Chapter 4 Solutions: For More Practice

4.4 We wish to maximize the rate of processing while minimizing the total cost required to do so. Therefore we are most interested in the cost per unit throughput. At first glance, it may seem reasonable that (Cost/Throughput) = (Cost/(1 run of program 1/Execution time)) = (Cost * Execution time)/(1 run of program 1) is an equivelent model of this. However this fails when we think about machines that can run multiple programs simultaneously. Consider the case where machine M can run 3 instances of program 1 concurrently, but takes twice as long to complete program 1 as equally priced machine M′, which can only run 1 program at a time. Then by the (Cost * Execution time), M′ would appear better, but M has 50% more throughput than M′.

4.5 M1 takes 7.0 seconds total, and M2 takes 11.5 seconds total. Thus, M1 is 11.5/7.0 = 1.64 times faster. The ratio of costs is 800/500 = 1.60. Therefore, M1 is more cost-effective, since it gets a 1.64 performance boost for a 1.6 cost decrease.

4.35 $\text{MIPS} = \dfrac{\text{Clock rate}}{\text{CPI} \times 10^6}$. Let's find the CPI for MFP first:

$$\text{CPI for MFP} = 0.1 \times 6 + 0.15 \times 4 + 0.05 \times 20 \times 0.7 \times 2 = 3.6$$

of course, the CPI for MNFP is simply 2. So $\text{MIPS for MFP} = \dfrac{1000}{\text{CPI}} = 278$ and $\text{MIPS for MNFP} = \dfrac{1000}{\text{CPI}} = 500$.

4.36

Instruction class	Frequency on MFP	Count on MFP in millions	Count on MNFP in millions
Floating-point multiply	10%	30	900
Floating-point add	15%	45	900
Floating-point divide	5%	15	750
Integer instructions	70%	210	210
Totals	100%	300	2760

4.37 $\text{Execution time} = \dfrac{\text{Instructions}}{\text{MIPS} \times 10^6}$. So execution time is $\dfrac{300}{278} = 1.08$ seconds, and execution time on MNFP is $\dfrac{2760}{500} = 5.52$ seconds.

4.38 The CPI of each machine is just the weighted average of the CPIs for each of the instruction classes. Thus:

CPI of Mbase $= 2(0.40) + 3(0.25) + 3\ (0.25) + 5(0.10)$

$= 0.8 + 0.75 + 0.75 + 0.50 = 2.8$ cycles/instruction

CPI of Mopt $= 2(0.40) + 2(0.25) + 3\ (0.25) + 4(0.10)$

$= 0.8 + 0.50 + 0.75 + 0.40 = 2.45$ cycles/instruction

4.39 The MIPS rating is in millions of instructions per second. Thus we see that

Instructions per second = (Instructions/cycles) * (Cycles/second) = 1/(CPI) * (Clock rate)

So:

MIPS rating of Mbase = (500×10^6 cycles/second) / (2.8 cycles/instruction) = 178.6×10^6 instructions/second = 178.6 MIPS.

and

MIPS rating of Mopt = (600×10^6 cycles/second) / (2.45 cycles/instruction) = 244.9×10^6 instructions/second = 244.9 MIPS.

4.40 Since Mbase and Mopt use the same instruction set, the relative performance can be determined as the ratio of their MIPS ratings (as opposed to the execution time).

Thus: Mopt is faster than Mbase by a factor of (244.9 MIPS/178.9 MIPS) = 1.37.

4.41 This problem can be done in one of two ways. Either find the new mix and adjust the frequencies first, or find the new (relative) instruction count and divide the CPI by that. We use the latter.

$$\text{Ratio of instructions} = 0.9 \times 0.4 + 0.9 \times 0.25 + 0.85 \times 0.25 + 0.1 \times 0.95 = 0.8925 .$$

So we can calculate CPI as

$$\text{CPI} = \frac{2 \times 0.4 \times 0.9 + 3 \times 0.25 \times 0.9 + 3 \times 0.25 \times 0.85 + 5 \times 0.1 \times 0.95}{0.8925} = 2.81$$

4.42 How must faster is Mcomp than Mbase?

$$\text{CPU time Mbase} = \frac{\text{IC} \times \text{CPI}}{\text{Clock rate}} = \frac{\text{IC} \times 2.8}{\text{Clock rate}}$$

$$\text{CPU time Mcomp} = \frac{\text{IC} \times 0.8925 \times 2.81}{\text{Clock rate}} = \frac{\text{IC} \times 2.5}{\text{Clock rate}}$$

So then

$$\frac{\text{Performance Mcomp}}{\text{Performance Mbase}} = \frac{\text{CPU time Mbase}}{\text{CPU time Mcomp}} = \frac{\dfrac{\text{Clock rate}}{\text{IC} \times 2.8}}{\dfrac{\text{Clock rate}}{\text{IC} \times 2.5}} = \frac{2.8}{2.5} = 1.12$$

4.43 The CPI is different from either Mbase or Mcomp; find that first:

$$\text{Mboth CPI} = \frac{2 \times 0.4 \times 0.9 + 2 \times 0.25 \times 0.9 + 3 \times 0.25 \times 0.85 + 4 \times 0.1 \times 0.95}{0.8925} = 2.45$$

$$\frac{\text{Performance Mboth}}{\text{Performance Mbase}} = \frac{\text{CPU time Mbase}}{\text{CPU time Mboth}} = \frac{\dfrac{\text{IC} \times 2.8}{\text{Clock rate}}}{\dfrac{\text{IC} \times 0.8925 \times 2.45}{\text{Clock rate}}} = \frac{\dfrac{2.8}{500\text{ MHz}}}{\dfrac{2.19}{600\text{ MHz}}} = 1.53$$

4.44 First, compute the performance growth after 6 and 8 months. After 6 months = $1.034^6 = 1.22$. After 8 months = $1.034^8 = 1.31$. The best choice would be to implement Mboth.

Months	Mbase	Mcomp	Mopt	Mboth
0	1.00			
. . .				
6	1.22	1.12	1.37	
8	1.31	1.20	1.46	1.53