Performance?

- Performance measures, report, and summarize
- Make intelligent choices
- See through the marketing hype
- Key to understanding underlying organizational motivation

Airplane	Passengers	Range (mi)	Speed (mph)
Boeing 737-100	101	630	598
Boeing 747	470	4150	610
BAC/Sud Concorde	132	4000	1350
Douglas DC-8-50	146	8720	544

•How much faster is the Concorde compared to the 747?

•How much bigger is the 747 than the Douglas DC-8?

Computer Performance: TIME, TIME, TIME

- Response Time (latency)
  - — How long does it take for my job to run?
  - — How long does it take to execute a job?
  - — How long must I wait for the database query?
- Throughput
  - — How many jobs can the machine run at once?
  - — What is the average execution rate?
  - — How much work is getting done?

- *If we upgrade a machine with a new processor what do we increase?*

If we add a new machine to the lab what do we increase?

Execution Time and Performance

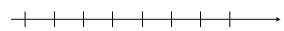
- Elapsed Time
  - – counts everything *(disk and memory accesses, I/O , etc.)*
  - – a useful number, but often not good for comparison purposes
- CPU time
  - – doesn't count I/O or time spent running other programs
  - – can be broken up into system time, and user time
- Our focus: user CPU time
  - – time spent executing the lines of code that are "in" our program
- For some program running on machine X,
  $\text{Performance}_X = 1 / \text{Execution time}_X$
- "X is n times faster than Y"
  $\text{Performance}_X / \text{Performance}_Y = n$
- Problem:
  - – machine A runs a program in 20 seconds
  - – machine B runs the same program in 25 seconds

Clock Cycles

- Instead of reporting execution time in seconds, we often use cycles

$$\frac{\text{seconds}}{\text{program}} = \frac{\text{cycles}}{\text{program}} \times \frac{\text{seconds}}{\text{cycle}}$$

- Clock "ticks" indicate when to start activities (one abstraction):



- cycle time = time between ticks = seconds per cycle
- clock rate (frequency) = cycles per second (1 Hz. = 1 cycle/sec)

A 200 Mhz. clock has a $\frac{1}{200 \times 10^6} \times 10^9 = 5$ nanoseconds cycle time

- Different instructions take different clock time
  - – Multiplication takes longer than add
  - – Floating point takes longer than integer
  - – Memory access takes longer than arithmetic or logic

Now that we understand cycles

- A given program will require
  - – some number of instructions (machine instructions)
  - – some number of cycles
  - – some number of seconds
- We have a vocabulary that relates these quantities:
  - – cycle time (seconds per cycle)
  - – clock rate (cycles per second)
  - – CPI (cycles per instruction)
    a floating point intensive application might have a higher CPI
  - – MIPS (millions of instructions per second)
    this would be higher for a program using simple instructions

Performance

- Performance is determined by execution time
- Do any of the other variables equal performance?
  - – # of cycles to execute program?
  - – # of instructions in program?
  - – # of cycles per second?
  - – average # of cycles per instruction?
  - – average # of instructions per second?

- Common pitfall: thinking one of the variables is indicative of performance when it really isn't.

CPI Example

- **Suppose we have two implementations of the same instruction set architecture (ISA).**

  For some program,

  Machine A has a clock cycle time of 10 ns. and a CPI of 2.0
  Machine B has a clock cycle time of 20 ns. and a CPI of 1.2

  What machine is faster for this program, and by how much?

- ***If two machines have the same ISA which of our quantities (e.g., clock rate, CPI, execution time, # of instructions, MIPS) will always be identical?***

of Instructions Example

- **A compiler designer is trying to decide between two code sequences for a particular machine. Based on the hardware implementation, there are three different classes of instructions: Class A, Class B, and Class C, and they require one, two, and three cycles (respectively).**

  The first code sequence has 5 instructions: 2 of A, 1 of B, and 2 of C
  The second sequence has 6 instructions: 4 of A, 1 of B, and 1 of C.

  Which sequence will be faster? How much?
  What is the CPI for each sequence?

MIPS example

- **Two different compilers are being tested for a 100 MHz. machine with three different classes of instructions: Class A, Class B, and Class C, which require one, two, and three cycles (respectively). Both compilers are used to produce code for a large piece of software.**

  The first compiler's code uses 5 million Class A instructions, 1 million Class B instructions, and 1 million Class C instructions.

  The second compiler's code uses 10 million Class A instructions, 1 million Class B instructions, and 1 million Class C instructions.

- **Which sequence will be faster according to MIPS?**
- **Which sequence will be faster according to execution time?**

Benchmarks

- **Performance best determined by running a real application**
  - **Use programs typical of expected workload**
  - **Or, typical of expected class of applications**
    e.g., compilers/editors, scientific applications, graphics, etc.
- **Small benchmarks**
  - **nice for architects and designers**
  - **easy to standardize**
  - **can be abused**
- **SPEC (System Performance Evaluation Cooperative)**
  - **companies have agreed on a set of real program and inputs**
  - **can still be abused (Intel's "other" bug)**
  - **valuable indicator of performance (and compiler technology)**
- **Spec 95 programs**
- **Spec 2000 programs**

Amdahl's Law

Execution Time After Improvement =

Execution Time Unaffected +(Execution Time Affected / Amount of Improvement)

- **Example:**

  "Suppose a program runs in 100 seconds on a machine, with multiply responsible for 80 seconds of this time. How much do we have to improve the speed of multiplication if we want the program to run 4 times faster?"

  How about making it 5 times faster?

- ***Principle: Make the common case fast***

Remember

- **Performance is specific to a particular program/s**
  - **Total execution time is a consistent summary of performance**

- **For a given architecture performance increases come from:**
  - **increases in clock rate (without adverse CPI affects)**
  - **improvements in processor organization that lower CPI**
  - **compiler enhancements that lower CPI and/or instruction count**

- **Pitfall: expecting improvement in one aspect of a machine's performance to affect the total performance**

- **You should not always believe everything you read! Read carefully!**
  (see newspaper articles, e.g., Exercise 2.37)