CS305
Computer Architecture

Computer Performance Quantification

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Aspects of Computer Performance

Who cares?

Customer

Vendor

Computer designer (us)

Metrics

time to deliver

reliability
- % past failed attempts
- % past delays

cost, per unit weight

max weight

delivery confirmation

online tracking

#destinations on offer

pickup service

Computer Performance Equation

customer = one executing program

metric - execution time ✓

response time Linux: time

Sysad: throughput

multi-user environment

Prog. execn. time	= #cycles x clock-cycle-time
	= #cycles / clock-frequency
Prog. execn. time	= #instrns x [#cycles/instrn] x clock-cycle-time

executed

average across executed instructions

Mnemonic: $\frac{\text{Time}}{\text{Prog}} = \frac{\text{Instructions}}{\text{Prog}} \times \frac{\#\text{cycles}}{\text{instrn}} \times \frac{\text{Time}}{\text{cycle}}$

Use of the Computer Performance Equation: Example-1

Should MIPS support **blt** instruction?

Option-A: yes

Implications: #instructions = 5 million, 20% higher cycle time

Option-B: no

Implications: 10% instructions are blt, need to be replaced with 2 instructions

Execn time in A: 5 million × CPI × (1.2 t) slower

Execn time in B: 5.5 million × CPI × t faster

Use of the Computer Performance Equation: Example-2

Two implementations of the same instruction set:
Implementation-1: 2GHz, CPI=1.5
Implementation-2: 2.4GHz, CPI=2
Which is faster and by how much?

Execn. time Option-1: $I \times 1.5 \times \frac{1}{(2 \times 10^9)}$

Option-2: $I \times 2 \times \frac{1}{(2.4 \times 10^9)}$ $\rightarrow \frac{20}{18}$

Use of the Computer Performance Equation: Example-3

Intel instruction set supports memory as operand in add:

Option-1: implement add as 3 cycles

Implication: #cycles increases from 2 million to 2.4 million

Option-2: additional hardware support

Implication: cycle length increases by 10%

Which option is better?

ET1: $(2.4 \times 10^6) \times t$

ET2: $(2 \times 10^6) \times 1.1t$ faster

Measuring the Factors in the Performance Equation

instrns × CPI × cycle time

executed

profiling

Simulators

h/w counters

instruction mix

$$CPI_{ave} = \sum CPI_i \times f_i$$

Types of instrns:

arithmetic

memory

branch

$$0.25 \times 2 + 0.75 \times 1 = 1.25$$

Factors Affecting Performance

Factor	Aspects Affected
Algorithm	#instructions, sometimes CPI
Programming Language	#instructions, CPI
Compiler	#instructions, CPI
ISA	#instructions, CPI, cycle time
Hardware implementation	CPI, cycle time

Algorithm HLL Compiler ISA H/w impl.

Compiler Design Decision Example

CPI for branch instructions: 2
CPI for lw/sw: 3
CPI for reg-reg: 1
Code-sequence-1: 8 branches, 8 loads, 2 stores, 8 reg-reg
Code-sequence-2: 2 branches, 14 loads, 2 stores, 8 reg-reg
Which is better? By what factor?

ET1: $(8\times2 + 8\times3 + 2\times3 + 8\times1) \times t$

ET2: $(2\times2 + 14\times3 + 2\times3 + 8\times1) \times t$

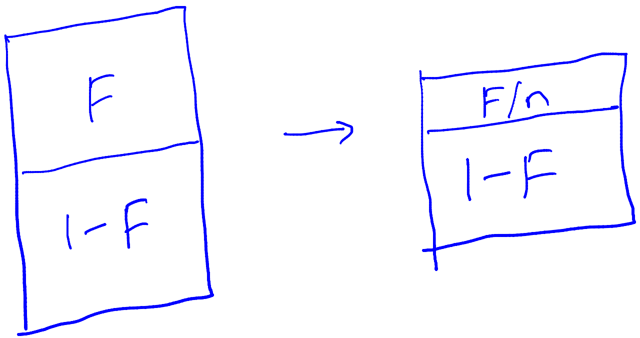
faster: $\frac{60}{54}$

Workload, Benchmark

- Which program to use for performance analysis?
- Benchmark: special or real ?
- SPEC: System Performance Evaluation Corporation
  - Since 1989
  - SPEC-2000 in textbook (includes gzip, gcc)
- How to summarize performance?
  - Think in terms of reproducibility of results
  - Give all possible details, e.g. input to program

Amdahl's Law

Performance improvement is limited by the fraction of program you are improving



$$\frac{1}{1-F+F/n} < \frac{1}{1-F}$$

Amdahl's Law: An Example

Intel wants to improve its CPU chip
Option-1: memory speedup 10x
Option-2: ALU speedup 2x
$F_{alu} = 0.5$, $F_{mem} = 0.2$, $F_{other} = 0.3$

Speedup 1 : $\dfrac{1}{1-0.2+\frac{0.2}{10}} \simeq 1.22$

Speedup-2 : $\dfrac{1}{1-0.5+\frac{0.5}{2}} \simeq 1.33$ ✓

Summary

- Computer performance quantification
  - Execution time is the primary metric
  - Helps answer various design questions quantitatively
- Role of benchmarks
- Amdahl’s law