A2 - Performance (solutions)

ECE 429

Question 1

Problem

Question 1.13 From Hennessy and Patterson Ed. 5

Your company is trying to choose between purchasing the Opteron or Itanium 2. You have analyzed your company's applications, and 60% of the time it will be running applications similar to wupwise, 20% of the time application similar to ammp, and 20% of the time applications similar to apsi.

a. If you were choosing just based on overall SPEC performance, which would you choose and why?

b. What is the weighted average of execution time ratios for this mix of applications for the Opteron and Itanium 2?

c. What is the speedup of the Opteron over the Itanium 2?

Solution

From Figure 1.17 in the textbook (page 43)

	Opteron		Itanium	
benchmark	time (s)	SPEC ratio	time (s)	SPEC ratio
wupwise	51.5	31.06	56.1	28.53
ammp	136.0	16.14	132.0	16.63
apsi	150.0	17.36	231.0	11.27
⋮	⋮	⋮	⋮	⋮
geometric mean		20.86		27.12

* note that the geometric mean includes additional benchmarks shown in the textbook, but not replicated here

a. Based on the overall SPEC performance (geometric mean of all benchmark tests), the Itanium 2 should be selected as it has a higher overall SPECRatio.

b. Note that it asks for the mean of the execution time ratios (SPECRatios). Since these are ratios, we will use a weighted geometric mean.

$$
\begin{aligned}
mean &= \sqrt[(0.6+0.2+0.2)]{(SPECRatio_{wupwise})^{0.6} * (SPECRatio_{ammp})^{0.2} * (SPECRatio_{apsi})^{0.2}} \\
&= (SPECRatio_{wupwise})^{0.6} * (SPECRatio_{ammp})^{0.2} * (SPECRatio_{apsi})^{0.2}
\end{aligned}
$$

$$\begin{aligned} Opteron &= (31.06)^{0.6} * (16.14)^{0.2} * (17.36)^{0.2} \\ &= 24.25 \end{aligned}$$

$$\begin{aligned} Itanium2 &= (28.53)^{0.6} * (16.63)^{0.2} * (11.27)^{0.2} \\ &= 21.27 \end{aligned}$$

Therefore using the weighted average, the Opteron would be selected.

c.

$$\begin{aligned} S &= \frac{SPECRatio_A}{SPECRatio_B} \\ &= \frac{24.25}{21.27} = 1.14 \end{aligned}$$

Question 2

Problem

Question 1.17 from Hennessy and Patterson ed. 5.

Your company has just bought a new Intel Core i5 dual-core processor, and you have been tasked with optimizing your software for this processor. You will run two applications on this dual core, but the resource requirements are not equal. The first application requires 80% of the resources and the other only 20% of the resources. Assume that when you parallelize a portion of the program, the speedup for that portion is 2.

a. Given that 40% of the first application is parallelizable, how much speedup would you achieve with that application if run in isolation?

b. Given that 99% of the second application is parallelizable, how much speedup would this application observe if run in isolation?

c. Given that 40% of the first application is parallelizable, how much *overall system speedup* would you observe if you parallelized it?

d. Given that 99% of the second application is parallelizable, how much overall system speedup would you observe if you parallelized it?

Solution

Note:

F_{enh} = fraction of the program that is enhanced S_{enh} = speedup of enhanced portion S = speedup

$$S = \frac{1}{(1 - F_{enh}) + \frac{F_{enh}}{S_{enh}}}$$

a.

$$S = \frac{1}{0.6 + \frac{0.4}{2}} = 1.25$$

b.

$$S = \frac{1}{0.01 + \frac{0.99}{2}} = 1.98$$

c.

$$S = \frac{1}{0.2 + \frac{0.8}{1.25}} = 1.19$$

d.

$$S = \frac{1}{0.8 + \frac{0.2}{1.98}} = 1.11$$

Question 3

Problem

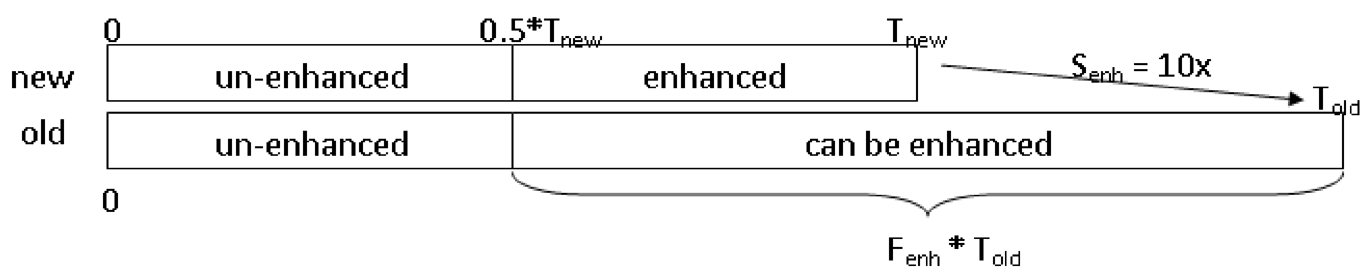
Question 1.15 from Hennessy and Patterson ed.5.

Assume that we make an enhancement to a computer that improves some mode of execution by a factor of 10. Enhanced mode is used 50% of the time, measured as a percentage of the execution time *when the enhanced modeis in use*. Recall that Amdahl's law depends on the fraction of the original *unenhanced* execution time that could make use of the enhanced mode. Thus we cannot directly use this 50% measurement to computer speedup with Amdahl's law.

a. what is the speedup we have obtained from fast mode?

b. What percentage of the original execution time has been converted to fast mode?

Solution



a.

$$0.5 * T_{new} = F_{enh} * T_{old} * \frac{1}{S_{enh}} \tag{1}$$

$$Amdahl's : T_{new} = \left[(1 - F_{enh}) + \frac{F_{enh}}{S_{enh}}\right] T_{old} \tag{2}$$

$$= T_{old} - T_{old} * F_{enh} + T_{old} * F_{enh} * \frac{1}{10} \tag{3}$$

Rearranging eq 1 and subbing in $S_{enh} = 10$:

$$F_{enh} = \frac{5 * T_{new}}{T_{old}}$$

Subbing into eq 3

$$T_{new} = T_{old} - T_{old} * \frac{5 * T_{new}}{T_{old}} + \frac{1}{10} T_{old} * \frac{5 * T_{new}}{T_{old}}$$
$$T_{new} = T_{old} - 4.5 * T_{new}$$
$$\frac{T_{old}}{T_{new}} = 5.5 = S$$

b.

$$S = 5.5 = \frac{1}{(1 - F_{enh}) + \frac{F_{enh}}{S_{enh}}} = \frac{1}{(1 - F_{enh}) + \frac{F_{enh}}{10}}$$

$$\frac{1}{5.5} = (1 - F_{enh}) + \frac{F_{enh}}{10}$$
$$= 1 - \frac{9}{10} F_{enh}$$

$$\frac{9}{10} F_{enh} = 1 - \frac{1}{5.5}$$
$$F_{enh} = 91\%$$

Question 4

Problem

Consider the following alternatives for a conditional branch instruction:

- CPU A: some condition code is set by a compare instruction and followed by a branch instruction which tests the condition code.
- CPU B: include a compare in the branch

The conditional branch instruction, on both CPUs, takes 2 cycles, while all other instructions take 1 clock cycle. For CPUA, 20% of all instructions executed are conditional branches; hence, since every branch needs a compare, another 20% of the instructions are compares. Since CPU A does not have the compare included in the branch, assume that its clock cycle time is 1.25x faster than that of CPU B. Which CPU is faster? Suppose CPU A was only 1.1x faster?

CPU A		
instruction	# cycles	IC
cmp	1	0.2* IC_A
bra	2	0.2* IC_A
other	1	0.6* IC_A

CPU B		
instruction	# cycles	IC
cmpbra	2	0.2* IC_A
other	1	0.6* IC_A

Solution

a.

$$\begin{aligned} T_A &= (\sum_{i=1}^{3} IC_i CPI_i) \times \text{Clock cycle Time}_A \\ &= (0.2 \times 1 + 0.2 \times 2 + 0.6 \times 1) IC_A \times CCT_A \\ &= 1.2 \times IC_A \times CCT_A \end{aligned}$$

$$\begin{aligned} T_B &= (\sum_{i=1}^{2} IC_i CPI_i) \times 1.25(\text{Clock cycle Time}_A) \\ &= (0.2 \times 2 + 0.6 \times 1) IC_A \times 1.25(CCT_A) \\ &= 1.25 \times IC_A \times CCT_A \end{aligned}$$

$\therefore$ CPU A is faster ($T_A < T_B$)

b.

$$\begin{aligned} T_B &= (\sum_{i=1}^{2} IC_i CPI_i) \times 1.1(\text{Clock cycle Time}_A) \\ &= (0.2 \times 2 + 0.6 \times 1) IC_A \times 1.1(CCT_A) \\ &= 1.1 \times IC_A \times CCT_A \end{aligned}$$

$\therefore$ CPU B is faster ($T_B < T_A$)

Question 5

Problem

a. If processor A has a higher clock rate than processor B, and processor A also has a higher MIPS rating than processor B, explain whether processor A will always execute faster than processor B.

b. Suppose that there are two implementations of the same instruction set architecture. Machine A has a clock cycle time of 20ns and an effective CPI of 1.5 for some program, and machine B has a clock cycle time of 15ns and an effective CPI of 1.0 for the same program. Which machine is faster for this program and by how much?

Solution

a.

$$\text{MIPS} = \frac{\text{clock rate}}{CPI \times 10^{-6}} \rightarrow CPI = \frac{\text{clock rate}}{\text{MIPS} \times 10^{-6}}$$

$$\begin{aligned} T &= IC \times CPI \times CCT \\ &= IC \times \frac{\text{clock rate}}{\text{MIPS} \times 10^{-6}} \times CCT \\ &= IC \times \frac{1}{\text{MIPS} \times 10^{-6}} \end{aligned}$$

$\therefore$ if the instruction count is the same, the computer with the higher MIPS is always faster, regardless of the clock rate

b.

$$T_A = 1.5 \times IC \times 20ns \qquad T_B = 1.0 \times IC \times 15ns$$
$$= 30 \times ICns \qquad = 15 \times ICns$$

$\therefore$ processor B is 2x as fast as processor A.