CMSC 411
Homework #1 Solutions

Exercise 1.6 From the text, the CPU time equation is

$$CPU\ Time = IC \times CPI \times Clk$$

From the exercise statement, we know that the CPI is always one for the unoptimized system. Therefore the CPU time on the unoptimized system, CPU_{un}, is

$$CPU_{un} = IC_{un} \times 1.0 \times Clk_{un}$$

From the exercise statement, the unoptimized machine has a clock rate that is 5% higher than that of the optimized machine, thus

$$Clk_{opt} = 1.05(Clk_{un})$$

In addition, the optimized machine does not execute one-third of the load and store instructions executed by the optimized machine. As a result, the instruction count of the optimized machine, IC_{opt}, is

$$IC_{opt} = .9(IC_{un})$$

Combining the above results, CPU_{opt} is expressed as

$$CPU_{opt} = .9(IC_{un}) \times 1.0 \times 1.05(Clk_{un})$$

Finally, the speedup of optimization over the unoptimized machine is

$$Speedup = \frac{CPU_{un}}{CPU_{opt}} = \frac{(IC_{un})(1.0)(Clk_{un})}{.9(IC_{un})(1.0)1.05(Clk_{un})} = 1.06$$

As a result, the increase in clock cycle time is offset by the reduction in instructions executed and the procedure call optimization increases performance by 6%.

Exercise 1.13(a) By definition,

$$MIPS = \frac{Instruction\ Count}{Execution\ Time \times 10^6}$$

Without coprocessor, the total instruction count is the number of integer instructions plus the number of floating-point instructions times the number of integer instructions required to execute each floating-point instruction: $I + F \times Y$. The time to execute the code is given as W seconds.

$$MIPS = \frac{I + F \times Y}{W \times 10^6}$$

For the configuration with the coprocessor, the total instruction count is $I + F$. The time to execute the code is given as B seconds.

$$MIPS = \frac{I + F}{B \times 10^6}$$

Exercise 1.13(b) To find I for the workstation without the coprocessor, plugging in the known values from the first equation of 1.13(a) yields

$$120 = \frac{I + (8 \times 10^6) \times 50}{4 \times 10^6}$$

Solving for I yields

$$I = 8 \times 10^7$$

Exercise 1.13(c) To find B for the workstation with the coprocessor, we use the value of I computed in 1.13(b) along with the value of F given in 1.13(b) and the stated rate of 80 MIPS for this configuration and plug it into the second equation of 1.13(a), we get:

$$B = 1.1$$

Exercise 1.13(d) From 1.13(c), the value of B was computed to be 1.1 seconds. From 1.13(b), the total number of floating point operations is $F = 8 \times 10^6$.

$$MFLOPS = \frac{8 \times 10^6}{10^6 \times 1.1} = 7.3$$

Exercise 1.13(e) We note that MIPS ratings computed goes down with the addition of the coprocessor, even though the execution time of the program improves. Thus the MIPS ratings are not providing an accurate representation of real performance. In any case, since adding the coprocessor improves execution time, it should be considered for purchase.

Exercise 1.14(a) Recall from Section 1.8 of the text:

$$MFLOPS = \frac{Number\ of\ Floating\ Point\ Operations\ in\ a\ Program}{(Execution\ Time\ in\ Seconds) \times 10^6}$$

After pluging the execution times given in Figure 1.11 of the text and the number of floating-point operations per program specified in the exercise statement into the above equation, we obtain the following table. It shows the execution times (in seconds) and the MFLOPS ratings.

Prog.	Computer A		Computer B		Computer C	
	Time	MFLOPS	Time	MFLOPS	Time	MFLOPS
P1	1	100	10	10	20	5
P2	1000	.1	100	1	20	5
Total	1001	–	110	–	40	–

Exercise 1.14(b) Using the table in Exercise 1.14(a), we can obtain the result in the following table.

Mean	Computer		
	A	B	C
Arithmetic	50.1	5.5	5.0
Harmonic	.2	1.8	5.0
Geometric (norm. to A)	1.0	1.0	1.6
Geometric (norm. to B)	1.0	1.0	1.6
Geometric (norm. to C)	1.4	1.4	1.0

Exercise 1.14(c) From 1.14(a) and 1.14(b), the harmonic mean seems to track total execution time the best. This makes sense given that we are examining rate information (MFLOPS). The arithmetic mean has opposite behavior. The geometric mean does not accurately reflect the differences in the magnitude of execution times.