Measuring Performance

Lecture 2
Section 1.4

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Outline

What Is Performance?

- How do we measure the performance of a processor?
  - Time
    - Response time – Real time required to execute a program.
    - CPU time – Processor time required to execute a program.
  - Speed
    - Clock speed – Clock cycles (clocks) per second.
    - Instructions per second.
  - Throughput – Number of programs executed in a given span of time.

Clock Speed

- The processor's clock is an electronic device that outputs a signal that alternates between 0 and 1.
- The cycle time is the time required to complete one 0-1 cycle.
- All processor activity is tied to the clock.
- The faster the clock, the faster the activity.
- A typical clock speed is 2 GHz = 2 billion cycles/sec = 2×10^9 cycles/sec.
- 2 GHz is equivalent to a cycle time of 500 picoseconds (ps).

Cycles per Instruction

- How many clocks per instruction (CPI)?
- It depends on the architecture.
- CISC - Complex Instruction Set Computer
  - Different instructions require different numbers of cycles.
- RISC - Reduced Instruction Set Computer
  - All instructions require the same number of cycles...
  - But there can be delays.

CISC Machine

- Processor A is a CISC processor.
  - Its clock speed is 1GHz.
  - An `add` instruction will load two numbers from memory, add them, and store the result in memory.
  - The `add` instruction requires 1 clock cycle.

RISC Machine Without Pipelining

- Processor B is a RISC processor.
  - Its clock speed is 2GHz.
  - An `add` instruction will load two numbers from registers, add them, and store the result in a register.
  - The `add` instruction requires 1 clock cycle.
  - The `load` instruction requires 1 clock cycle.
  - the `store` instruction requires 1 clock cycle.

RISC Machine With Pipelining

- Processor C is like processor B, except that it uses a 4-stage pipeline.
- Each stage requires 1 clock cycle.
- Its clock speed is 4 GHz.

Outline

Outline

The CPU Performance Equation

- The CPU performance equation:

$$\begin{aligned}\text{CPU time} &= \text{Instruction count} \times \text{CPI} \times \text{Clock cycle time}\\ &= \frac{\text{Instruction count} \times \text{CPI}}{\text{Clock rate}}.\end{aligned}$$

Outline

Example

Example

- Computer *A* has a clock cycle time of 250 ps and a CPI of 2.0 for a program.
- For the same program, Computer *B* has a clock cycle time of 500 ps and a CPI of 1.2.
- Which computer executes the program faster?
- How much faster?

Example

Answer

- Compute the number of instructions per second executed by each computer.
- For Computer A:

$$\begin{aligned}
\text{secs/instruction (SPI)} &= 2.0\ \text{CPI} \times \frac{250\ \text{ps}}{1\ \text{cycle}} \\
&= \frac{2.0\ \text{cycles}}{1\ \text{instruction}} \times \frac{250\ \text{ps}}{1\ \text{cycle}} \\
&= \frac{500\ \text{ps}}{1\ \text{instruction}}.
\end{aligned}$$

Example

Answer

- For Computer *B*:

$$\begin{aligned}\text{secs/instruction (SPI)} &= 1.2\text{ CPI} \times \frac{500\text{ ps}}{1\text{ cycle}} \\ &= \frac{1.2\text{ cycles}}{1\text{ instruction}} \times \frac{500\text{ ps}}{1\text{ cycle}} \\ &= \frac{600\text{ ps}}{1\text{ instruction}}.\end{aligned}$$

- Therefore, Computer *A* is faster.
- Computer *A* is $\frac{600}{500} = 1.2$ times faster than Computer *B*.
- Computer *B* is 1.2 times slower than Computer *A*.

Different Instruction Classes

Example

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

- Instructions do not all require the same number of cycles.
- Suppose we have three classes of instructions *A*, *B*, and *C*, requiring 1, 2, and 3 cycles, respectively.

Different Instruction Classes

Example

Code sequence	Instruction counts for each instruction class		
	A	*B*	*C*
1	20	10	20
2	40	10	10

- Which code sequence will execute faster?
- How much faster?

Different Instruction Classes

Answer

- Compute the number of clocks for the code sequences.

$$\begin{aligned}\text{Cycles for seq 1} &= (20 \times 1) + (10 \times 2) + (20 \times 3) \\ &= 20 + 20 + 60 \\ &= 100. \\ \text{Cycles for seq 2} &= (40 \times 1) + (10 \times 2) + (10 \times 3) \\ &= 40 + 20 + 30 \\ &= 90.\end{aligned}$$

- Sequence 2 is faster.
- It is $\frac{100}{90} = 1.11$ times faster.

MIPS and FLOPS

- One poor measure of performance is MIPS (millions of instructions per second).
- Another poor measure is FLOPS (floating-point operations per second).
- The following example will demonstrate this.

MIPS and FLOPS

Example

Processor	Instr. Count	No. Instructions			CPI			Clock Rate
		L/S	FP	Branch	L/S	FP	Branch	
P1	5.0×10^6	30%	30%	40%	1.50	1.0	2.0	4 GHz
P2	2.0×10^6	40%	30%	30%	1.25	1.0	2.5	3 GHz

- Compute MIPS for both processors.
- Compute FLOPS for both processors.
- Compute the performance of both processors.

Processor P1

Answer

- Computations for P1:

$$\begin{aligned}
\text{CPI} &= (0.30 \times 1.50) + (0.30 \times 1.0) + (0.40 \times 2.0) \\
&= 1.55. \\
\text{MIPS} &= \frac{4 \times 10^9 \text{ CPS}}{1.55 \text{ CPI}} \\
&= 2.58 \times 10^9 \text{ IPS} . \\
\text{FLOPS} &= \frac{4 \times 10^9 \text{ CPS}}{1.0 \text{ CPI}} \\
&= 4.0 \times 10^9 \text{ IPS} . \\
\text{Run time} &= \frac{5.0 \times 10^6 \text{ instr}}{2.58 \times 10^9 \text{ IPS}} \\
&= 1.94 \times 10^{-3} \text{ sec.}
\end{aligned}$$

Processor P2

Answer

- Computations for P2:

$$\begin{aligned}
\text{CPI} &= (0.40 \times 1.25) + (0.30 \times 1.0) + (0.30 \times 2.5) \\
&= 1.55. \\
\text{MIPS} &= \frac{3 \times 10^9 \text{ CPS}}{1.55 \text{ CPI}} \\
&= 1.94 \times 10^9 \text{ IPS}. \\
\text{FLOPS} &= \frac{3 \times 10^9 \text{ CPS}}{1.0 \text{ CPI}} \\
&= 3.0 \times 10^9 \text{ IPS}. \\
\text{Run time} &= \frac{2.0 \times 10^6 \text{ instr}}{1.94 \times 10^9 \text{ IPS}} \\
&= 1.03 \times 10^{-3} \text{ sec.}
\end{aligned}$$

Outline

Assignment

Assignment

- Read Section 1.4.