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 (⇒ 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 assume Spatial Locality: more than just 4 bytes useful to program

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 enabling (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
  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 CS 61C slides online: 926

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Proving UCB CS B.S. >> Stanford's

- 97/98 Degrees: 242 (Cal) vs. 176 (Stanford)
  - Cal: L&S Computer Science + EECS Option C

- Performance Benchmarks
  - Programming Contests
  - Going to Industry
  - Going to Graduate School
  - Number National Undergraduate Awards

- Cost: Tuition, Overall

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ACM Programming Contests

<table>
<thead>
<tr>
<th>Year</th>
<th>Regional</th>
<th>International</th>
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<tbody>
<tr>
<td>94</td>
<td>1. UCB, 2. Stanford</td>
<td>2. UCB, 22, St.</td>
</tr>
<tr>
<td>95</td>
<td>1. UCB, 5. Stanford</td>
<td>1. UCB, ??, St.</td>
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<tr>
<td>96</td>
<td>2. Stanford, 4. UCB, 16. St., ??UCB</td>
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<tr>
<td>97</td>
<td>1. Stanford, 2. UCB, 11. UCB, 24St.</td>
<td></td>
</tr>
<tr>
<td>98</td>
<td>1. UCB, 2. Stanford</td>
<td>7. UCB, 38 St.</td>
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- Stanford wins regional 1/6 years, never won international
- Berkeley wins register 4/6 years, Won international, 5/6 times ahead of Stanford

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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)

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

- About 25% of Berkeley CS 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

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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. Dartmouth (9)
Berkeley vs. Stanford CS Degrees

- **Performance**: Berkeley wins (large factors)
- **Cost Benchmark**
  - Tuition Only: $22,100 (Stanford) v. $3,766 (Cal)
  - Berkeley wins 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 wins by factor of 2.2
- **Cost-Performance**: Berkeley best in world?

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

- Goal Line
- Goal Line
- End Zone
- End Zone
- 100 yards (91.4 meters)

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, last Monday)
  - 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 captain 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: 6'2" 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
  - "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:
- Better educated than Stanford people, and They Never Give Up!
- 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)
- Future is up to you!