Com S 321 Homework 4 Due: Thursday, Sept. 21, Midnight
Fall 2017

1. We wish to compare the performance of two different machines: M1 and M2. The following measurements have been made on these machines:

Program	Time on M1	Time on M2
1	10 secs	5 secs
2	3 secs	4 secs

Which machine is faster for each program and by what percent?

2. Consider the two machines and programs in Problem 1. The following additional measurements are made:

Program	Instructions executed on M1	Instructions executed on M2
1	$200 * 10^6$	$160 * 10^6$

Find the instruction execution rate (instructions per second) for each machine when running program 1.

3. If the clock rates of machines M1 and M2 in Problem 1 are 200 MHz and 300 MHz respectively, find the clock cycles per instruction (i.e., CPI) for program 1 on both machines using data given in Problems 1 and 2.

4. Assume that the CPI for program 2 on each machine is the same as the CPI for program 1 computed in Problem 3. Using these CPI values find the Instruction Count for program 2 running on each machine (use the execution times from Problem 1).

5. Suppose that machine M1 in Problem 1 costs $10,000 and M2 costs $15,000. If you ran program 1 on machines M1 and M2, clearly M2 executes the program faster (5 secs instead of 10 secs). However, you may not want to spend $5,000 extra on machine M2 to get a gain of 5 seconds for just a single run of program 1. But if you needed to run program 1 a large number of times and were concerned with the cost/performance ratio over thousands of runs instead of a single run, which machine would you buy in large quantities and why?

6. Consider two different implementations, M1 and M2, of the same instruction set. There are four classes of instructions (A, B, C, and D) in the instruction set. M1 has a clock rate of 500 MHz. The average number of cycles for each instruction class on M1 is as follows:

Class	CPI for this class
A	1
B	2
C	3
D	4

M2 has a clock rate of 750 MHz. The average number of cycles for each instruction class on M2 is as follows:

Class	CPI for this class
A	2
B	2
C	4
D	4

Peak performance is defined as the fastest rate that a machine can execute an instruction sequence. It is determined by assuming that ALL instructions in a given instruction sequence execute at the smallest number of cycles.

Determine the peak performance of machines M1 and M2 expressed as instructions per second.

7. If the number of instructions executed in a certain program is divided equally among the classes of instructions in Problem 6, how much faster is M2 than M1?
(Hint: First compute the CPI for M1 and M2: For M1, CPI = (1+2+3+4)/4 = 2.5; for M2, CPI = (2+2+4+4)/4 = 3).

8. Using the data from problems 6 and 7, at what clock rate would machine M1 have the same performance as the 750-MHz version of machine M2?

9. We are studying two implementations of a machine, one with and one without special floating-point hardware. Consider a program P with the following mix of operations:

Floating-point multiply	10%
Floating-point add	15%
Floating-point divide	5%
Integer instructions	70%

Machine MFP (Machine with Floating-point) has floating-point hardware and can therefore implement the floating-point operations directly. It requires the following number of clock cycles for each instruction class:

Floating point Multiply	6	cycles
Floating point Add	4	cycles
Floating point Divide	20	cycles
Integer instructions	2	cycles

Machine MNFP (Machine with No Floating Point) has no floating-point hardware and so must emulate the floating-point operations using integer instructions. Each integer instruction on MNFP takes 2 clock cycles (so its CPI is 2). The number of integer instructions needed to implement each of the floating-point operations on MNFP is as follows:

Floating point multiply	30 integer instructions
Floating point add	20 integer instructions
Floating point divide	50 integer instructions

Both machines have a clock rate of 1000 MHz.

(a) Find the MIPS rating for both MFP and MNFP.

(b) If the MFP machine needs 300 million instructions for the program P, how many integer instructions are needed on the MNFP machine for the same program P?

(c) What is the execution time in seconds for program P on MFP and MNFP, assuming the instruction count from part (b)?

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1] - For program 1 E.T of M_1 is 10 secs while execution time for M_2 is 5 secs. Thus, M_2 is faster than M_1. M_2 is faster than M_1 →: $\frac{E.T. M_1}{E.T. M_2} = 1 + \frac{N}{100}$; $\frac{10}{5} = 1 + \frac{N}{100}$; $N = 100$ by 100%

- For program 2 E.T of M_1 is 3 secs while E.T of M_2 is 4 secs. Thus, M_1 is faster than M_2. M_1 is faster than M_2:
$\frac{E.T M_2}{E.T M_1} = \frac{4}{3} = 1 + \frac{N}{100}$, $N = 33.333$. by 33.333 %

2] Execution Rate = $\frac{\text{Instructions executed on machine}}{\text{Time taken}}$

- Machine 1:
$$E.R = \frac{200 * 10^6}{10} = 20 * 10^6$$

- Machine 2:
$$E.R = \frac{160 * 10^6}{5} = 32 * 10^6$$

3] CPI = $\frac{E.T * \text{Clock Rate}}{\text{Instructions Executed on M}}$

- Machine 1:
$$CPI = \frac{10 * 200 * 10^6}{200 * 10^6} = 10$$

- Machine 2:
$$CPI = \frac{5 * 300 * 10^6}{160 * 10^6} = 9.375$$

4] $CPI.M_1 = 10$, $CPI.M_2 = 9.375$, $ET.M_1 = 3$, $ET.M_2 = 4$

- Machine 1:

$$MIPS = \frac{\text{Clock Rate}}{CPI * 10^6}, \quad E.T = \frac{I.C}{MIPS * 10^6}$$

$$MIPS = \frac{200 * 10^6}{10 * 10^6} = 20$$

$$3 = \frac{I.C}{20 * 10^6}, \quad I.C = 3 * 20 * 10^6 = 60 * 10^6$$

- Machine 2:

$$MIPS = \frac{300 * 10^6}{9.375 * 10^6} = 32$$

$$4 = \frac{I.C}{32 * 10^6}, \quad I.C = 4 * 32 * 10^6 = 128 * 10^6$$

5] I am going to purchase machine 2 because the $\frac{\text{Cost}}{\text{Speedup}} = \frac{15K}{2} = 7.5K < 10K$. Also, machine 2 is 2-wice as fast as machine 1 & it doesn't cost 2-wice as much.

6] • Machine 1:

$$\text{Peak MIPS} = \frac{500 * 10^6}{1 * 10^6} = 500 \text{ MIPS/IPS}$$

- Machine 2:

$$P.M = \frac{750 * 10^6}{2 * 10^6} = 375 \text{ MIPS/IPS}$$

7] $CPI.M_1 = 2.5$, $CPI.M_2 = 3$

$$M_1.MIPS = \frac{500 * 10^6}{2.5 * 10^6} = 200$$

$$M_2.MIPS = \frac{750 * 10^6}{3 * 10^6} = 250$$

→ M_2 is faster than M_1 by $\frac{250}{200} = 1.25$ times. Or 25%

8 $CPI_{M_1} = 2.5$, $CPI_{M_2} = 3$, $MIPS_{M_1} = 1.25 * MIPS_{M_2}$, $MIPS_{M_2} = 250$

$$\boxed{E.T = \frac{I.C * CPI}{C.R}} \rightarrow \frac{I.C * 2.5}{C.R} = \frac{I.C * 3}{750 * 10^6}$$

– Machine 1 will have the same performance as M_2 at $\boxed{C.R = 625\,Mhz}$

9 (a) • $CPI_{MFP} = 0.1 * 6 + 0.15 * 4 + 0.05 * 20 + 0.7 * 2$
$= 3.6$

• $MIPS_{MFP} = \frac{1000 * 10^6}{3.6 * 10^6} = 277.778$

• $CPI_{MNFP} = 2$

• $MIPS_{MNFP} = \frac{1000 * 10^6}{2 * 10^6} = 500$

(b)

Flt.pt *	10%	0.1 * 300M = 30M
Flt.pt +	15%	0.15 * 300M = 45M
Flt.pt ÷	5%	0.05 * 300M = 15M
I.I	70%	0.7 * 300M = 210M

– On MNFP, the Flt.pt instructions need to be emulated by integer instructions. # of instructions on MNFP:

Flt.pt *	30 * 30M = 900 M
Flt.pt +	45 * 20M = 900 M
Flt.pt ÷	50 * 15M = 750 M

$\text{Total}\ \#_{MNFP} = 900M + 900M + 750M + 210M = 2760M$

(c) $E.T_{MFP} = \frac{IC_{MFP}}{MIPS * 10^6} = \frac{300 * 10^6}{277.778 * 10^6} = 1.08$

$E.T_{MFP} = \frac{2760 * 10^6}{500 * 10^6} = 5.52$