CSCI 210: Computer Architecture
Lecture 23: Performance

Stephen Checkoway

Oberlin College

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Slides from Cynthia Taylor

Announcements

- Problem Set 7 due Friday
- Lab 6 due Sunday
- Office Hours Friday 13:30–14:30

Measures of "Performance"

- Execution Time
- Frame Rate
- Throughput (operations/time)
- Responsiveness
- Performance / Cost
- Performance / Power

Match (**Best**) Performance Metric to Domain

<u>Performance Metrics</u>

1. Network Bandwidth (data/sec)
2. Network Latency (ms per roundtrip)
3. Frame Rate (frames/sec)
4. Throughput (ops/sec)

	Online Games	High-def video	Torrent Download	Server Farm
A	4	3	1	2
B	4	1	3	2
C	2	1	3	4
D	2	3	1	4
E	None of the above			

Metrics for running a program

- Execution Time – how long does it take to run?
- CPI – (clock) cycles per instruction
- Instruction Count – how many instructions does it have?
- Clock cycle time

All Together Now

$$\boxed{\text{CPU Execution Time} = \text{Instruction Count} \times \text{CPI} \times \text{Clock Cycle Time}}$$

All Together Now

seconds

CPU Execution Time = Instruction Count X CPI X Clock Cycle Time

instructions

cycles/instruction

seconds/cycle

- You have a 1 billion (10^9) instruction program, a 500 MHz processor, and an execution time of 3 seconds. What is the CPI for this program?

- Note that 1 MHz = 1 million (10^6) cycles per second

Selection	CPI
A	3
B	15
C	1.5
D	15*10^9
E	None of the above

seconds

CPU Execution Time = Instruction Count X CPI X Clock Cycle Time

instructions

cycles/instruction

seconds/cycle

Who Affects Performance?

		IC				CT
CPU Execution Time	=	Instruction Count	X	CPI	X	Clock Cycle Time

- There are a number of people involved in processor / programming design
- Each of these elements of the performance equation can be impacted by different designer(s)
- Next slides will be about who can impact what.

Who Affects Performance?

CPU Execution Time	=	IC Instruction Count	X	CPI	X	CT Clock Cycle Time

- What can a programmer influence?

Selection	Impacts
A	IC
B	IC, CPI
C	IC, CPI, and CT
D	IC and CT
E	None of the above

Who Affects Performance?

		IC				CT
CPU Execution Time	=	Instruction Count	X	CPI	X	Clock Cycle Time

- What can a compiler influence?

Selection	Impacts
A	IC
B	IC, CPI
C	IC, CPI, and CT
D	CPI and CT
E	None of the above

Who Affects Performance?

$$\underset{\text{Time}}{\text{CPU Execution}} = \overset{\color{blue}{IC}}{\text{Instruction Count}} \times \text{CPI} \times \overset{\color{blue}{CT}}{\text{Clock Cycle Time}}$$

- What can an instruction set architect influence?

Selection	Impacts
A	IC
B	IC, CPI
C	IC, CPI, and CT
D	CPI and CT
E	None of the above

Who Affects Performance?

		IC				CT
CPU Execution Time	=	Instruction Count	X	CPI	X	Clock Cycle Time

- What can a hardware designer influence? Assume they are designing a chip for a fixed ISA.

Selection	Impacts
A	IC
B	IC, CPI
C	IC, CPI, and CT
D	CPI and CT
E	None of the above

If we run two different programs on the same machine, how do the number of instructions, CPI, and clock cycle time compare?

	Number of instructions	CPI	Clock cycle time
A	Same	Same	Same
B	Different	Same	Same
C	Different	Different	Same
D	Different	Different	Different
E	Different	Same	Different

If we run the same program on two different machines with different ISAs, how do the number of instructions, CPI, and clock cycle time compare?

	Number of instructions	CPI	Clock cycle time
A	Same	Same	Same
B	Same	Same	Different
C	Same	Different	Different
D	Different	Different	Different
E	Different	Same	Same

If we run the same program on two different machines with the same ISA, how do the number of instructions, CPI, and clock cycle time compare?

	Number of instructions	CPI	Clock cycle time
A	Same	Same	Same
B	Same	Same	Different
C	Same	Different	Different
D	Different	Different	Different
E	Different	Same	Same

How we can measure CPU performance

- Millions of instructions per second

- Performance on benchmarks—programs designed to measure performance

- Performance on real programs

MIPS (not the name of the architecture)

$$\text{MIPS} = \text{Millions of Instructions Per Second}$$

$$= \frac{\text{Instruction Count}}{\text{Execution Time} * 10^6}$$

$$= \frac{\text{Clock rate}}{\text{CPI} * 10^6}$$

- program-dependent
- deceptive

Benchmarks - Which Programs?

- Peak throughput measures (simple programs)?

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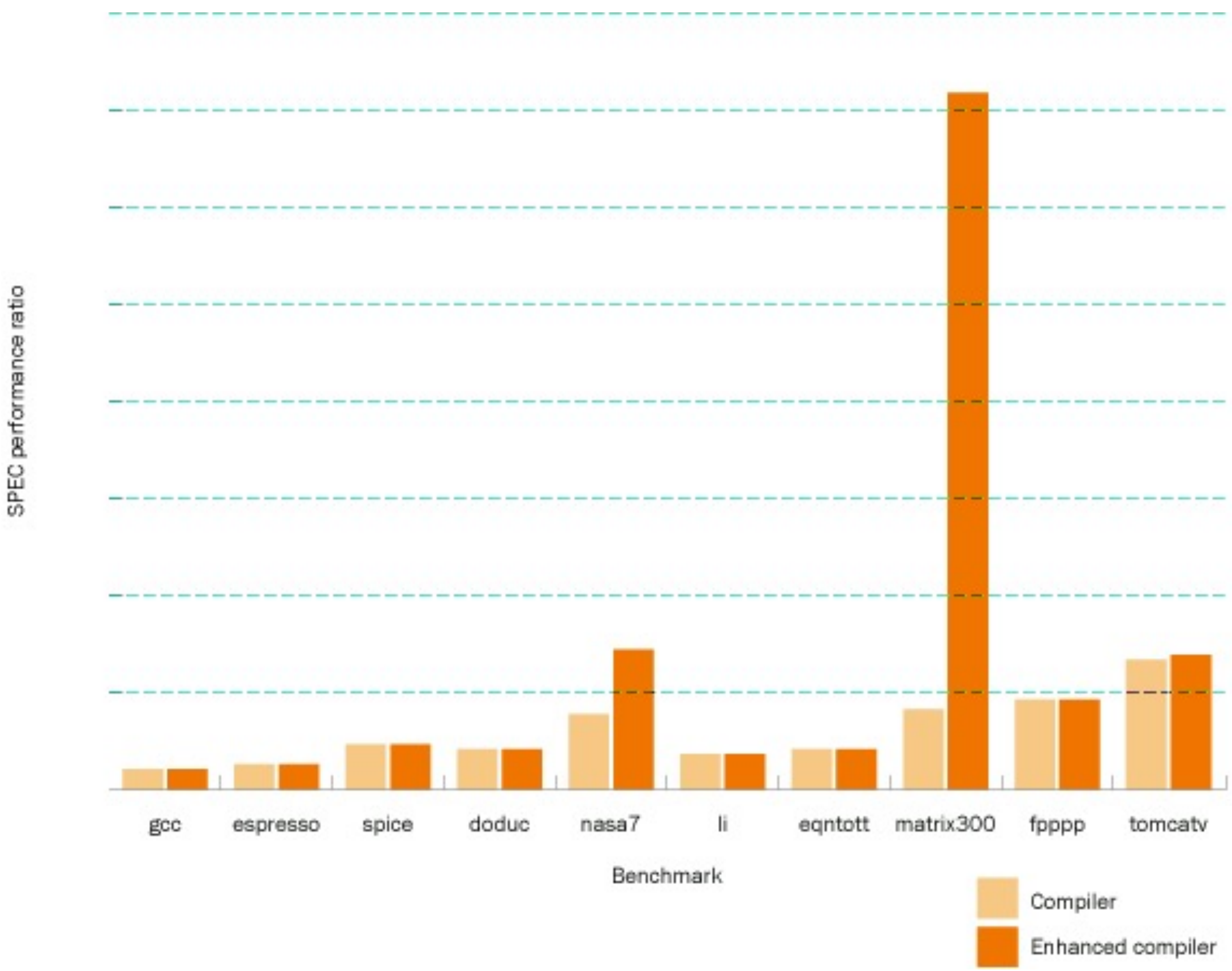
- Peak throughput measures (simple programs)?
- Synthetic benchmarks (whetstone, dhrystone,...)?
- Real applications
- SPEC (best of both worlds, but with problems of their own)
  - System Performance Evaluation Cooperative
  - Provides a common set of real applications along with strict guidelines for how to run them.
  - provides a relatively unbiased means to compare machines.

Danger in Benchmark-Specific Performance Measures

measures compiler as much as architecture!



Speedup

- Often want to compare performance of one machine against another

$$\text{Performance} = \frac{1}{\text{Execution Time}}$$

$$\text{Speedup (A over B)} = \frac{\text{Performance}_A}{\text{Performance}_B}$$

$$\text{Speedup (A over B)} = \frac{ET_B}{ET_A}$$

Reading

- Next lecture: Datapath
  - Section 5.2

- Problem Set 7 due Friday

- Lab 6 due Sunday