Final Lecture

- Review CS 252, follow on courses
- Research style
- Discussion on Future?

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Chapter 1: Introduction

- Amdahl's Law: perennial pitfall
  - Make the common case fast
- Principle of Locality: foundation for many performance optimizations

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Appendix A Big Picture

- Importance of floating point accuracy
- 11/22/94 San Jose Mercury News: “More than 2 million of the Pentium chips shipped by Intel Corp. contain a flaw but, the company said Tuesday, it affects only the calculations of theoretical mathematicians.…
- "I know it's buzzing all over the Net. But there are maybe several dozen people that this would affect," said High (an Intel spokesman). "So far, we've only heard from one."
- 11/3094: San Francisco Chronicle headline “Intel Pentium bug more serious than claimed”
- “once in billions with random numbers” => Bug can occur in 4th or 5th digit
- Defensive programming if detect Pentium, even if flawed chips become < 1% of all shipped (currently 20)

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Top 10 New Intel slogans for the Pentium

9.9999973251	It's a flaw, Dammit, not a Bug
8.9999163362	It's Close Enough, We Say So
7.9999414610	Nearly 300 Correct Opcodes
6.9999831538	You Don't Need to Know What's Inside
5.9999835137	Redefining the PC--and Mathematics As Well
4.9999999021	We Fixed It, Really
3.9998245917	Division Considered Harmful
2.9991523619	Why Do You Think They Call It Floating Point?
1.9999103517	We're Looking for a Few Good Flaws
0.9999999998	The Errata Inside

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Quality

- Broader question of responsibility of quality in design
- Intel discovered in summer, fixed and started shipping without saying anything to public
- Internet shed light on problem
- Intel did initial spin control
- How should you handle errors in things you work on?
  - HW products?
  - SW products
  - Papers?

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Chapter 2: Performance and Cost

- 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? CS 250 “VLSI Systems Design”
- Interested in learning more on performance? CS 266 “Introduction to Systems Performance”

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Chapter 3: 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 addressing modes, few reg.)
- 80x86: importance of being their first
- Interested in learning more on compilers and ISA?
  CS 265 "Advanced Programming Language Implementation"

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Chapters 4/5: Pipelined

- Magic of Pipelining
- 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
- Fueling 2X / 18 months increase

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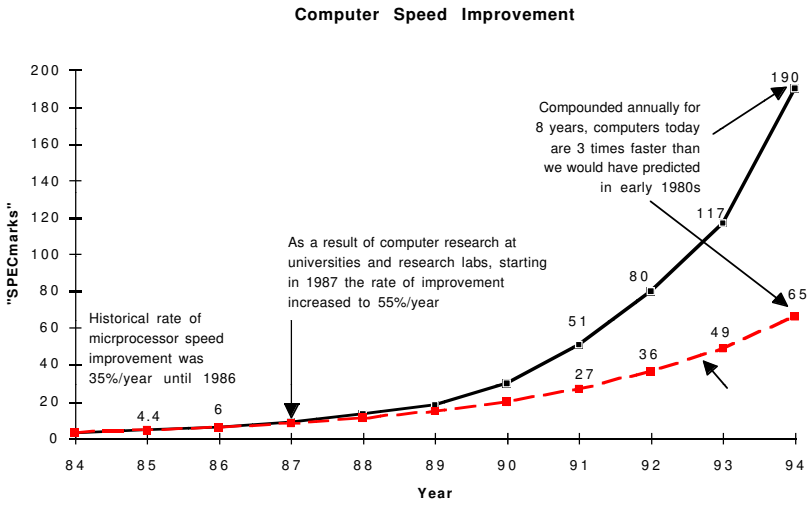
Processor performance over time



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Chapter 6: 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 advance (4X/ 3 years) since 1970s**
- **Memory hierarchy likely overriding issue in algorithms today; do algorithms and data structures of 1960s work with machines of 1990s?**

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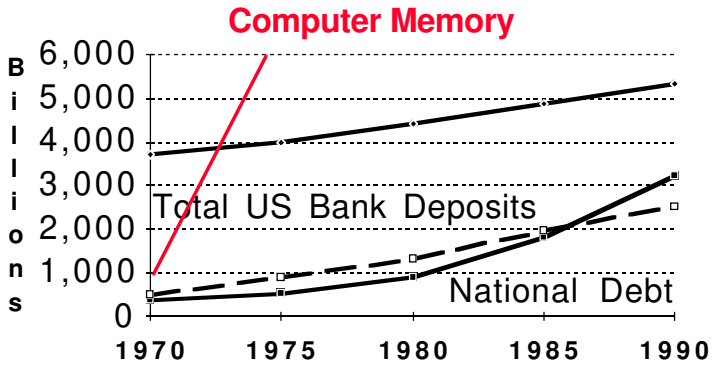
Technology: Memory Perspective

- > 10,000X increase since 1970!
  another > 50X by ≈2001!
- Compared to other phenomena:



- Since 1970: < 10X Banks, Debt; < 2X population

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Chapter 7: Storage I/O

- Bandwidth, Latency, Reliability
- Queuing theory
  - Interested in learning more? IEOR 267 (Wolff)
- 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 263A, IEOR 267 (Wolff), (Statistics 200A)
- Interested in learning more on SW storage systems?
  CS 286 "Implementation of Data Base Systems"

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Chapter 8: 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" (Spring 95?)

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Chapter 9: 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, Algorithms, Applications
- Interested in learning more on multiprocessors:
  CS 258 "Parallel Computer Architecture" (Spring 95)
  E 267 "Programming Parallel Computers" (Spring 95)
  CS 273 "Foundations of Parallel Computation" (Spring 95)

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The Bet

Danny Hillis believes that while supercomputers with a small number of data streams may be best sellers, the biggest machines will be machines with many data steams, and these will perform the bulk of the computations. Gordon Bell bet Hillis that in the last quarter of calendar year 1995 more sustained MFLOPS will be shipped in machines using few data streams (<100) rather than many data streams (>1000). This bet concerns only supercomputers, defined as machines costing more than $1,000,000 and used for scientific applications. Sustained MFLOPS is defined for this bet as the number of floating-point operations per month, so availability of machines affects their rating. The loser must write and publish an article explaining why his prediction failed.

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Projects

- **Many, many interesting projects**
- **Projects and grades available no later than Wed Dec 7 in 634**
- **Several students and faculty said they enjoyed poster session and mentioned what great jobs you did (may have poster holders installed on 5th floor)**
- **Will make all papers available in 634 Soda if you want to make copies**
- **You have seen the full conference cycle: selection, investigation, oral and written presentation, deadlines**
- **I will send copies to people outside Berkeley who suggested the studies**
- **Some are good enough to be published with more work, if you have the time**

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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

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Role Changes during Project

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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; acquired by feedback
- *Students* are the coin of the academic realm

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Impact of Industry on Computer Architecture Research in the Future?

- 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)? Networks of Workstations? Multiprocessor servers + Xterms?
- Will PCs drive out all traditional forms of hardware?
- Will parallel programming become commercially significant?
- Perhaps topics largely ignored will become focus of research:
  - Ease of Use, Manufacturing, Installation
  - Cost of Ownership
  - Fault Tolerance

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CS&E Research in the Future?

- Processors are beyond resources of universities to compete (like DRAMs): see Alpha 211164 or MIPS R10000
- 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/ …?
- CS&E moves from "pyramids in the desert" model to "satellites in the Solar system" model

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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, ...
- 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."

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