CSSE232
Computer Architecture

Performance

Class status

- Reading for today:
  - Sections 1.4-1.9

- Lab 2 due soon

Class status

- What should you put in a comment at the top of your lab code?

- Your team member names!

Outline

- Performance
  - Measures of performance
  - Calculating CPU time
  - Instruction count and CPI
  - Amdahl's Law
  - Examples on the board

Computer Performance

- What are the measures of performance?

Computer Performance

- What are the measures of performance?
  - Many, many possible measures
    - Energy use, reliability, size, etc.
  - In this class we will use execution time

- Methods of calculation
  - Relative performance
  - Comparing code segments

Relative Performance

- "X is n time faster than Y"
- Example: time taken to run a program
  - 10s on A, 15s on B
  - Execution Time_B / Execution Time_A
    = 15s / 10s = 1.5
  - So A is 1.5 times faster than B

$$\frac{Performance_x}{Performance_y} = \frac{ExecutionTime_y}{ExecutionTime_x} = n$$

CPU Time

- Performance improved by
  - Reducing number of clock cycles
  - Increasing clock frequency
  - Hardware designer must often trade off clock rate against cycle count

$$CPU\,Time = CPU\,Clock\,Cycles \times Clock\,Cycle\,Time$$

$$CPU\,Time = \frac{CPU\,Clock\,Cycles}{Clock\,Freq}$$

CPU Time Example

- Computer A: 2GHz clock, 10s CPU time
- Designing Computer B
  - Aim for 6s CPU time
  - Can do faster clock, but causes 1.2 × clock cycles
- How fast must Computer B's clock be?

$$
\begin{aligned}
Clock\,Freq_A &= \frac{Clock\,Cycle_A}{CPU\,Time_A} \\
2 \times 10^9 &= \frac{Clock\,Cycle_A}{10s} \\
20 \times 10^9 &= Clock\,Cycle_A
\end{aligned}
$$

$$
\begin{aligned}
6s &= \frac{1.2 \times Clock\,Cycle_A}{Clock\,Freq_B} \\
Clock\,Freq_B &= \frac{1.2 \times 20 \times 10^9}{6s} \\
&= 4,000,000,000 = 4\text{GHz}
\end{aligned}
$$

Instruction Count and CPI

- Instruction Count for a program
  - Determined by program, ISA and compiler
- Average cycles per instruction
  - Determined by CPU hardware
  - If different instructions have different CPI
    - Average CPI affected by instruction mix

$$ExecTime = Instruction\,Count \times CPI \times \frac{1}{Clock\,Freq}$$

CPI Example

- Computer A: Cycle Time = 250ps, CPI = 2.0
- Computer B: Cycle Time = 500ps, CPI = 1.2
- Same ISA
- Which is faster, and by how much?

$$\begin{aligned}
\text{CPU Time}_A &= \text{Instruction Count} \times \text{CPI}_A \times \text{Cycle Time}_A \\
&= I \times 2.0 \times 250\text{ps} = I \times 500\text{ps} \\
\text{CPU Time}_B &= \text{Instruction Count} \times \text{CPI}_B \times \text{Cycle Time}_B \\
&= I \times 1.2 \times 500\text{ps} = I \times 600\text{ps}
\end{aligned}$$

$$\frac{\text{CPU Time}_B}{\text{CPU Time}_A} = \frac{I \times 600\text{ps}}{I \times 500\text{ps}} = 1.2$$

Performance Summary

- Performance depends on
  - Algorithm: affects IC, possibly CPI
  - Programming language: affects IC, CPI
  - Compiler: affects IC, CPI
  - Instruction set architecture: affects IC, CPI, T_c

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

Pitfall: Amdahl's Law

- Improving an aspect of a computer and expecting a proportional improvement in overall performance

$$T_{improved} = \frac{T_{affected}}{\text{improvement factor}} + T_{unaffected}$$

Pitfall: Amdahl's Law

- Example: multiply instructions account for 80s of the total 100s program time
  - How much improvement in multiply performance to get 5× overall?

5x improvement = 100s / 5 = 20s

$$20\text{s} = \frac{80\text{s}}{n} + 20\text{s}$$

  - Can't be done!

- Corollary: make the common case fast

CPI Example

- Alternative compiled code sequences using instructions in classes A, B, C

Class	A	B	C
CPI for class	1	2	3
IC in sequence 1	2	1	2
IC in sequence 2	4	1	1

- Sequence 1: IC = 5
  - Clock Cycles
    $= 2 \times 1 + 1 \times 2 + 2 \times 3$
    $= 10$
  - Avg. CPI = 10/5 = 2.0
- Sequence 2: IC = 6
  - Clock Cycles
    $= 4 \times 1 + 1 \times 2 + 1 \times 3$
    $= 9$
  - Avg. CPI = 9/6 = 1.5

Examples Handout on the board

Review and Questions

- Performance
  - Measures of performance
  - Calculating CPU time
  - Instruction count and CPI
  - Amdahl's Law
  - Examples on the board