CS10
The Beauty and Joy of Computing

Lecture #8 : Concurrency

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AT A RECENT FIRESIDE CHAT…

Nvidia CEO Jen-Hsun Huang said: "whatever capability you think you have today, it's nothing compared to what you're going to have in a couple of years … due to supercomputers in the cloud". Now, cloud computing does what you could do on your PC. Imagine 40,000 times that!

www.theregister.co.uk/2010/09/24/huang_muses_at_gtc/

Happy Confucius Day!

Knowledge is recognizing what you know and what you don't.

I hear and I forget.
I see and I remember.
I do and I understand.

Concurrency & Parallelism, 10 mi up…

Intra-computer

- Today's lecture
- Multiple computing "helpers" are cores within one machine
- Aka "multi-core"
  - Although GPU parallism is also "intra-computer"

Inter-computer

- Week 12's lectures
- Multiple computing "helpers" are different machines
- Aka "distributed computing"
  - Grid & cluster computing

Anatomy: 5 components of any Computer

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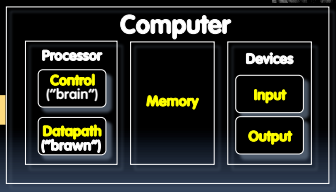
John von Neumann invented this architecture



a) Control
b) Datapath
c) Memory
d) Input
e) Output

What causes the most headaches for SW and HW designers with multi-core computing?

But what is INSIDE a Processor?

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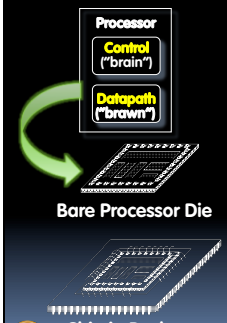
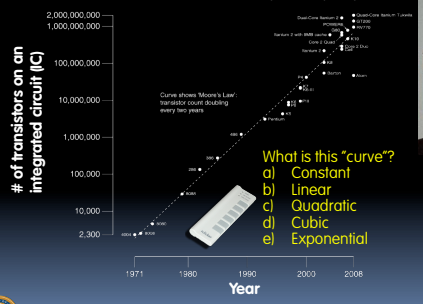


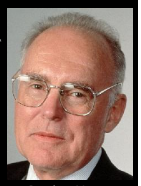
- Primarily Crystalline Silicon
- 1 mm – 25 mm on a side
- 2009 "feature size" (aka process) ~ 45 nm = 45 x 10^{-9} m (then 32, 22, and 16 [by yr 2013])
- 100 - 1000M transistors
- 3 - 10 conductive layers
- "CMOS" (complementary metal oxide semiconductor) - most common
- Package provides:
  - spreading of chip-level signal paths to board-level
  - heat dissipation.
- Ceramic or plastic with gold wires.

Moore's Law

en.wikipedia.org/wiki/Moore's_law

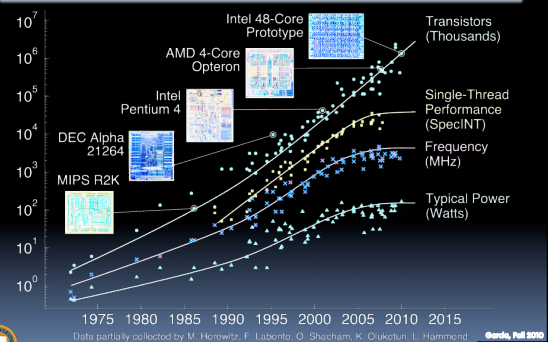
Predicts: 2X Transistors / chip every 2 years



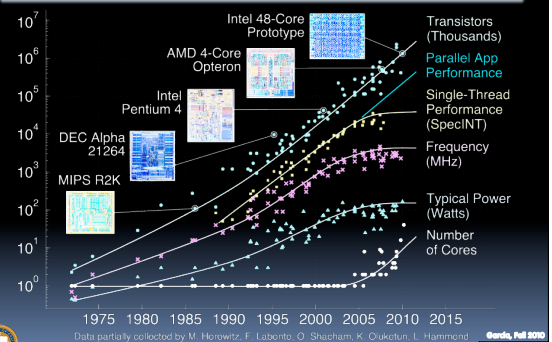


Gordon Moore
Intel Cofounder
B.S. Cal 1950!

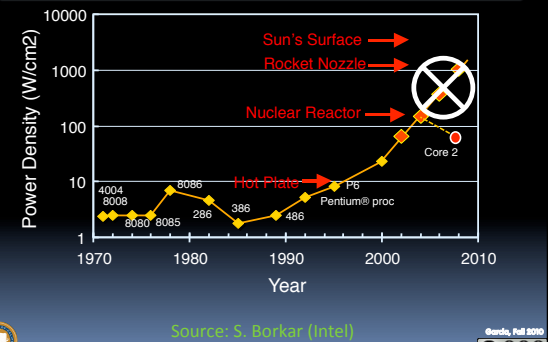
Moore's Law and related curves



Moore's Law and related curves



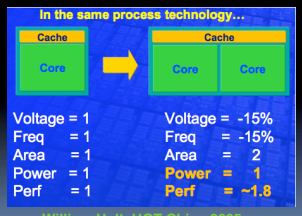
Power Density Prediction circa 2000



Source: S. Borkar (Intel)

Going Multi-core Helps Energy Efficiency

- Power of typical integrated circuit ~ C V^2 *f*
  - C = Capacitance, how well it "stores" a charge
  - V = Voltage
  - *f* = frequency. I.e., how fast clock is (e.g., 3 GHz)



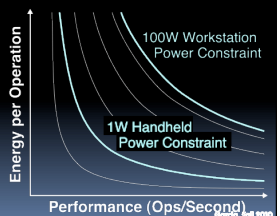
William Holt, HOT Chips 2005

Activity Monitor (on the lab Macs) shows how active your cores are

Energy & Power Considerations

$$\text{Power} = \frac{\text{Energy}}{\text{Second}} = \frac{\text{Energy}}{\text{Op}} \times \frac{\text{Ops}}{\text{Second}}$$

Power	Energy
Chip Packaging	Battery Life
Chip Cooling	Electricity Bill
System Noise	Mobile Device Weight
Case Temperature	
Data-Center Air Conditioning	



Courtesy: Chris Batten

view.eecs.berkeley.edu

Parallelism again? What's different this time?

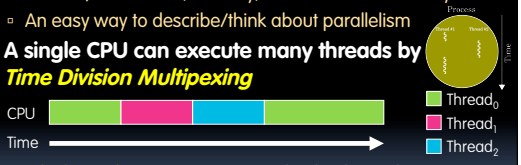
"This shift toward increasing parallelism is not a triumphant stride forward based on breakthroughs in novel software and architectures for parallelism; instead, this plunge into parallelism is actually a retreat from even greater challenges that thwart efficient silicon implementation of traditional uniprocessor architectures."

– Berkeley View, December 2006

- HW/SW Industry bet its future that breakthroughs will appear before it's too late

Background: Threads

- **A *Thread* stands for "thread of execution", is a single stream of instructions**
  - A program / process can split, or fork itself into separate threads, which can (in theory) execute simultaneously.
  - An easy way to describe/think about parallelism
- **A single CPU can execute many threads by *Time Division Multipexing***



- ***Multithreading* is running multiple threads through the same hardware**

en.wikipedia.org/wiki/Amdahl's_law

Speedup Issues : Amdahl's Law

- Applications can almost never be completely parallelized; some serial code remains

- s is serial fraction of program, P is # of cores (was processors)
- **Amdahl's law:**

Speedup(P) = Time(1) / Time(P)

≤ 1 / (s + [(1-s) / P)], and as P → ∞

≤ 1 / s

- Even if the parallel portion of your application speeds up perfectly, your performance may be limited by the sequential portion

Speedup Issues : Overhead

- **Even assuming no sequential portion, there's…**
  - Time to think how to divide the problem up
  - Time to hand out small "work units" to workers
  - All workers may not work equally fast

  - Some workers may fail
  - There may be contention for shared resources
  - Workers could overwriting each others' answers
  - You may have to wait until the last worker returns to proceed (the slowest / weakest link problem)
  - There's time to put the data back together in a way that looks as if it were done by one

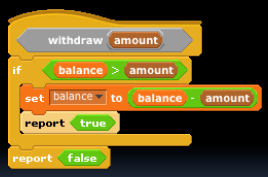
Life in a multi-core world…

- **This "sea change" to multi-core parallelism means that the computing community has to rethink:**
  - a) Languages
  - b) Architectures
  - c) Algorithms
  - d) Data Structures
  - e) All of the above

en.wikipedia.org/wiki/Concurrent_computing

But parallel programming is hard!

- **What if two people were calling withdraw at the same time?**
  - E.g., balance=100 and two withdraw 75 each
  - Can anyone see what the problem *could* be?
  - This is a race condition
- **In most languages, this is a problem.**
  - In Scratch, the system doesn't let two of these run at once.



en.wikipedia.org/wiki/Deadlock

Another concurrency problem … deadlock!

- **Two people need to draw a graph but there is only one pencil and one ruler.**
  - One grabs the pencil
  - One grabs the ruler
  - Neither release what they hold, waiting for the other to release

- **Livelock also possible**
  - Movement, no progress
  - Dan and Luke demo

Summary

- **"Sea change" of computing because of inability to cool CPUs means we're now in multi-core world**
- **This brave new world offers lots of potential for innovation by computing professionals, but challenges persist**