Tutorial 1 Performance benchmark

COMP2120B Computer organization

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Overview

- $MIPS\ rate = \frac{I_c}{T \times 10^6} = \frac{f}{CPI \times 10^6}$
- (average) Cycles per instruction: $CPI = \frac{\sum_{i=1}^{n} CPI_i \times I_i}{I_c}$
- Time needed to run a program: $T = I_c \times CPI \times \tau$
- I_c: Instruction count
- f: Clock rate
- τ: Clock cycle time, $f = \frac{1}{\tau}$

Question 1

(Problem 2.1 in textbook)

- A benchmark program is run on a **40 MHz processor**. The executed program consists of **100,000 instruction** executions, with the following instruction mix and clock cycle count.
- Determine the effective $\boldsymbol{CPI}$, $\boldsymbol{MIPS}$ **rate**, and **execution time** for this program.

Instruction Type	Instruction Count	Cycles per Instruction
Integer arithmetic	45,000	1
Data transfer	32,000	2
Floating point	15,000	2
Control transfer	8,000	2

Question 1 – execution time

- Total number of instructions: 100000
- Total number of cycles: $(45000 \times 1 + 32000 \times 2 + 15000 \times 2 + 8000 \times 2) = 155000$
- Cycle time: $\frac{1}{40 \times 10^6} = 25 \times 10^{-9} = 25ns$
- Time of execution: $155000 \times 25 \times 10^{-9} = 3.875ms$

Instruction Type	Instruction Count	Cycles per Instruction
Integer arithmetic	45,000	1
Data transfer	32,000	2
Floating point	15,000	2
Control transfer	8,000	2

Clock rate: **40MHz**

Instructions: **100,000**

Question 1 - CPI

- CPI: (average) clock cycle per instruction
- $CPI = \frac{\sum_{i=1}^{n} CPI_i \times I_i}{I_c} = \frac{(45000\times1+32000\times2+15000\times2+8000\times2)}{100000} = 1.55$

Instruction Type	Instruction Count	Cycles per Instruction
Integer arithmetic	45,000	1
Data transfer	32,000	2
Floating point	15,000	2
Control transfer	8,000	2

Clock rate: **40MHz**

Instructions: **100,000**

Question 1 – $MIPS$

- $MIPS$: Millions of instructions per second.
- $MIPS\ rate = \frac{I_c}{T \times 10^6} = \frac{f}{CPI \times 10^6}$
- $\frac{f}{CPI \times 10^6} = \frac{40 \times 10^6}{1.55 \times 10^6} = \frac{800}{31} \approx 25.81$

$$\frac{I_c}{T \times 10^6} = \frac{100000}{T \times 10^6} = \frac{800}{31}$$

$$\Rightarrow T = \frac{3.1 \times 10^6}{800 \times 10^6} = 3.875ms$$

Which is the same as our previous result.

Instruction Type	Instruction Count	Cycles per Instruction
Integer arithmetic	45,000	1
Data transfer	32,000	2
Floating point	15,000	2
Control transfer	8,000	2

Clock rate: **40MHz**

Instructions: **100,000**

Question 2

(Problem 2.2 in textbook)

- Consider two different machines, with two different instruction sets, both of which have a clock rate of **200 MHz**.
- The following measurements are recorded on the two machines running a given set of benchmark programs.
  - Determine the effective **CPI**, **MIPS rate**, and **execution time** for each machine.
  - Comment on the results.

Machine A

Instruction Type	Instruction Count (millions)	Cycles per Instruction
Arithmetic and logic	8	1
Load and store	4	3
Branch	2	4
Others	4	3

Machine B

Instruction Type	Instruction Count (millions)	Cycles per Instruction
Arithmetic and logic	10	1
Load and store	8	2
Branch	2	4
Others	4	3

Question 2 – solutions

	CPI	MIPS rate	Execution time
Machine A	2.22	90	0.2s
Machine B	1.92	104.3	0.23s

Machine A

Instruction Type	Instruction Count (millions)	Cycles per Instruction
Arithmetic and logic	8	1
Load and store	4	3
Branch	2	4
Others	4	3

Machine B

Instruction Type	Instruction Count (millions)	Cycles per Instruction
Arithmetic and logic	10	1
Load and store	8	2
Branch	2	4
Others	4	3

Question 3
(Problem 2.3 in textbook)

- Early examples of CISC and RISC design are the VAX 11/780 and the IBM RS/6000, respectively. Using a typical benchmark program, the following machine characteristics result.
- The final column shows that the VAX required 12 times longer than the IBM measured in CPU time.
  - What is the **relative size** of the instruction counts of the machine code for this benchmark program running on the two machines?
  - What are the **CPI** values for the two machines?

Processor	Clock Frequency (MHz)	Performance (MIPS)	CPU Time (secs)
VAX 11/780	5	1	$12x$
IBM RS/6000	25	18	x

Question 3 – instruction count

Processor	Clock Frequency (MHz)	Performance (MIPS)	CPU Time (secs)
VAX 11/780	5	1	$12x$
IBM RS/6000	25	18	x

- $MIPS\ rate = \frac{I_c}{T\times 10^6}$
- For VAX 11/780: $\frac{I_c}{12x\times 10^6} = 1 \Rightarrow I_C = 12x \times 10^6$
- For IBM RS/6000: $\frac{I_c}{x\times 10^6} = 18 \Rightarrow I_C = 18x \times 10^6 > 12x \times 10^6$
- The instruction count of the machine code running on IBM RS/6000 is higher than that on VAX 11/780.

Question 3 – CPI

Processor	Clock Frequency (MHz)	Performance (MIPS)	CPU Time (secs)
VAX 11/780	5	1	$12x$
IBM RS/6000	25	18	x

- $MIPS\ rate = \frac{f}{CPI \times 10^6}$
- For VAX 11/780: $\frac{5 \times 10^6}{CPI \times 10^6} = 1 \Rightarrow CPI = 5$
- For IBM RS/6000: $\frac{25 \times 10^6}{x \times 10^6} = 18 \Rightarrow CPI = \frac{25}{18} \approx 1.39$

Question 4

(Problem 2.4 in textbook)

- Four benchmark programs are executed on three computers with the following results.
- The table shows the execution time in seconds, with **100,000,000** instructions executed in each of the four programs.

	Computer A	Computer B	Computer C
Program 1	1	10	20
Program 2	1000	100	20
Program 3	500	1000	50
Program 4	100	800	100

- Calculate the **MIPS values** for each computer for each program.
- Then calculate the arithmetic and harmonic means assuming equal weights for the four programs, and rank the computers based on arithmetic mean and harmonic mean.

Question 4 – $MIPS$

- **100M** instructions are executed in each of the four programs

$MIPS$	Computer A	Computer B	Computer C
Program 1	100M/1M = 100	100M/10M = 10	100M/20M = 5
Program 2	100M/1000M = 0.1	100M/100M = 1	100M/20M = 5
Program 3	100M/500M = 0.2	100M/1000M = 0.1	100M/50M = 2
Program 4	100M/100M = 1	100M/800M = 0.125	100M/100M = 1

Question 4 – means

- $AM: \frac{1}{N}\sum a_i$
- $HM: \frac{N}{\sum \frac{1}{a_i}}$

$MIPS$	Computer A	Computer B	Computer C
Program 1	100	10	5
Program 2	0.1	1	5
Program 3	0.2	0.1	2
Program 4	1	0.125	1
AM	101.3/4 = 25.325	11.225/4 = 2.806	13/4 = 4.25
Rank by AM	1	3	2
HM	4/(1/100 + 1/0.1 + 1/0.2 + 1/1) = 0.250	4/(1/10 + 1/1 + 1/0.1 + 1/0.125) = 0.209	4/(1/5 + 1/5 + 1/2 + 1/1) = 2.105
Rank by HM	2	3	1