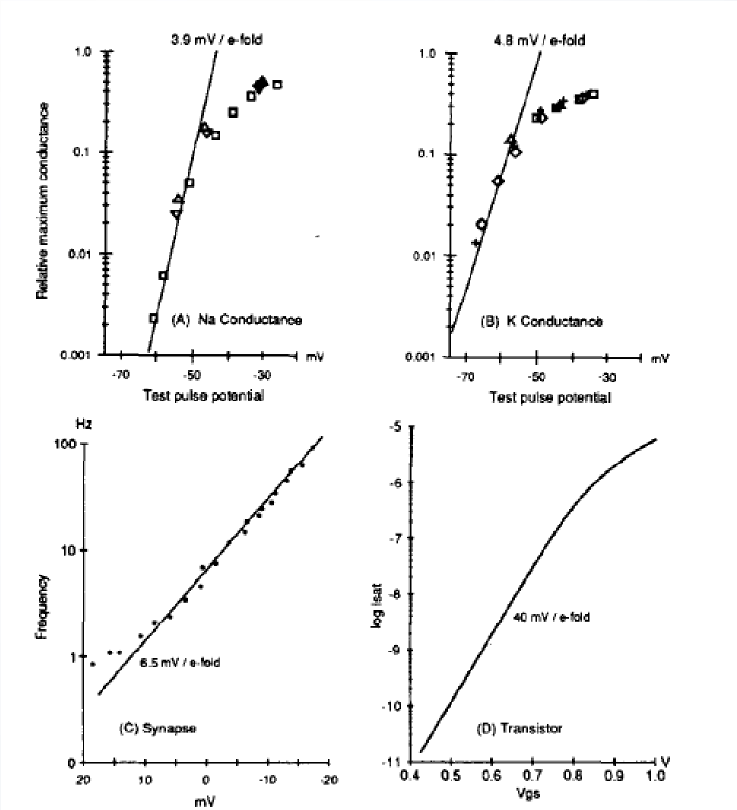


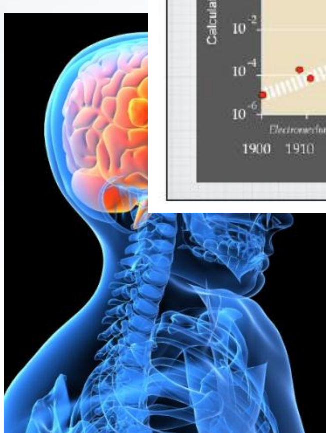
Fig. 1 Current–voltage plots for several important devices

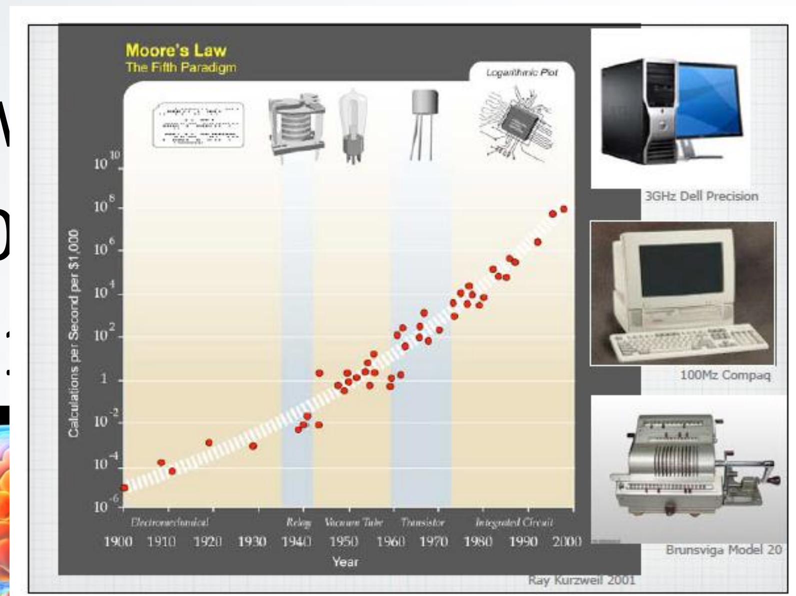
Georgia Tech

Advantages

- Modern integrated circuits cannot downsize anymore

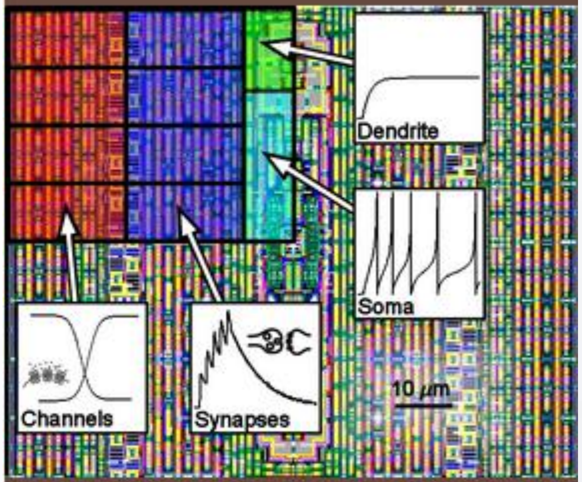
- Less pow… computing
  - 200,000…
  - 10 W – 1… ns/s





Neurogrid

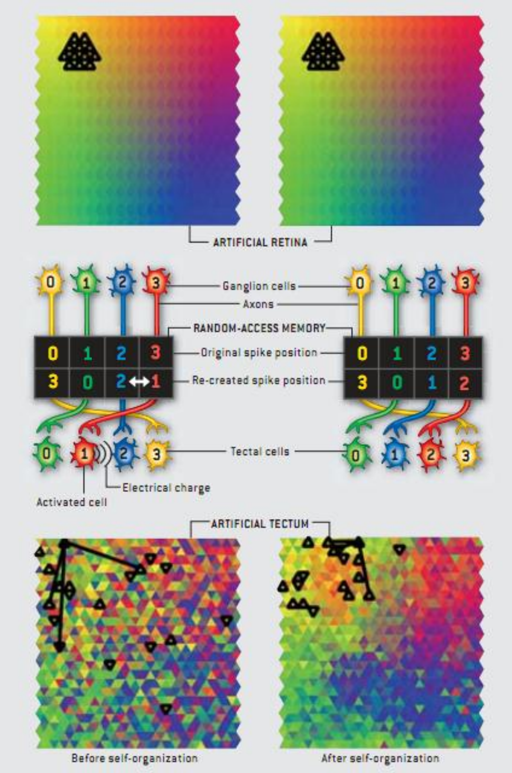
- Simulation of biological brain
- Analog computation
- Digital communication



Neurogrid's Neuron
Occupying 41.6x50.0 sq-μm, 337 transistors model a soma (cyan), a dendrite (green), four synapse populations (blue), and four ion-channel populations (red). The ion-channels drive the dendrite, which drives the soma; the synapses drive either one—or an ion-channel population—modeling voltage-dependent or modulatory synapses [John Arthur 2009].

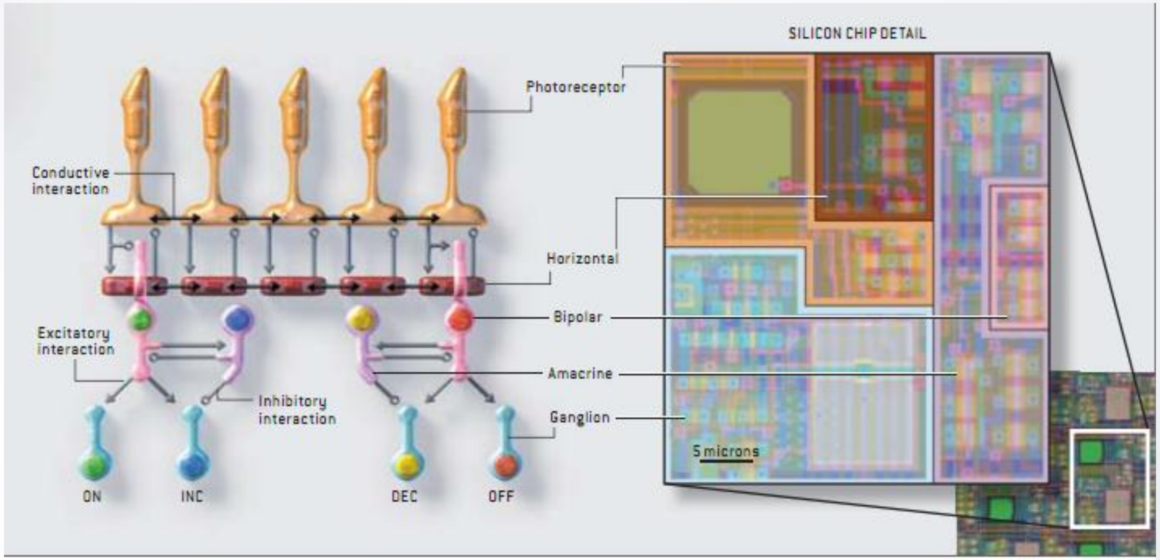
Vision Chips

- Simulation of retina in silicon chip
- How visual field is interpreted to the brain
- Emulation of the retina



The challenge

- Retina cell
  - 0.5 mm thickness
  - 0.5 grams
  - 0.1 W



Using memristors

- Able to emulate excitatory/inhibitory synapse
- Change in voltage – rapid recovery of resistance
- Maintain resistance

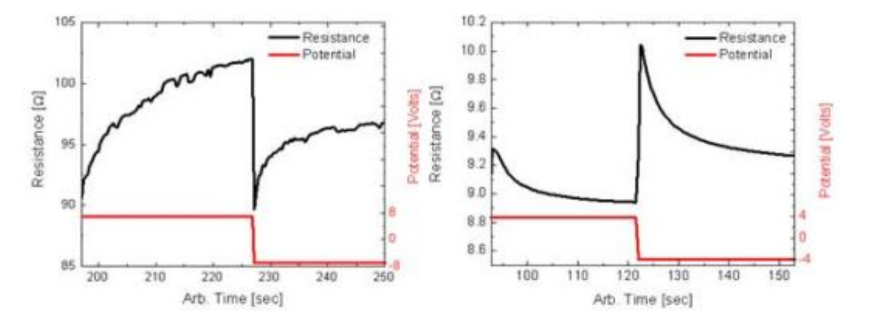
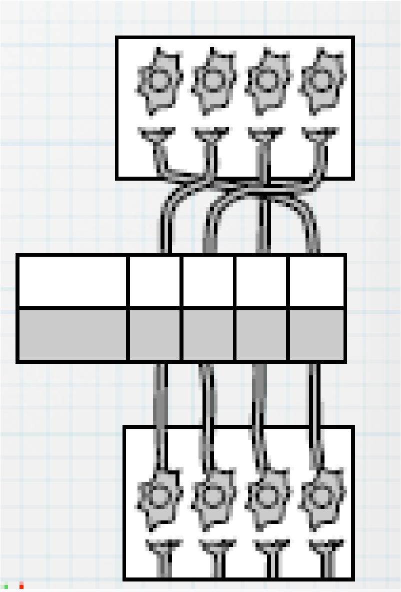


Figure 1 Large 40 um $LiNbO_2$ memristors are the only known macroscopic demonstration of memristance. Having both n-type (left) and p-type (right) operation allows memristors that have complementary behavior (increase/decreasing resistance with applied voltage) and suggests the ionic/electronic equivalent of CMOS circuitry may be possible. Resistors show minimal hysteresis and zero set/reset voltage (i.e. a truly analog memristor).

Work in progress…

- Today’s computers rely on serial connections
- Relatively new branch for computing



Sources

- Boahen, Kwabena. “Making a computer that works like the brain.” 30 July 2008. Online video clip. Youtube. Accessed April 4, 2011.
- Koch, Christof, Mathur, Bimal “Neurmorphic vision chips.” IEEE Xplore May 1996.
- “Neurogrid.” Brains in Silicon. 2006. Stanford University. <http://www.stanford.edu/group/brainsinsilicon/index.html>
- Mead, Carver “Neuromorphic Electronic Systems.” IEEE October 1990.
- Calley, W. Laws, Doolittle, Alan W. and Henderson, Walter. “COM Technology Facilitating both Inhibitory and
- Excitatory Synapses for Potential Neuromorphic Computing Applications.” IEEE December 2009.