Lecture 23: Course Summary, Future Predictions, and Your Cal Cultural History

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Computer Science 252
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Final Lecture

• Review CS 252, follow on courses
• Research style
• Discussion on Future of CS&E Research?
• Learning about your heritage as Cal students/ future alumni
• Course evaluation by HKN
• Pizza at LaVal’s
Chapter 1: Performance and Cost

• Amdahl’s Law: perennial pitfall
  – Make the common case fast
• Integrated Circuits will continue to dominate computer technology: 30M to 100M transistors/microprocessor by end of decade
• Cost vs. Price
• Margins pay the workers of the computer industry
• For better or worse, benchmarks shape a field
• Interested in learning more on integrated circuits? EE 241 “Advanced Digital Integrated Circuits” CS 250 “VLSI Systems Design” (TA?)
• Interested in learning more on performance? CS 266 “Introduction to Systems Performance”
Chapter 2: Instruction Set Architecture

- What ISA looks like to pipeline?
  - Cray: load/store machine; registers; simple instr. format
- RISC: Making an ISA that supports pipelined execution
- VAX: Making an ISA that minimizes opcode space, easy for compilers (many addr. modes, few reg.)
- 80x86: importance of being their first
- Interested in learning more on compilers and ISA?
  CS 264/5 “Advanced Programming Language Design and Optimization”
  CS 294 “Reconfigurable Computers” (Wawzyrnek)
Chapters 3/4: Pipelined Implementation

- **Miracle of Pipelining:** Bandwidth vs. latency
- **Superscalar to break single instruction/clock cycle limit**
  - Hazards/Dependencies as limit: HW & SW techniques to overcome limits
  - Conditional Branches as one Limit: branch prediction
  - Memory system as another limit
  - Compiler & machine organization try to overcome limits
- **Out-of-order execution:** partially overcome some limits at dramatic complexity increase
- **Sustaining 2X increase / 18 months rat race**
As a result of computer research at universities and research labs, starting in 1987 the rate of improvement increased to 55%/year. Compounded annually for 8 years, computers today are 3 times faster than we would have predicted in early 1980s.

Historical rate of microprocessor speed improvement was 35%/year until 1986.

Historical trend projected until 1994 @ 35%/year.
Appendix B: Vector Processors

- High-level operations work on linear arrays: "vectors"
- Alternate model much easier for hardware: more powerful instructions, more predictable memory accesses, fewer branches, longer pipeline, ...
- Key terms: Chime, Convoy, Chaining, Initiation rate, Start-up time, Vector Length Register, Strip mining, Stride, Gather/Scatter, Vector Mask Register
- Interesting metrics: $R_\infty$ (speed infinite vector), $N_{1/2}$ (length=1/2 speed $R_\infty$), $N_V$ (length faster than scalar)
- What % of computation is vectorizable?
For new multimedia apps?
Chapter 5: Memory Hierarchy

- Many, many options for caches
- 4 Questions: where, who, which, write
- 3 C: capacity, conflict, compulsory
- As CPUs get faster, more time spent in memory hierarchy: 150 clock cycles to DRAM x 4 instruction issues => potentially 600 instruction issues during miss
- DRAMs continue amazing capacity advance (4X/3 years) since 1970s but small advance in latency
- Memory hierarchy likely overriding issue in algorithms today; do algorithms and data structures of 1960s work with machines of 1990s?
Technology: Memory Perspective

• > 10,000X increase since 1970! another > 50X by ≈2001!

• Compared to other phenomena:

Computer Memory

- Since 1970: < 10X Banks, Debt; < 2X population
Chapter 6: Storage I/O

- Bandwidth, Latency, Reliability
- Queuing theory
- RAID: performance and reliability
- Disks growing at 4X/3 years more recently
  - Still get email messages to reduce file storage
- Fantastic potential of tertiary storage:
  100s TBs => Library on Congress at finger tips
- Interested in learning more on queueing theory?
  IEOR 161 (Ross), IEOR 267 (Wolff), IEOR 268
- Interested in learning more on SW storage systems?
  CS 286 “Implementation of Data Base Systems”
Chapter 7: Networks

• Similarities of MPP interconnects, LANs, WANs
• Bandwidth vs. Latency in communication
• Switches everywhere, possibly even replacing memory busses
• Exciting Area: Internet read about in newspaper everyday
• Who will win: Sun 100 Mbit Ethernet, HP 100 Mbit Ethernet, Switched 10 Mbit Ethernet, ATM?
• Interested in learning more on networks? CS 268 “Computer Networks”
Chapter 8: Multiprocessors

- Potential for both performance and reliability
- Shared, uniform memory access vs. Shared non-uniform memory access vs. Message Passing
- Cache coherency protocols: Snooping vs. directory
- Successful today for file servers, time sharing, databases
- Will parallel programming become popular for production programs? If so, need to know 3As: Architecture, Applications, Algorithms
- Interested in learning more on multiprocessors: CS 258 “Parallel Computer Architecture”
  E 267 “Programming Parallel Computers”
  CS 273 “Foundations of Parallel Computation”
CS 252 Projects

• Many, many interesting projects
• Several students and faculty said they enjoyed poster session and mentioned what great jobs you did
• Many capable of being turned into published papers, if you have the time
• You have seen the full conference cycle: topic selection, investigation, real deadlines, poster session, written presentation
Doing Research: Don’t follow this Bad Career Advice

• Invent a Field and Stick to it
• Let Complexity be Your Guide
• Never be Proven Wrong
• Use the Computer Scientific Method
• Avoid Feedback
• Publishing Journal Papers IS Technology Transfer
• Write Many (Bad) Papers
• Give Bad Talks
Role Changes during Project
Alternatives to a Bad Career

• Goal is to have impact:
  *Change way people do Computer Science & Engineering*
  - Evaluation of academic research uses bad benchmarks
    => skews academic behavior

• Many 3 - 5 year projects gives more chances for impact

• Feedback is key: seek out & value critics

• Do “Real Stuff”: make sure you are solving some problem that someone cares about

• Taste is critical in selecting research problems, solutions, experiments, & communicating results; taste is acquired and improved by feedback

• *Students* are the coin of the academic realm
Impact of Industry on Computer Architecture Research in the Future?

• Will PCs drive out all traditional forms of hardware?
• Given cost of IC Fab line increasing to $1B investment, can anything but 80x86/PowerPC be justified economically? Video games? Set top units?
• What replaces the big computer (MPP/mainframe)? NOWs? Multiprocessor servers + Network Computers?
• Will parallel programming become commercially significant beyond databases and operating systems?
• Perhaps topics largely ignored will become focus of research:
  – Ease of Use, Manufacturing, Installation
  – Cost of Ownership
  – Fault Tolerance, Reliability
CS&E Research in the Future?

• Are processors beyond resources of universities to compete (like DRAMs)? see Alpha 21264
• What about compilers? operating systems? data bases?
• Should CS&E systems research move up a level, standing on shoulders rather than on toes?
• Does CS&E theory make sense as a separate entity (courses/conferences/journals) v. spectrum of practical to theoretical architecture/DB/OS/…?
Support of CS&E Research in the Future?

• Re-evaluation of social contract between citizens and scientists has changed: transition from understanding-driven research that promises to somehow deliver a safer, healthier, and wealthier society to strategic research that helps directly with problems facing society: jobs, K-12 education, ...
  – Who will argue the research case in face of balanced budget?

• Will CS&E fair better than physics, chemistry?
  – Industrial Research increasing jobs for CS&E, radical cut back in other traditional sciences

• We are living that ancient Chinese curse: “May you live in interesting times.”
Cal Cultural History:
ABCs of American 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 (“a pass”) sometimes

• How to stop players carrying the ball? Grab them & knock them down by making knee hit the ground (“tackle”)
  – if drop ball (“fumble”), other players can pick it up and score

• Score by moving ball into goal (“cross the goal line” or “into the end zone”) scoring a “touchdown” (6 points), or kicking ball between 2 poles (“goal posts”) scoring a “field goal” (3, unless after touchdown = 1: “extra point”)

• Kick ball to other team after score (“kickoff”); laterals OK

• Game ends when no time left & person with ball is stopped
Football Field

Goal Line 10 20 30 40 50 40 30 20 10 Goal Line

End Zone

End Zone
The Spectacle of Football

- **Rose Bowl**: Prestigious bonus game played January 1 if have a great year; preceded by parade; national TV coverage
- Play nearby archrival for last game of season
- Cal’s archrival is Stanford; stereotype is Private, Elitist, Snobs
- **The Big Game**: Cal vs. Stanford, winner gets a trophy ("The Axe") : Oldest rivalry west of Mississippi
- American college football is a spectacle
  - School colors (Cal: Blue & Gold; Stanford: Red & White)
  - School nicknames (Cal: Golden Bear; Stanford: Cardinal)
  - School mascot (Cal: Oski the bear; Stanford: a tree(!))
  - Leaders of cheers ("cheerleaders")
- "Bands" (orchestras that march) from both schools at games; before game, at halftime, after game
  - Stanford Band more like a drinking club; ≈ "Animal House"
  - Plays one song: "All Right Now"
  - Stanford used to yell “boring” at band during Cal’s performance
1929 Rose Bowl Game

- Cal vs. Georgia Tech
- Cal going left to right (==>), GeorgiaTech right to left (<=)
- Georgia Tech player fumbles football
- Cal player, Roy Reigel, picks up football and tries to avoid Georgia Tech players
- Let’s see what happens on video
1982 Big Game

• “There has never been anything in the history of college football to equal it for sheer madness.” *Sports Illustrated*

• Stanford “Quarterback” (person who passes the ball forward) is John Elway, best ever? Goes on to be a professional All Star football player (still playing today)

• Cal Quarterback is Gail Gilbert, goes on to be a non-starting professional football player (still playing today)

• Stanford lost 4 games at end of game; if Stanford wins, it goes to a bowl game; Stanford is favored to win

• Let’s see what happens on video
Notes About “The Play”

• Cal only had 10 men on the field; last second another came on (170 pound Steve Dunn #3) & makes key 1st block
• Kevin Moen #26: never scored in 4 years at Cal  
  – laterals to Rodgers (and doesn’t give up)
• Richard Rodgers #5: “Don’t fall with the ball.” (Never give up)  
  – laterals to Garner
• Dwight Garner #43: 5’9” 185 pound running back  
  – almost tackled, laterals to Ford
• Mariet Ford #1: 5’9”, 165 pound wide receiver  
  – leg cramps, overhead lateral to Moen & blocks 3 players
• Moen cuts through Stanford band into end zone
• On the field for Stanford during touchdown: 22 football players, 3 cheerleaders, 3 members of Axe committee, 144 member Stanford band (172 for Stanford v. 11 for Cal)
• “Weakest part of the Stanford defense was the woodwinds.”
• 4 Cal football players play + Stanford Trombone player (Gary Tyrrell) hold reunion every year at big game time
Your Cal Cultural History

• Cal students/alumni heritage is the greatest college football plays in > 100 years
• Cal students/alumni work hard and play hard
• Cal students/alumni take pity on Stanford students/alumni
• Cal students/alumni never give up!
• Cal students/alumni triumph over great odds!