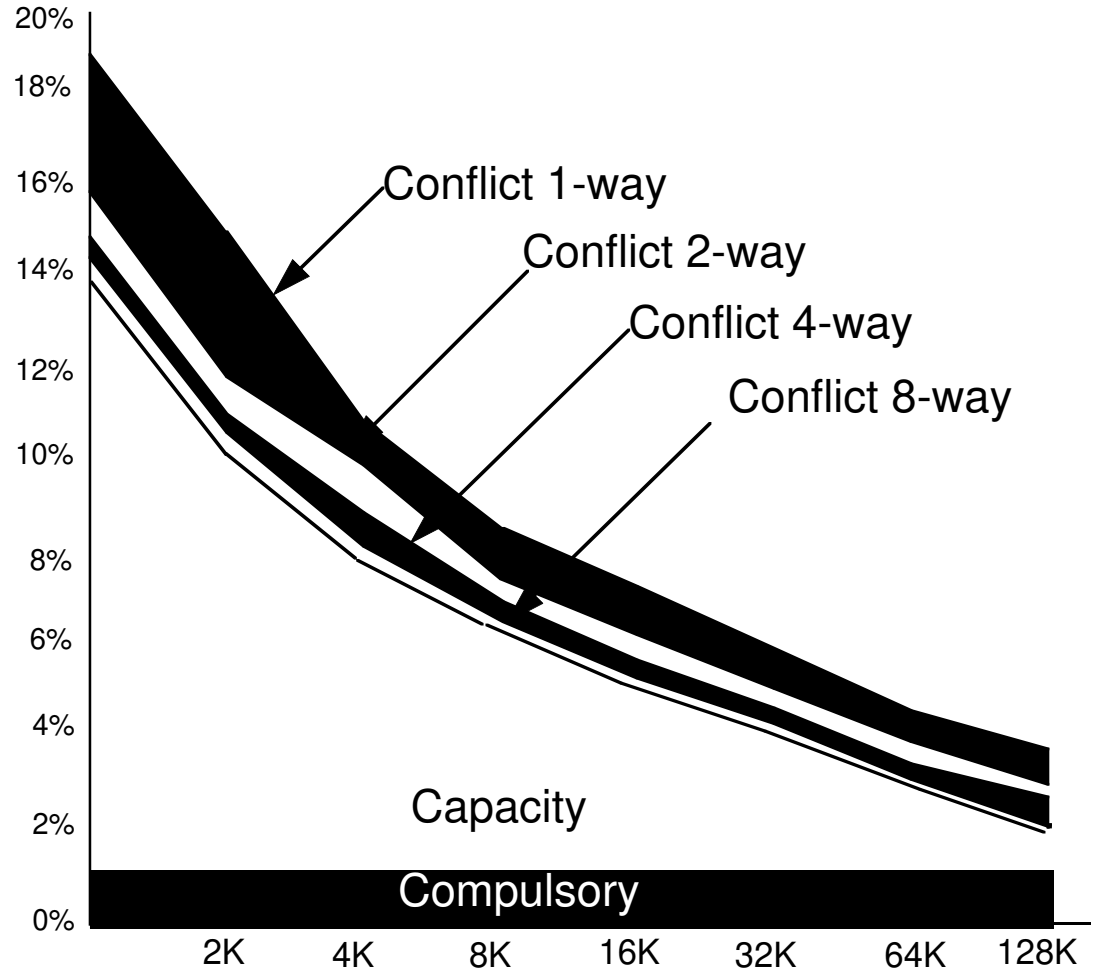
Miss Rates


20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
Conflict 1-way
Conflict 2-way
Conflict 4-way
Conflict 8-way
Capacity
Compulsory
2K
4K
8K
16K
32K
64K
128K

The Problem with Miss Rate ...

It doesn't tell the whole story:

Consider increasing direct-mapped cache from 32K to 64K.

Miss Rate drops from 5% to 4%. If the larger cache implies a cycle time of 18ns and the smaller cache implies a cycle time of 15ns, the smaller cache machine has BETTER PERFORMANCE.

Postulate: CPI w/o stalls the same
Miss penalty 180ns
Memory references per instruction = 1.5

CPU Time = (CPU execution clock cycles + Memory-stall clock cycles)
$\times$ Clock cycle time

Smaller vs Larger Cache (continued)

$$\text{Memory-stall clock cycles} = \frac{\text{Instructions}}{\text{Program}} \times \frac{\text{Misses}}{\text{Instruction}} \times \text{Miss penalty}$$

$$\text{Misses} = \text{Instruction miss rate} + \text{Data miss rate} \times \frac{\text{Data references}}{\text{Instructions}}$$

Let IC be *instructions per program*

Smaller Cache

Memory stall clock cycles =
IC $\times$ (0.05 + 0.05 $\times$ 0.5) $\times$ $\frac{\text{Absolute miss penalty}}{\text{Clockcycle time}}$
= IC $\times$ 0.075 $\times$ 180/15 = .9IC

Larger Cache

Memory stall clock cycles =
IC $\times$ (0.04 + 0.04 $\times$ 0.5) $\times$ $\frac{\text{Absolute miss penalty}}{\text{Clockcycle time}}$
= IC $\times$ 0.06 $\times$ 180/18 = .6IC

Smaller vs Larger Cache (continued)

Memory-stall clock cycles = 0.9IC (Small cache) and 0.6IC (Large cache).
Substituting into the CPU time equation, letting CPI w/o stalls be C:

CPU Time = (CPU execution clock cycles + Memory-stalls clock cycles)
$\times$ Clock cycle time

Small Cache

CPU time
=((C $\times$ IC) + (0.9 $\times$ IC) $\times$ 15ns
= 15$\times$C$\times$IC + 13.5 $\times$ IC
= (15C + 13.5)IC

Large Cache

CPU time
=((C $\times$ IC) + (0.6 $\times$ IC) $\times$ 18ns
= 18$\times$C$\times$IC + 10.8 $\times$ IC
= (18C + 10.8)IC

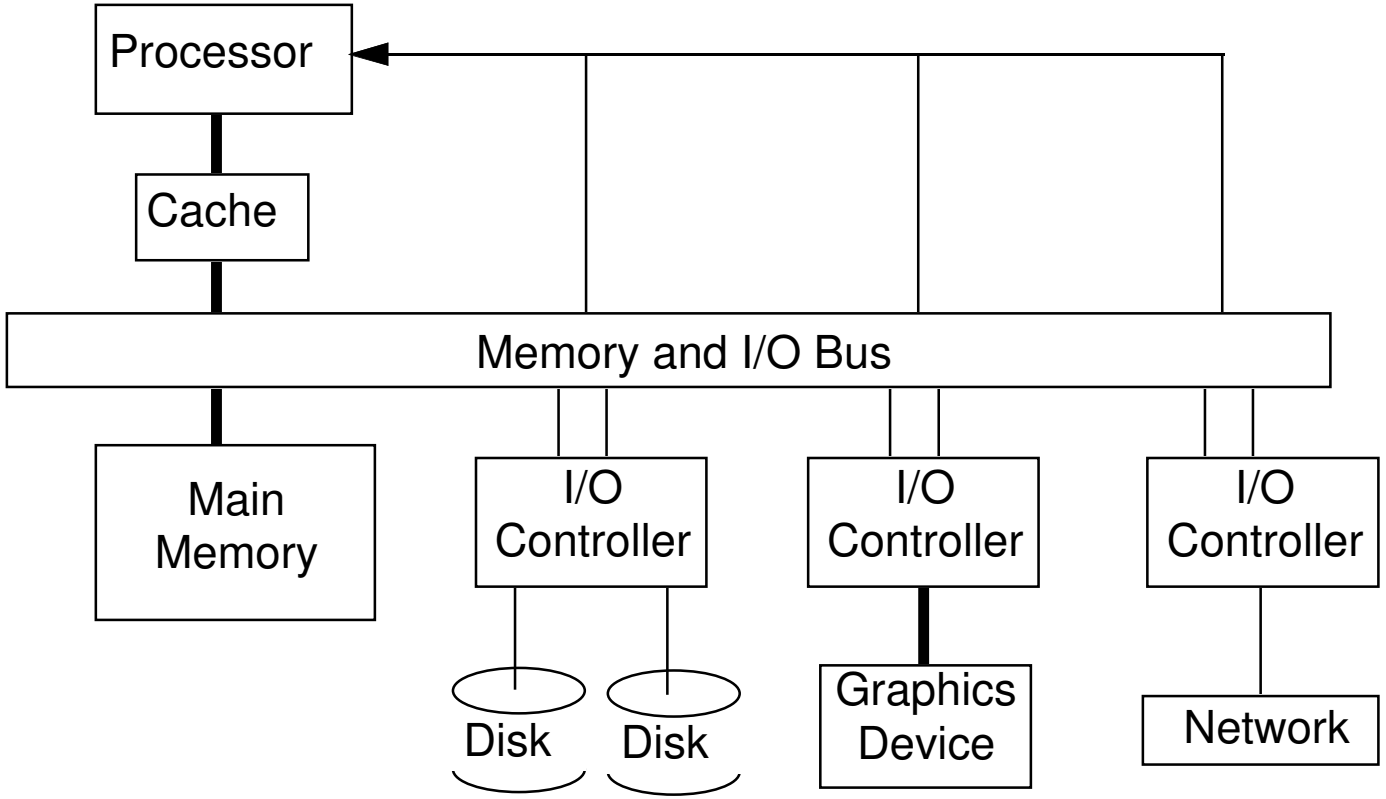
Input / Output

I/O is the practical topic most often ignored in computer science. Partly, there is a wide diversity among I/O devices. It is nevertheless very important.

Device	Type	Partner	Data Rate (KB/sec)
Keyboard	Input	Human	0.01
Laser Printer	Output	Human	100.00
Graphics Disp	Output	Human	30,000.00
Floppy	Store	Machine	50.00
Tape	Store	Machine	2,000.00

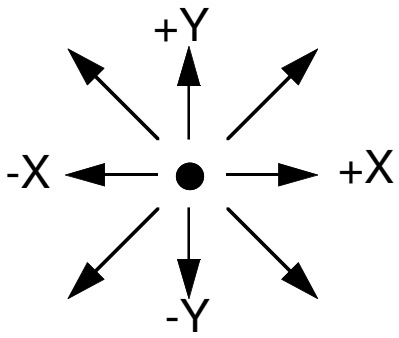
Years	CPU Time	I/O Time	Elapsed Time	%I/O
0	90 Seconds	10 Seconds	100 Seconds	10%
1	90/1.5=60	10 Seconds	70 Seconds	14%
2	60/1.5=40	10 Seconds	50 Seconds	20%
3	40/1.5=27	10 Seconds	37 Seconds	27%
4	27/1.5=18	10 Seconds	28 Seconds	36%
5	18/1.5=12	10 Seconds	22 Seconds	45%

Typical Architecture



Mouse

•The physical device has counters that record motion of the ball in the +X, -X, +Y and - Y directions.



•The counter values as well as the button positions are read-able by the processor.

•How does the processor know that the mouse has moved? It looks, using a process called polling.

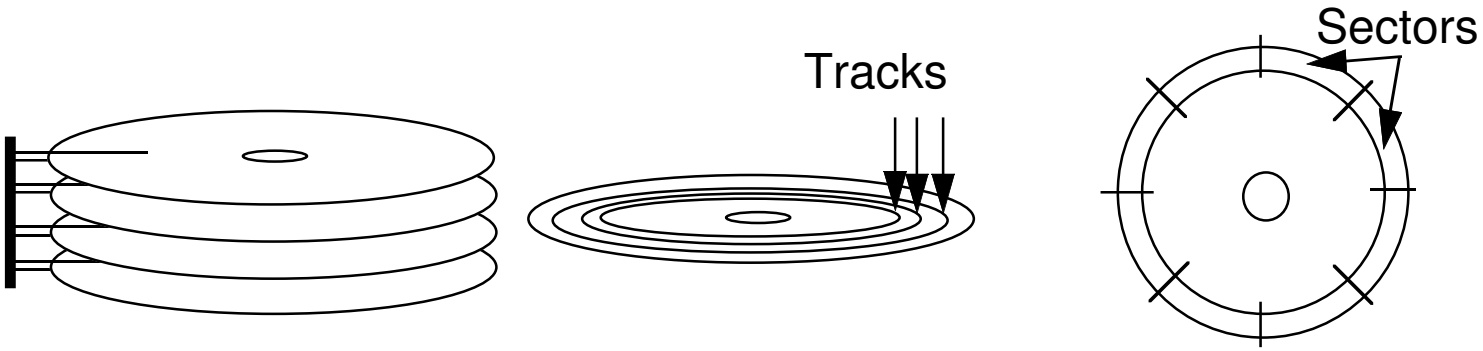
–Polling: A periodic check of status information to detect an unpredictable event.

Disks

Floppies are cheap and mobile.

A hard disk has more favorable properties:

- It can be larger because it is rigid.
- It can store more because it can be more precisely controlled.
- It can transfer data faster because it can spin faster.
- It can incorporate more than one platter.



Disk Terminology

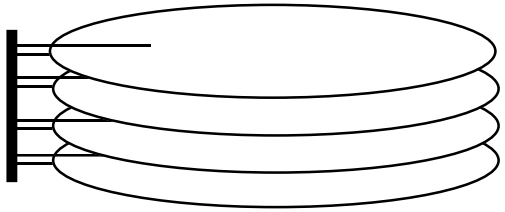
Seek time -- time to move the arm so the read head is positioned on a specific track. 12-20 ms average.
Performance measures:

Min seek time, Max seek time, Average seek time.

Average seek time: Sum of all seeks/number seeks.

Observed average is lower than reported average due to consecutive reading and OS efforts at to locality.

Rotational latency -- delay before the proper sector moves under the disk read head. 0.5 of revolution 3600-5400 RPM
Transfer rate -- MB/sec rate at which a sector is read off of the disk and transferred to the system bus. 2-4MB/sec.



Networks

RS-232 is a 0.3-19.2Kb/sec. standard for attaching terminals to computers.

Local Area Network (LAN) or Ethernet is a 10Mb/sec packetized interconnect technology.

Wide Area Networks typified by ARPANet use 56Kb telephone lines and store-and-forward packetization for long-haul communication.

Newer technologies, e.g. fiber optics, can raise transfer rate to 1 Gb/sec.