Systems Inspired by the Brain

A Brain Built From Atomic Switches Can Learn

Problem:

- Today's circuits are inefficient
- Limits exist to miniaturization and efficiency
- Moore's Law: "the observation that the number of transistors in a dense integrated circuit doubles approximately every two years"
    - Rate currently slowing to a halt

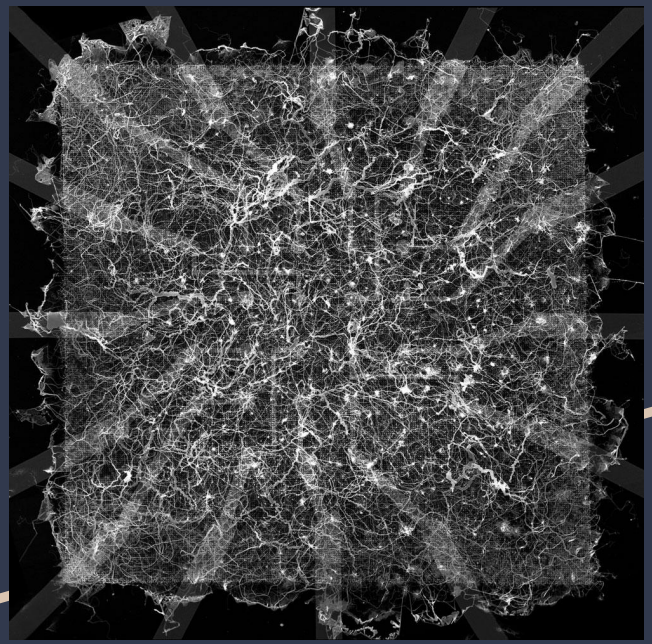
Why The Brain?

- The Brain - tremendously energy efficiency
  - Power consumption: one 20-watt light bulb
- K computer - supercomputer in Kobe, Japan
  - Power consumption: 10,000 light bulbs
- Took 40 minutes to simulate a second of 1% of human brain activity

Solution

- Create systems that mimic the brain's structure
- Typically neural networks
- Different approach taken at the California NanoSystems Institute @ UCLA
  - Researches Adam Steig and Jim Gimzewski
  - "Inspired by the brain to generate the properties that enable to brain to do what it does"

What is it?

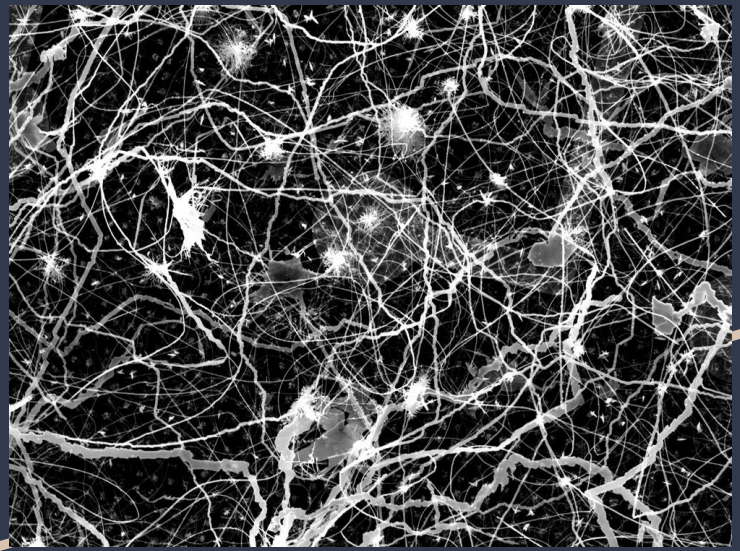


- 2mm by 2mm mesh of nanowires
- Connected with artificial synapses
- Atomic Switches

Atomic Switches

- Nanoscale circuit element
- Behavior observed to be synapse-like
- Controlled using ions
- Several types

Similarities to the Brain



- Disorganized structure
- Ability to learn
- Power-Law behavior
  - “Criticality” is possible
  - State between order and chaos indicating maximum efficiency has been achieved
- Ability to create a “sleeping” state in system

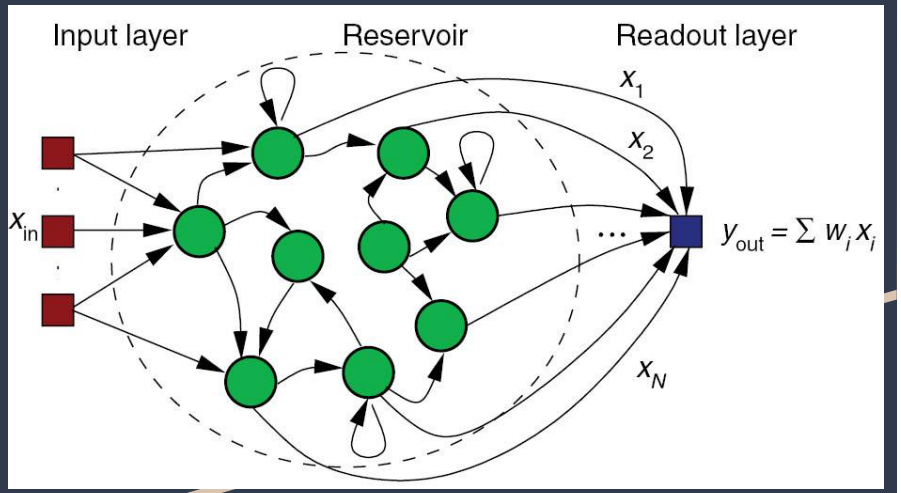
Benefits

- Able to perform simple learning and logic operations
- Clean out unwanted noise from signals
- Switches are able to
  - Remember their history
  - Interact with each other
- No need for software
  - Training
- Fast
  - Doesn’t separate processing and memory

Possible Applications

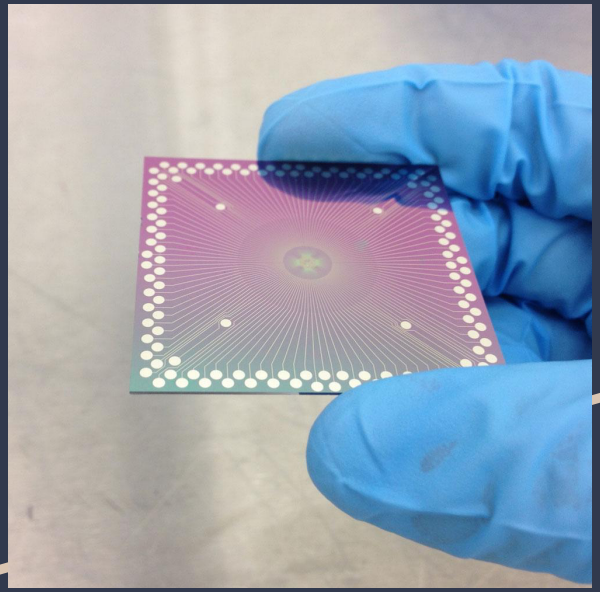
- Voice or Image Recognition
  - Due to its ability to clean out unwanted noise from signals
- Align structural complexity of system with that which is being modeled
- Reservoir Computing

Reservoir Computing



- Extension of neural networks
  - Machine Learning
  - AI
- Input is fed into a “reservoir”
- “Readout” mechanism looks at the reservoir and gives corresponding output
- In this case:
  - One input → many different outputs (“reservoir”)
  - Combined to create desired computation

Challenges



- Finding the right inputs and outputs
- Encoding these inputs and outputs
- Training the device
- Relatively new technology

Works Cited

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