CS61C
Machine Structures:
End of Episode I

(Lecture 28)

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Outline

- Review Big Ideas and Examples
- Administrivia
- Page quiz: More pages Book vs. 61C slides?
- Cost, Performance analyses of Computer Science Bachelors of Science Degrees: Cal vs. Stanford
- Your Cal Cultural Heritage, including videotape
- Predicting the Future
- HKN Evaluation

From First Lecture

- 15 weeks to learn big ideas in CS&E
  - Principle of abstraction, used to build systems as layers
  - Compilation v. interpretation to move down layers of system
  - Pliable Data: a program determines what it is
  - Stored program concept: instructions are data
  - Principle of Locality, exploited via a memory hierarchy (cache)
  - Greater performance by exploiting parallelism
  - Principles/pitfalls of performance measurement

Principle of abstraction, systems as layers

- Programming Languages:
  - C / Assembly / Machine Language
  - Pseudoinstructions in Assembly Language
- Translation:
  - Compiler / Assembler / Linker / Loader
- Network Protocol Suites:
  - TCP / IP / Ethernet
- Memory Hierarchy:
  - Registers / Caches / Main memory / Disk

Compilation v. interpretation to move down

- Programming Languages:
  - C / Assembly / Machine Language
  - Compilation
- Network Protocol Suites:
  - TCP / IP / Ethernet
  - Interpretation
- Memory Hierarchy:
  - Caches / Main memory / Disk: Interpretation
  - Registers / Cache: Compilation

Pliable Data: a program determines what it is

- Instructions (fetched from memory using PC)
- Types include Signed Integers, Unsigned Integers, Characters, Strings, Single Precision Floating Point, Double Precision Floating Point
- Everything has an address ($\Rightarrow$ pointers)
- TCP packet? IP packet? Ethernet packet?

Stored program concept: instructions as data

- Allows computers to switch personalities
- Simplifies compile, assembly, link, load
- Distributing programs easy: on any disk, just like data
  - ⇒ binary compatibility, upwards compatibility (8086, 80286, 80386, 80486, Pentium I, II, III)
- Allows for efficient Dynamic Libraries: modify the code to patch in real address
- Makes it easier for viruses: Send message that overflows stack, starts executing code in stack area, take over machine

Principle of Locality

- Exploited by memory hierarchy
- Registers assume Temporal Locality: data in registers will be reused
- Disk seeks faster in practice: short seeks are much faster, so disk accesses take less time ⇒ due to Spatial Locality
- Disks transfer in 512 Byte blocks assuming spatial locality: more than just 4 bytes useful to program
- Networks: most traffic is local, so local area network vs. wide area network

Greater performance by exploiting parallelism

- Pipelining
  - Overlap execution to increase instruction throughput vs. instruction latency
- Input/Output
  - Overlap program execution with I/O, only interrupt when I/O complete
  - DMA data while processor does other work
- RAID (Redundant Array of Inexp. Disks)
  - Replace a few number of large disks with a large number of small disks ⇒ more arms moving, more heads transferring (even though small disks maybe slower)

Performance measurement Principles/Pitfalls

- Processors
  - only quoting one factor of 3-part product: clock rate but not CPI, instruction count
  - Cache miss rate vs. Average memory time
- Networks
  - only looking peak bandwidth, not including software start-up overhead for message
- Disks
  - Seek time much better than what manufacturer quotes (3X to 4X)
  - Data transfer rate worse than what manufacturer quotes (0.75X)

Rapid Change AND Little Change

- Continued Rapid Improvement in Computing
  - 2X every 1.5 years (10X/5yrs, 1000X/15yrs)
  - Processor speed, Memory size - Moore's Law as enabler (2X transistors/chip/1.5 yrs); Disk capacity too (not Moore's Law)
  - Caches, Pipelining, Branch Prediction, ...
- 5 classic components of all computers
  1. Control
  2. Datapath } Processor (or CPU)
  3. Memory
  4. Input
  5. Output

Administrivia

- All grades up-to-date?
  - See Kelvin ASAP about disagreements
- Sunday 5/9 Final Review starting 2PM (1 Pimintel)
  - Practice Final, Solution available online now
- Wed 5/12 Final 5-8PM in 1 Pimintel
  - 2 sheets of paper, both sides, #2 pencils (no calculators)
  - Any problems with time, last chance to contact mds@cory for early final

Online Notes

- Guess Which has more:
  pages in COD (including Appendix A)
  vs.
  CS 61C online slides?
- Pages in COD 2/e: 837
- Total CS61C slides online: 926

Is UCB CS B.S. >> Stanford's?

- 97/98 Degrees: 242 (Cal) v. 116 (Stanford)
  - Cal: L&S Computer Science + EECS Option C
  - Stanford: Computer Science (C.S. Dept.) + Computer Systems Engineering (E.E. Dept.) + Symbolic Systems (Interdepartmental)
- Performance Benchmarks
  - Programming Contests
  - Going to Industry
  - Going to Graduate School
  - Number National Undergraduate Awards
- Cost: Tuition, Overall

ACM Programming Contests

Year	Regional	International
93	1. UCB, 5. UCB, 6. Stanford	6. UCB, ?? St.
94	1. UCB, 2. Stanford	2. UCB, 22, St.
95	1. UCB, 5. Stanford	1. UCB, ??, St.
96	2. Stanford, 4. UCB,	16. St., ??UCB
97	1. Stanford, 2. UCB,	11. UCB, 24St.
98	1. UCB, 2. Stanford	7. UCB, 38 St.

- Stanford wins regional 1/6 years, never won international
- Berkeley wins regional 4/6 years,
  Won international, 5/6 times ahead of Stanford

Going to Industry

- Gordon Moore: "Lots more people from Silicon Valley from Cal than Stanford"
- "Berkeley B.S. degree is about equivalent to a Stanford M.S. degree"
  - Intel recruiter, several others companies
- 1997-98 Starting Salaries B.S. in CS (according to Placement centers)
- Stanford: $41,000 to $56,000
- Berkeley: median $50,000
  (know of $70,000 jobs)

Going on to Ph.D. in C.S. Fall 99

- 1997: About 25% of Berkeley EECS students go on for PhD, <5% of Stanford students go for PhD

Admitting School	Stanford	Berkeley
Univ. Washington	5	7
MIT	3	6
Carnegie Mellon	1	4
Stanford	??	6
Berkeley	0	8

Outstanding Undergraduate Awards

- Started 1995, by Computing Research Association
- 2 Nominations / school / year: 2 Winners, few Runners Up, several Honorable Mentions
  - Total: 10 winners, 24 Runners Up, 49 Hon. Men.

Number winners	Total Named	Points (3/2/1)
40. Stanford (0)	22. Stanford (2)	22. Stanford (2)
5. MIT (1)	14. MIT (2)	11. MIT (4)
1. Dartmouth (2)	2. Cornell (5)	3. Darmouth (9)
1. Harvard (2)	2. Harvard (5)	2. Harvard (10)
1. Berkeley (2)	1. Berkeley (6)	1. Berkeley (11)

Berkeley vs. Stanford CS Degrees

- **Cost Benchmark**
  - Tuition Only: $22,100 (Stanford) v. $3,766 (Cal)
  - Berkeley cheaper by factor of 5.9
  - 4.5 years * Tuition/Room/Books/Board
  - Stanford Cost: 4.5 * $32,444 = $145,998
  - Berkeley Cost: 4.5 * $14,598 = $65,691
  - Berkeley cheaper by factor of 2.2
- **Cost-Performance: Any university anywhere close to Berkeley?**

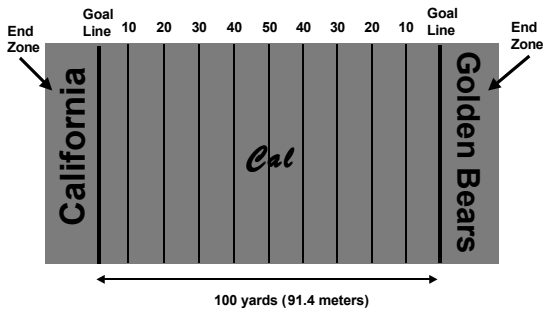
Cal Cultural History: ABCs of Football

- Started with "soccer"; still 11 on a team, 2 teams, 1 ball, on a field; object is to move ball into "goal"; most goals wins
- New World changes the rules to increase scoring:
  - Make goal bigger! (full width of field)
  - Carry ball with hands
  - Can toss ball to another player backwards or laterally (called a "lateral") anytime and forwards ("pass") sometimes
- How to stop players carrying the ball? Grab them & knock them down by making knee hit the ground ("tackle")

ABCs of American Football

- Score by
  - moving football into goal ("cross the goal line" or "into the end zone") scoring a "touchdown" (6 points)
  - kicking football between 2 poles ("goal posts") scoring a "field goal" (worth 3 points, unless after touchdown, then its just 1 point: "extra point")
- Kick ball to other team after score ("kickoff"); laterals OK
- Game ends when no time left (4 15 min quarters) and person with ball is stopped (Soccer time only: 2 45 min halves, time stops play)

Football Field



The Spectacle of American Football

- Cal's archrival is Stanford; stereotype is Private, Elitist, Snobs
- Play nearby archrival for last game of season
  - Called "The Big Game": Cal vs. Stanford, winner gets a trophy ("The Axe") : Oldest rivalry west of Mississippi; 100th in 1997
- American college football is a spectacle
  - School colors (Cal Blue & Gold v. Red & White)
  - Nicknames (Golden Bears v. Stanford Cardinal)
  - School mascot (Oski the bear v. a tree(!))
  - Leaders of cheers ("cheerleaders")

The Spectacle of American Football

- "Bands" (orchestras that march) from both schools at games
- March/play Before game, at halftime, after game
- Stanford Band more like a drinking club; See the movie "Animal House"?
  - Plays one song: "All Right Now"
- Stanford used to yell "boring" at band during Cal's performance
  - Like the "In Crowd" at High School?

1982 Big Game

- "There has never been anything in the history of college football to equal it for sheer madness." ***Sports Illustrated***
- Stanford Quarterback is John Elway, who goes on to be a professional All Star football player (retired 1999)
  - greatest quarterback in college history
- Cal Quarterback is Gail Gilbert, who goes on to be a non-starting professional football player (retired 1996)
- Stanford lost 4 games in last minutes of game
- Stanford has just taken lead with 4 seconds left in game; Cal team captian yells in huddle "Don't fall with the ball!"; look at video

Notes About "The Play"

- Cal only had 10 men on the field; last second another came on (170 pound Steve Dunn #3) and makes key 1st block
- Kevin Moen #26: 6'1" 190 lb. safety,
  - laterals to Rodgers (and doesn't give up)
- Richard Rodgers #5: 6' 200 lb. safety, "Don't fall with the ball."
  - laterals to Garner
- Dwight Garner #43: 5'9" 185 lb. running back
  - almost tackled, 2 legs & 1 arm pinned, laterals
- Richard Rodgers #5 (again): "Give me the ball"
  - laterals to Ford

Notes About "The Play"

- Mariet Ford #1: 5'9", 165 pound wide receiver
  - Smallest player, leg cramps; overhead blind lateral to Moen and blocks 3 players
- Moen (again) cuts through Stanford band into end zone (touchdown!), smashes Trombonist
- On field for Stanford: 22 football players, 3 Axe committee members, 3 cheerleaders, 144 Stanford band members (172 for Stanford v. 11 for Cal)
  - "Weakest part of the Stanford defense was the woodwinds."
- 4 Cal players + Stanford Trombonist (Gary Tyrrell) hold reunion every year at Big Game; Stanford revises history (20-19 on Axe)

2nd to last 61C slide: First, Thanks to the TAs!

- Josh Cantrell,
- Michael Chu,
- Brendan Ferguson,
- Nemanja Isailovic,
- Gek Siong Low,
- Kelvin Lwin,
- Dmitriy Portnov,
- Mark Spiller,
- Tai Ping Yu

The Future for Cal Alumni:

- What's The Future?
- New Millennium
  + Internet, Satellites Imagery, ...
  + Rapid Change in Technology
  + World's Best Education
  + Hard Work
  + Never Give Up
- "The best way to predict the future is to invent it" (Alan Kay, Xerox PARC)
- Future is up to you!