Computer Systems are Different!

Frans Kaashoek and Robert Morris
6.033 Spring 2009
Composibility via static discipline

- Be tolerant of inputs and strict on outputs

Figure 1-3: How gain and non-linearity of a digital component restore levels. The range of accepted inputs is much wider than the range of generated outputs.
Moore’s law

Transistors/die doubles every ~18 months
Lithography: 
the driver behind transistor count

- Components/area $O(x^2)$ with feature size
- Total components $O(a)$ with die area
- Switching rate $O(x)$ with feature size

Trends in Minimum Feature Size and Die Area
CPU performance

Trends in CPU performance growth, from microprocessors to supercomputers
DRAM density

Trends in semiconductor RAM density
Disk: Price per GByte drops at ~30-35% per year
ENIAC

- 1946
- Only one
- 5000 adds/sec
- 20 10-digit registers
- 18,000 vacuum tubes
- 124,500 watts
- Not really stored program
UNIVAC (Universal Automatic Computer)

- 1951
- 46 sold
- 2000 ops/sec
- 1,000 12-digit words (mercury)
- 5000 tubes
- $1.5 million
IBM System/360-40

- 1964
- 1.6 MHz
- 16-256 KB core
- $225,000
- Family of six
- 32-bit
- Time-sharing
Cray 1: supercomputer

- 1976
- 80 sold
- 80 MHz
- 8 Mbyte SRAM
- 230,000 gates
- $5 million
DEC PDP-8 (1964)

- 60,000 sold
- 330,000 adds/sec
- 4096 12-bit words
- $18,000
Apple II

- 1977
- 1 MHz
- 6502 microprocessor
- 4 to 48 Kilobytes RAM
- $1300
- Basic, Visicalc
IBM’s wrist watch

- 2001
- Linux and X11
- 74 Mhz CPU
- 8 Megabyte flash
- 8 Megabyte DRAM
- Wireless
Software follows hardware

Millions of lines of source code

- Windows 3.1 (1992)
- Windows NT (1992)
- Solaris (1998)
- Windows 95
- Windows 98
- Windows NT 5.0 (1998)
- Red Hat Linux 6.2 (2000)
- Red Hat Linux 7.1 (2001)
- Windows XP
- Vista

- Windows Vista (2007)
Cheap → Pervasive

Internet Domain Survey Host Count

Source: Internet Software Consortium (www.isc.org)
Pervasive → qualitative change

Slide from David Culler, UC Berkeley
Latency improves slowly

Moore’s law (~70% per year)

DRAM access latency (~7% per year)

Speed of light (0% per year)
Heat is a problem
Recent Intel CPU Clock Rates

![Graph showing the increase in CPU clock rates from 486 to Pentium 4 HT over time.]
The Future: will it be painful?

AMD Barcelona Quad-core chip
What went right?

- Unbounded composibility
- General-purpose computers
  - Only need to make one thing fast
- Separate arch from implementation
  - S/W can exploit new H/W
- Cumulative R&D investment over years