



UC Berkeley  
Computer Science  
Lecturer SOE  
Dan Garcia

# CS39N The Beauty and Joy of Computing

## Lecture #14 Future of Computing

2009-11-23

### IBM SIMULATES CAT BRAIN

IBM has built a computer with 147,456 processors and 144 terabytes of memory that simulates a cat's cerebral cortex. It runs 1/100x the speed of an actual cat's brain. They want to see how "thoughts are formed and how the neurons and synapses work together". In 10 years they'll be able to simulate human brain.

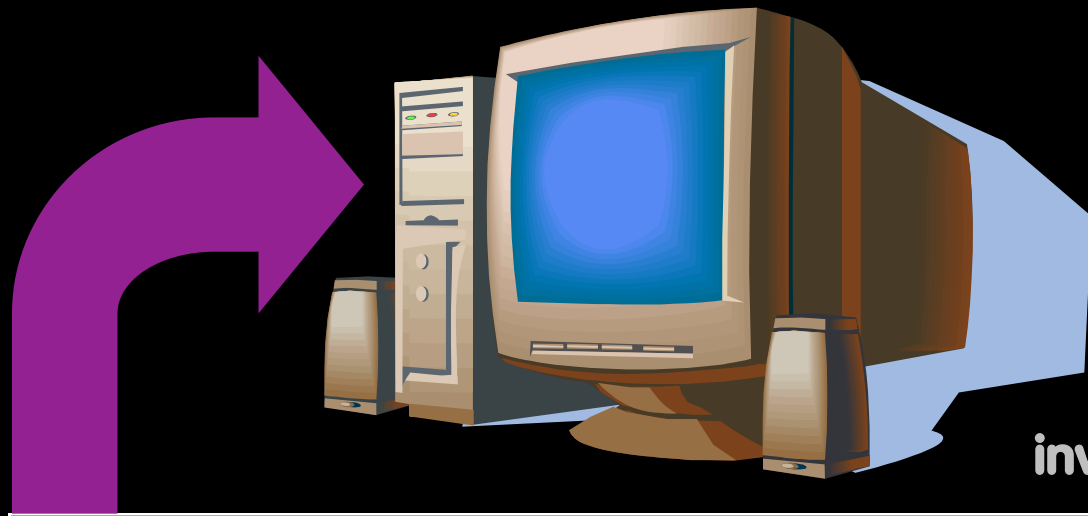


# Lecture Overview

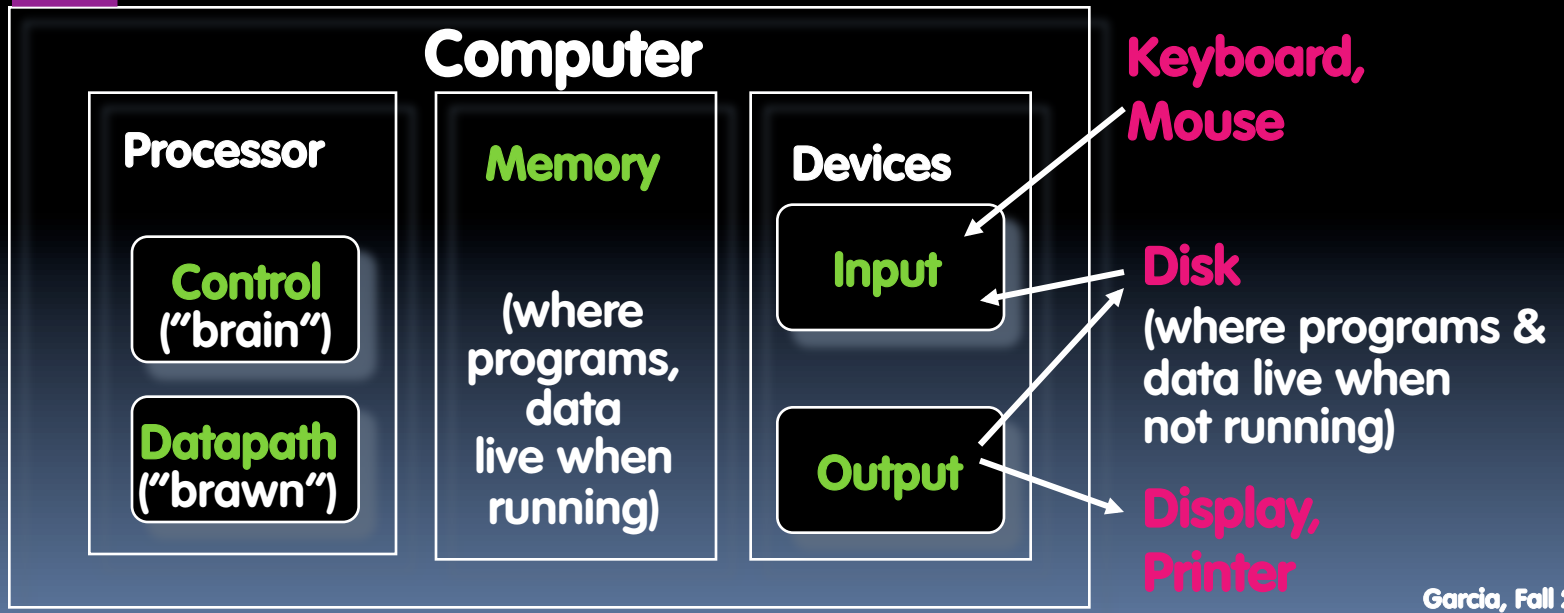
- **Where will today's computers go?**
  - 5 parts of a computer
  - Moore's Law
  - Technology growth
- **Quantum Computing**
- **DNA Computing**
- **Biological Machines**
- **Smart Grid + Energy**



# 5 Components of any Computer

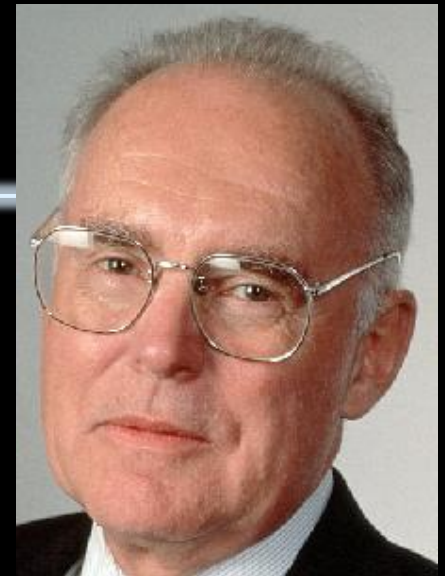


John von Neumann invented this architecture



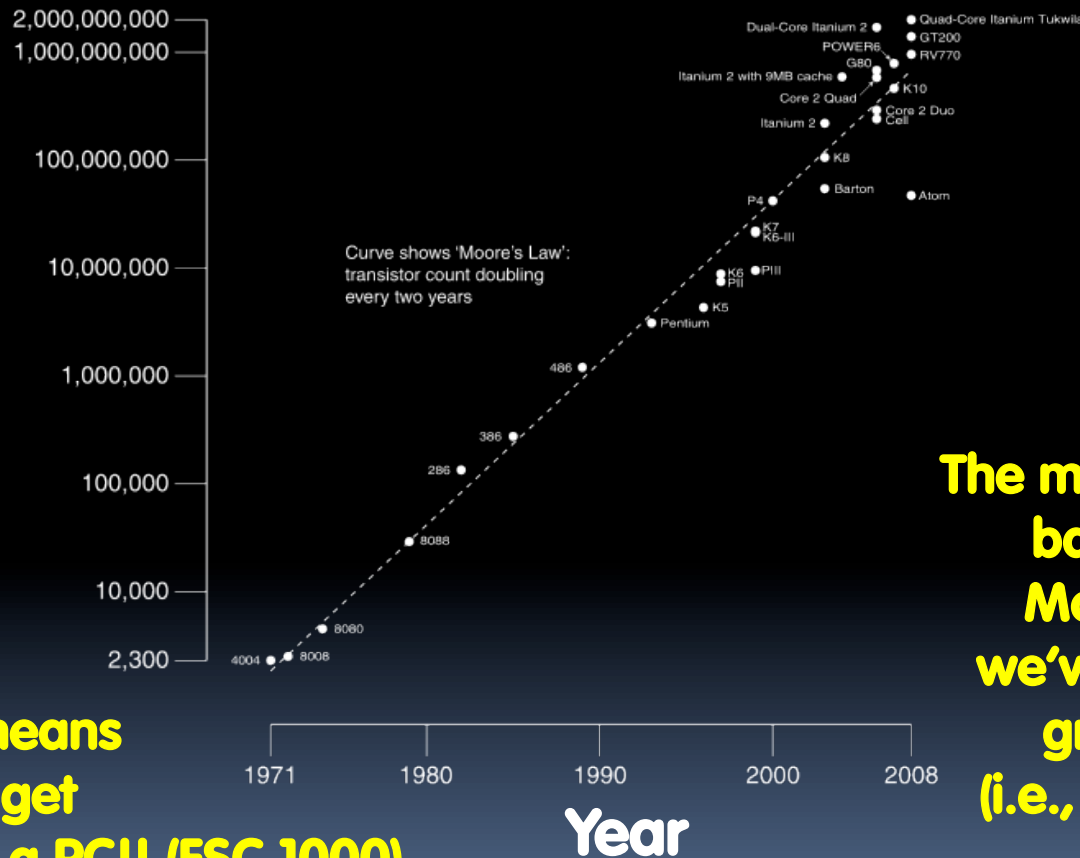
# Moore's Law

Predicts: 2X Transistors / chip every 2 years



Gordon Moore  
Intel Cofounder  
B.S. Cal 1950!

# of transistors on an  
integrated circuit (IC)



The GPU  
movement means  
now we can get  
1 Teraflop on a PC!! (ESC 1000)

The multi-core movement is  
based on the belief that  
Moore's Law is over and  
we've got to go parallel to  
grow in performance...  
(i.e., era of the single-core  
processor is over)



[en.wikipedia.org/wiki/Moore's\\_Law](http://en.wikipedia.org/wiki/Moore's_Law)

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# Computer Technology - Growth!

## ■ Processor

- Speed 2x / 2 years (since '71)
- 100X performance last decade
- When you graduate: 4 GHz, 32 Cores

## ■ Memory (DRAM)

- Capacity: 2x / 2 years (since '96)
- 64x size last decade.
- When you graduate: 128 GibiBytes

## ■ Disk

- Capacity: 2x / 1 year (since '97)
- 250X size last decade.
- When you graduate: 8 TeraBytes

Kilo ( $10^3$ ) & Kibi ( $2^{10}$ )



Mega ( $10^6$ ) & Mebi ( $2^{20}$ )



Giga ( $10^9$ ) & Gibi ( $2^{30}$ )



Tera ( $10^{12}$ ) & Tebi ( $2^{40}$ )



Peta ( $10^{15}$ ) & Pebi ( $2^{50}$ )



Exa ( $10^{18}$ ) & Exbi ( $2^{60}$ )



Zetta ( $10^{21}$ ) & Zebi ( $2^{70}$ )



Yotta ( $10^{24}$ ) & Yobi ( $2^{80}$ )



# Kilo, Mega, Giga, Tera, Peta, Exa, Zetta, Yotta

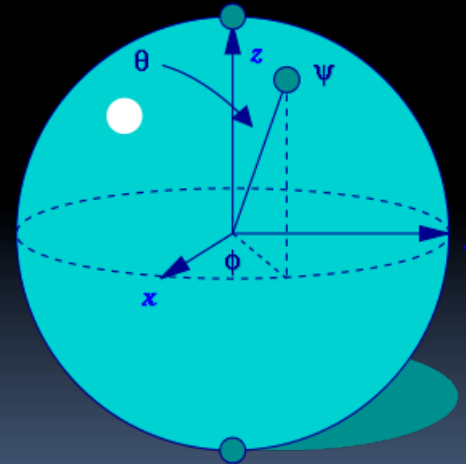
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- Kid meets giant Texas people exercising zen-like yoga. – Rolf O
- Kind men give ten percent extra, zestfully, youthfully. – Hava E
- Kissing Mentors Gives Testy Persistent Extremists Zealous Youthfulness. – Gary M
- Kindness means giving, teaching, permeating excess zeal yourself. – Hava E
- Killing messengers gives terrible people exactly zero, yo
- Kindergarten means giving teachers perfect examples (of) zeal (&) youth
- Kissing mediocre girls/guys teaches people (to) expect zero (from) you
- Kinky Mean Girls Teach Penis-Extending Zen Yoga
- Kissing Mel Gibson, Teddy Pendergrass exclaimed: “Zesty, yo!” – Dan G
- Kissing me gives ten percent extra zeal & youth! – Dan G (borrowing parts)



# Quantum Computing (1)

- Proposed computing device using quantum mechanics
  - This field in its infancy...
- Normally: **bits**, which are either 0 or 1
- Quantum: **qubits**, either 0, 1 or “quantum superposition” of these
  - This is the key idea
- If you have 2 bits, they’re in exactly one of these:
  - 00, 01, 10 or 11
- If you have 2 qubits, they’re in **ALL** these states with varying probabilities



A Bloch sphere is the geometric representation of 1 qubit

[en.wikipedia.org/wiki/Quantum\\_computer](http://en.wikipedia.org/wiki/Quantum_computer)

[www.youtube.com/watch?v=Xq4hkzGZskA](http://www.youtube.com/watch?v=Xq4hkzGZskA)

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# Quantum Computing (2)

- **Imagine a problem with these four properties:**
  - The only way to solve it is to guess answers repeatedly and check them,
  - There are  $n$  possible answers to check,
  - Every possible answer takes the same amount of time to check, and
  - There are no clues about which answers might be better: generating possibilities randomly is just as good as checking them in some special order.
- ...like trying to crack a password from an encrypted file
- **A normal computer**
  - would take (in the worst case)  $n$  steps
- **A quantum computer**
  - can solve the problem in steps proportional to  $\sqrt{n}$
- **Why does this matter?**





# Quantum Computing (3)

- Say the password is exactly 72 bits (0/1)
- That's  $2^{72}$  possibilities
- Let's say our Mac lab attacked the problem
  - 30 machines/lab \* 8 cores/machine \* 3 GHz (say 3 billion checks per second/core)
  - = 720,000,000,000 checks/sec/lab
  - = 720 Gchecks/sec/lab
- Regular computers
  - $2^{72}$  checks needed / 720 Gchecks/sec/lab
  - ≈ 6.6 billion sec/lab
  - ≈ **208 years/lab**
- 72-qubit quantum computers in time  $\propto$  to  $\sqrt{2^{72}} = 2^{36}$ 
  - $2^{36}$  checks needed / 720 Gchecks/sec/lab
  - ≈ **0.1 sec/lab**



# DNA Computing

- Proposed computing device using DNA to do the work
  - Take advantage of the different molecules of DNA to try many possibilities at once
  - Ala parallel computing
  - Also in its infancy
- In 2004, researchers claimed they built one
  - Paper in "Nature"



[en.wikipedia.org/wiki/DNA\\_computing](http://en.wikipedia.org/wiki/DNA_computing)

# Biological Machines

- Michel Maharbiz and his team at Cal have wired insects (here a giant flower beetle) and can control flight
  - Implanted as Pupa
- Vision
  - Imagine devices that can collect, manipulate, store and act on info from environment



# Smart Grid + Energy

- Arguably the most important issue facing us today is climate change
- Computing can help
- Old: generators “broadcast” power
- New: “peer-to-peer”, with optimal routing
  - From: ability (to power) To according to need
- Energy
  - Computing helps with climate modeling and simulation
  - “Motes”, or “Smart dust” are small, networked computing measurement devices
    - E.g., could sense no motion + turn lights off



# Summary

- What a wonderful time we live in; we're far from done
  - What about privacy?
- Find out the problem you want to solve
  - Computing can and will help us solve it
- We probably can't even imagine future software + hardware breakthroughs

