Course Name:计算机组成原理
Course Code:CS202
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Assignment 1

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Score : ________

Problem 1 (1.9) Score: ________.

Assume for arithmetic, load/store, and branch instructions, a processor has CPIs of 1, 12, and 5, respectively. Also assume that on a single processor a program requires the execution of 2.56E9 arithmetic instructions, 1.28E9 load/store instructions, and 256 million branch instructions. Assume that each processor has a 2 GHz clock frequency.

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 $0.7 \times p$ (where p is the number of processors) but the number of branch instructions per processor remains the same.

(1) Find the total execution time for this program on 1, 2, 4, and 8 processors, and show the relative speedup of the 2, 4, and 8 processor result relative to the single processor result.

(2) If the CPI of the arithmetic instructions was doubled, what would the impact be on the execution time of the program on 1, 2, 4, or 8 processors?

(3) To what should the CPI of load/store instructions be reduced in order for a single processor to match the performance of four processors using the original CPI values?

Solution: (1) Consider the program on one processor, the total cycle count is $1 \times 2.56 \times 10^9 + 12 \times 1.28 \times 10^9 + 5 \times 2.56 \times 10^8 = 1.92 \times 10^{10}$. Then consider the total excution time, that is, the *cycle count*/*cycle frequency*:

$$\text{Excution time for one processor is } 1.92 \times 10^{10}/(2 \times 10^9) = 9.6 \times 10^9$$

By the same way, the total execution time for this program on 2, 4, and 8 processors are shown in the following table.

processor count	arithmetic inst.	L/S inst.	branch inst.	cycles	excution time	speed up rate
1	2.56E9	1.28E9	2.56E8	1.92E10	9.60E9	1.00
2	1.83E9	9.14E8	2.56E8	1.41E10	7.05E9	1.36
4	9.14E8	4.57E8	2.56E8	7.68E9	3.84E9	2.50
8	4.57E8	2.29E8	2.56E8	3.46E9	1.73E9	5.55

Table 1: Excution time and speed-up rate

(2) The answer is shown in following table.

processor count	excution time
1	9.84E9
2	7.95E9
4	4.30E9
8	2.47E9

Table 2: Excution after double the CPI of arithmetic instructions

(3) Assume the $CPI_{L/S\_inst.}$ is ruduce to x. Then the excution time (Hint: the performance is measured by the excution time) of one processor is

$$2.56 \times 10^9 + 1.28 \times 10^9 x + 2.56 \times 10^8 \times 5 = 3.84 \times 10^9 + 1.28 \times 10^8 x$$

With original CPI values, the excution time of four processors is

$$2.56 \times 10^9/(0.7 \times 4) + 1.28 \times 10^9 \times 12/(0.7 \times 4) + 2.56 \times 10^8 \times 5 = 7.68 \times 10^9$$

To minimize the difference of performance, that is to ruduce the *abs* difference of the two result above:

$$\left|(3.84 \times 10^9 + 1.28 \times 10^8 x) - (7.68 \times 10^9)\right| \qquad \text{Then } x = 3. \text{ That is the answer.}$$

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Problem 2 (1.11) Score: ________.

The results of the SPEC CPU2006 bzip2 benchmark running on an AMD Barcelona has an instruction count of 2.389E12, an execution time of 750 s, and a reference time of 9650 s.

(1) Find the CPI if the clock cycle time is 0.333 ns.

(2) Find the SPECratio.

(3) Find the increase in CPU time if the number of instructions of the benchmark is increased by 10% without affecting the CPI.

(4) Find the increase in CPU time if the number of instructions of the benchmark is increased by 10% and the CPI is increased by 5%.

(5) Find the change in the SPECratio for this change.

(6) Suppose that we are developing a new version of the AMD Barcelona processor with a 4 GHz clock rate. We have added some additional instructions to the instruction set in such a way that the number of instructions has been reduced by 15%. The execution time is reduced to 700 s and the new SPECratio is 13.7. Find the new CPI.

(7) This CPI value is larger than obtained in 1.11.1 as the clock rate was increased from 3 GHz to 4 GHz. Determine whether the increase in the CPI is similar to that of the clock rate. If they are dissimilar, why?

(8) By how much has the CPU time been reduced?

(9) For a second benchmark, libquantum, assume an execution time of 960 ns, CPI of 1.61, and clock rate of 3 GHz. If the execution time is reduced by an additional 10% without af ecting to the CPI and with a clock rate of 4 GHz, determine the number of instructions.

(10) Determine the clock rate required to give a further 10% reduction in CPU time while maintaining the number of instructions and with the CPI unchanged.

(11) Determine the clock rate if the CPI is reduced by 15% and the CPU time by 20% while the number of instructions is unchanged.

Solution: (1) CPU time = Instruction count × CPI × clock cycle time, then $CPI = \frac{750s}{2.389\times10^{12}\times0.333\times10^{-9}s} \approx 0.943$.

(2) The SPECratio is $\frac{T_{ref}}{T_{actual}} = \frac{9650s}{750s} \approx 12.87$.

(3) From CPU time = Instruction count × CPI × clock cycle time, hence if number of instructions of the benchmark is increased by 10% then the CPU time is insreased by 10%.

(4) From (3) we can obtain that $\frac{T_{new}}{T_{old}} = 1.1 \times 1.05 = 1.155$($T_{old}$ represents the CPU time before change, and T_{new} represents the CPU time after change). That is, the CPU time is increased by 15.5%.

(5) The change of SPECratio can extract from the change of excution time because:

$$\frac{SPECratio_{new}}{SPECratio_{old}} = \frac{\frac{T_{ref}}{T_{actual_{new}}}}{\frac{T_{ref}}{T_{actual_{old}}}} = \frac{T_{actual_{old}}}{T_{actual_{new}}} = \frac{1}{1.155} \approx 0.866$$

That is, the SPECratio is decreased by 13.4%.

(6) CPU time = Instruction count × CPI × clock cycle time, then CPI = $\frac{700\times4\times10^{9}}{0.85\times2.389\times10^{12}} \approx 1.38$

(7) Clock rate ratio is $\frac{4GHz}{3Ghz} \approx 1.33$. CPI ratio is $\frac{1.38}{0.94} \approx 1.47$. So they are dissimilar. The reason is when the number of instructions has been reduced by 15%, the CPU time is decreased from 750s to 700s at the same time, then there is a difference between clock rate ratio and CPI ratio.

(8) $\frac{700s}{750s} \approx 0.933$, so the CPU time has been reduced by 6.7%.

(9) Number of instructions = CPU time $\times \frac{CPI}{CPUtime} = 960 \times 0.9 \times 4 \times 10^{9}/1.61 \approx 2.147 \times 10^{12}$

(10) Only change clock rate to rudece the CPU time. Clock rate = Number of instructions × CPI / CPU time. The new clock is $3GHz \times \frac{1}{0.9} \approx 3.33GHz$.

(11) Change clock rate and CPI to rudece the CPU time. Clock rate = Number of instructions × CPI / CPU time. The new clock is $3GHz \times 0.85 \times \frac{1}{0.8} \approx 3.19GHz$.

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