

CS 465 - Homework 1 – Fall 2016

Team Members:

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Part 2 (30% of grade for homework 1): [Exercises related to chapter 1.](#)

1. [20% of homework 1] Assume that the CPI for arithmetic, load/store, and branch instructions of a processor is 1, 10, and 6, respectively. Also assume that on a single processor a program requires the execution of  $2.56 \times 10^9$  arithmetic instructions,  $1.28 \times 10^9$  load/store instructions, and  $1.28 \times 10^8$  branch instructions. Assume that each processor has a 2 GHz clock frequency.

a. Find the total execution time (in sec) for this program on a single processor.

	arithmetic instructions	load/store instructions	branch instructions
CPI	1	10	6
Instruction count	$2.56 \times 10^9$	$1.28 \times 10^9$	$1.28 \times 10^8$

$$\begin{aligned}
 \text{CPU Time} &= \text{Instruction Count} \times \text{CPI} \times \text{Clock Cycle} \\
 &= \frac{\text{Instruction Count} \times \text{CPI}}{\text{Clock Rate}} \\
 &= \frac{1 \times 2.56 \times 10^9 + 10 \times 1.28 \times 10^9 + 6 \times 1.28 \times 10^8}{2 \text{ Ghz}} \\
 &= \frac{1 \times 2.56 \times 10^9 + 10 \times 1.28 \times 10^9 + 6 \times 1.28 \times 10^8}{2 \times 10^9 \frac{\text{cycles}}{\text{seconds}}} \\
 &= 8.064 \text{ seconds}
 \end{aligned}$$

b. Assume that, as the program is parallelized to run over multiple cores, the number of arithmetic and load/store instructions per processor is divided by 0.8 \* p (where p is the number of processors) but the number of branch instructions per processor remains the same. Find the total execution time for this program on 2 and 8 processors and show the relative speedup.

Execution time for 2 processors:  $0.8 \times p = 0.8 \times 2 = 1.6$

$$\begin{aligned}
 &= \frac{\frac{1 \times 2.56 \times 10^9}{1.6} + \frac{10 \times 1.28 \times 10^9}{1.6} + 6 \times 1.28 \times 10^8}{2 \times 10^9 \frac{\text{cycles}}{\text{seconds}}} = 5.184 \text{ seconds}
 \end{aligned}$$

$$\text{Relative speed up} = \frac{\text{Old}}{\text{new 8 processor}} = \frac{8.064 \text{ seconds}}{5.184 \text{ seconds}} = 1.555$$

Execution time for 8 processors:  $0.8 \times p = 0.8 \times 8 = 6.4$

$$= \frac{\frac{1 \times 2.56 \times 10^9}{6.4} + \frac{10 \times 1.28 \times 10^9}{6.4} + 6 \times 1.28 \times 10^8}{2 \times 10^9 \frac{\text{cycles}}{\text{seconds}}} = 1.584 \text{ seconds}$$

$$\text{Relative speed up} = \frac{\text{Old}}{\text{new 8 processor}} = \frac{8.064 \text{ seconds}}{1.584 \text{ seconds}} = 5.091$$

c. If the CPI of the arithmetic instructions was tripled, what would be the impact on the execution time of the program on 1, 2, or 8 processors? Point out the general trend you observe.

Execution time for 1 processors:

$$= \frac{3 \times 2.56 \times 10^9 + 10 \times 1.28 \times 10^9 + 6 \times 1.28 \times 10^8}{2 \times 10^9 \frac{\text{cycles}}{\text{seconds}}} = 10.624 \text{ seconds}$$

Execution time for 2 processors:  $0.8 \times p = 0.8 \times 2 = 1.6$

$$= \frac{\frac{3 \times 2.56 \times 10^9}{1.6} + \frac{10 \times 1.28 \times 10^9}{1.6} + 6 \times 1.28 \times 10^8}{2 \times 10^9 \frac{\text{cycles}}{\text{seconds}}} = 6.784 \text{ seconds}$$

Execution time for 8 processors:  $0.8 \times p = 0.8 \times 8 = 6.4$

$$= \frac{\frac{3 \times 2.56 \times 10^9}{6.4} + \frac{10 \times 1.28 \times 10^9}{6.4} + 6 \times 1.28 \times 10^8}{2 \times 10^9 \frac{\text{cycles}}{\text{seconds}}} = 1.984 \text{ seconds}$$

The trend is that the times are increasing which means that the execution is becoming slower for each different processors.

d. To what should the CPI of load/store instructions be reduced in order for a single processor to match the performance of 8 processors using the original CPI values?

We need to find the load store to match the time 1.584 *seconds* so we need to solve the Equation for the load/store.

$$\frac{1 \times 2.56 \times 10^9 + \frac{\text{load}}{\text{store}} \times 1.28 \times 10^9 + 6 \times 1.28 \times 10^8}{2 \times 10^9 \frac{\text{cycles}}{\text{seconds}}} = 1.584 \text{ seconds}$$

$$\text{load/store} \times 1.28 \times 10^9 = (1.584 \times 2 \times 10^9) - (2.56 \times 10^9 + 6 \times 1.28 \times 10^8)$$

$$\text{load/store} = \frac{(1.584 \times 2 \times 10^9) - (2.56 \times 10^9 + 6 \times 1.28 \times 10^8)}{1.28 \times 10^9}$$

$$\text{load/store} = 0.125$$

2. [10% of homework 1] Consider a computer running a program that requires 320 sec, with 90 sec spent executing floating point (FP) instructions, 100 sec executing Load/Store (L/S) instructions, 60 sec spent executing branch (BR) instructions, and 70 sec spent executing integer (INT) instructions.

	Total running Time	floating point (FP) instructions	Load/Store (L/S) instructions	branch (BR) instructions	integer (INT) instructions
	320	90	100	60	70
a	297.5	67.5	100	60	70
b	313	90	100	60	63
c	245	90	100	60-80=-20	70

a. By how much is the total time reduced if the time for FP instructions is reduced by 25% (assuming all other instructions are not changed)?

$$\text{FP} = 0.25 \times 90 = 22.5 \quad \text{Total time} = 320 - 22.5 = 297.5$$

b. By how much is the time for INT instructions reduced if the total time is reduced by 10% (assuming all other instructions are not changed)?

$$\text{INT} = 0.10 \times 70 = 7 \quad \text{Total time} = 320 - 7 = 313$$

c. Can the total time be reduced by 25% by reducing only the time for branch instructions?

Total time needs to be reduced by  $= 0.25 \times 320 = 80$  but the branch instructions takes only 60 seconds so it will be impossible to be reduced less than it takes. Reducing the branch instructions will not help in this case.

