CSE 305: Computer Architecture

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Recap

Defining Performance

- desktop
  - gets the job done first
    - Response time
- datacenter server
  - completed the most jobs during a day
    - throughput

Execution Time & Bandwidth

Execution/Response time

- the time between the start & completion of a task

Bandwidth/Throughput

- the total amount of work done in a given time

Relative Performance

Computer X is n times as fast as computer Y,

$$\text{Performance}_X = \frac{1}{\text{Execution time}_X}$$

$$\frac{\text{Performance}_X}{\text{Performance}_Y} = \frac{\text{Execution time}_Y}{\text{Execution time}_X} = n$$

then, the execution time on Y is n times as long as it is on X.

Today's Topic

Measuring Computer Performance Contd.

- CPU clocking and clock rate
- Instruction Count
- Clock cycle per instruction
- The classic CPU performance equation

CPU Clock Cycles

- computers are constructed using a clock that determines when events take place
- these discrete time intervals are called clock cycles, or clock cycle time
- clock period, the time for a complete clock cycle
  - e.g., 250 picoseconds, or 250 ps
- clock rate, the number of completed clock cycles in 1 second
  - e.g., 4 gigahertz, or 4 GHz

$$\text{clock rate} = \frac{1}{\text{clock period}}$$

CPU Clock Cycles

Relation with CPU Performance

$$\begin{array}{c}\text{CPU execution time}\\ \text{for a program}\end{array} = \begin{array}{c}\text{CPU clock cycles}\\ \text{for a program}\end{array} \times \text{Clock cycle time}$$

$$\begin{array}{c}\text{CPU execution time}\\ \text{for a program}\end{array} = \frac{\text{CPU clock cycles for a program}}{\text{Clock rate}}$$

CPU Clock Cycles

Example

Our favorite program runs in 10 seconds on computer A, which has a 2 GHz clock. We are trying to help a computer designer build a computer, B, which will run this program in 6 seconds. The designer has determined that a substantial increase in the clock rate is possible, but this increase will affect the rest of the CPU design, causing computer B to require 1.2 times as many clock cycles as computer A for this program. What clock rate should we tell the designer to target?

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Instruction Performance

- execution time for a program depends on number of instructions in a program
- number of clock cycles required for a program can be written as,

$$\text{CPU clock cycles} = \text{Instructions for a program} \times \begin{array}{c}\text{Average clock cycles}\\ \text{per instruction}\end{array}$$

- average number of clock cycles per instruction is abbreviated as CPI

Instruction Performance

Example

Suppose we have two implementations of the same instruction set architecture. Computer A has a clock cycle time of 250 ps and a CPI of 2.0 for some program, and computer B has a clock cycle time of 500 ps and a CPI of 1.2 for the same program. Which computer is faster for this program and by how much?

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The Classic CPU Performance Equation

- combining the last two formulas, we can write the basic performance equation in terms of instruction count, CPI, and clock cycle time:

$$\text{CPU time} = \text{Instruction count} \times \text{CPI} \times \text{Clock cycle time}$$

$$\text{CPU time} = \frac{\text{Instruction count} \times \text{CPI}}{\text{Clock rate}}$$

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$$\text{CPU time} = \frac{\text{Instruction count} \times \text{CPI}}{\text{Clock rate}}$$

$$\text{Time} = \frac{\text{Seconds}}{\text{Program}} = \frac{\text{Instructions}}{\text{Program}} \times \frac{\text{Clock cycles}}{\text{Instruction}} \times \frac{\text{Seconds}}{\text{Clock cycle}}$$

The Classic CPU Performance Equation

Example 1

A given application written in Java runs 15 seconds on a desktop processor. A new Java compiler is released that requires only 0.6 as many instructions as the old compiler. Unfortunately, it increases the CPI by 1.1. How fast can we expect the application to run using this new compiler? Pick the right answer from the three choices below:

a. $\frac{15 \times 0.6}{1.1} = 8.2 \text{ sec}$

b. $15 \times 0.6 \times 1.1 = 9.9 \text{ sec}$

c. $\frac{15 \times 1.1}{0.6} = 27.5 \text{ sec}$

The Classic CPU Performance Equation

Example 2

A compiler designer is trying to decide between two code sequences for a particular computer. The hardware designers have supplied the following facts:

	CPI for each instruction class		
	A	B	C
CPI	1	2	3

For a particular high-level language statement, the compiler writer is considering two code sequences that require the following instruction counts:

	Instruction counts for each instruction class		
Code sequence	A	B	C
1	2	1	2
2	4	1	1

Which code sequence executes the most instructions? Which will be faster? What is the CPI for each sequence?

What's Next

- The power wall
- The switch from uniprocessors to multiprocessors
- Benchmarking the intel core i7
- Fallacies and Pitfalls

Reference

- Computer Organization and Design: The Hardware/Software Interface, *Chapter 1, 1.6*
  - David A. Patterson
  - John L. Hennessy