Assignment1

1.9

> 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 x p (where p is the number of processors) but the number of branch instructions per processor remains the same.

CPI

- arithmetic：1
- load/store：12
- branch instructions：5

Single processor a program

- arithmetic：2.56×10^9
- load/store：1.28×10^9
- branch instructions：2.56×10^8

Clock frequency

2 Ghz = 2×10^9 hz

Multiple cores

- arithmetic：/0.7p
- load/store：/0.7p
- branch instructions：/1

1.9.1

> 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.

According to:

$Clock\ Cycles = \sum_{i=1}^{n} Instruction\ Count_i \times CPI_i$

$Execution\ Time = \frac{Clock\ Cycles}{Clock\ Frequency}$

processor num	arithmetic num(1)	load/store num(12)	branch num(5)	execution time	speedup
1	2.56×10^9	1.28×10^9	2.56×10^8	9.6	1
2	1.83×10^9	9.14×10^8	2.56×10^8	7.04	1.36
4	9.12×10^8	4.57×10^8	2.56×10^8	3.84	2.5
8	4.57×10^8	2.29×10^8	2.56×10^8	2.4	4.29

1.9.2

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?

processor num	arithmetic num(1)	load/store num(12)	branch num(5)	execution time	speedup(relative to 1.9.1)
1	5.12×10^9	1.28×10^9	2.56×10^8	10.88	0.88
2	3.66×10^9	9.14×10^8	2.56×10^8	7.965	1.2
4	1.82×10^9	4.57×10^8	2.56×10^8	4.3025	2.23
8	9.14×10^8	2.29×10^8	2.56×10^8	2.47	3.89

1.9.3

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?

Execution time of four processors: 3.84s

If single processor's performance match with the four processors, which means:

$$\frac{5.12 \times 10^9 + 1.28 \times 10^9 \times CPI_{load/store} + 2.56 \times 10^8 \times 5}{2 \times 10^9} = 3.84$$

Solve the equation we find:

$$CPI_{load/store} = 3$$

1.11

> 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.

- instruction count: 2.389×10^{12}
- execution time: 750s
- reference time: 9650s

1.11.1

> Find the CPI if the clock cycle time is 0.333 ns.

$$CPI = \frac{CPU\ Time}{Instruction\ Count \times Clock\ Cycle\ Time}$$
$$CPI = \frac{750}{2.389 \times 10^{12} \times 0.333 \times 10^{-9}} = 0.94$$

1.11.2

> Find the SPECratio.

$$SPECratio = \frac{9650}{750} = 12.87$$

1.11.3

> Find the increase in CPU time if the number of instructions of the benchmark is increased by 10% without aff ecting the CPI.

$$Instruction\ count_{new} = 1.1 Instruction\ Time$$
$$CPUtime_{new} = \frac{1.1 Instruction\ count \times CPI}{Clock\ rate} = 1.1 CPUtime = 825s$$
$$increase = \frac{825}{750} = 1.1$$

Thus, CPU time is increased by 10%.

1.11.4

> 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%.

$$Instruction\ count_{new} = 1.1 Instruction\ count$$
$$CPI_{new} = 1.05 CPI$$
$$CPUtime = \frac{1.1 Instruction\ count \times 1.05 CPI}{Clock\ rate} = 1.155 CPUtime = 866.25s$$
$$increase = \frac{866.25}{750} = 1.155$$

Thus, CPU time is increased by 15.5%.

1.11.5

> Find the change in the SPECratio for this change.

$$SPECratio_{new} = \frac{9650}{866.25} = 11.14$$
$$SPECchange = \frac{11.14}{12.86} = 0.86$$

Thus, the SPECratio is decreased by 14%.

1.11.6

> 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.

$$CPUTime_{new} = \frac{9650}{13.7} = 700$$

$$CPI = \frac{CPUTime_{new} \times Clock\ Rate}{0.85 Instruction\ Count} = \frac{700 \times 4 \times 10^9}{0.85 \times 2.389 \times 10^{12}} = 1.38$$

1.11.7

> 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?

$$Clock\ rate\ ratio = \frac{4GHz}{3GHz} = 1.33$$

$$CPI_{4GHz} = 1.37, CPI_{3GHz} = 1.33$$

$$CPI\ ratio = \frac{1.37}{1.33} = 1.45$$

They are different.

Although the number of instructions has been reduced by 15%, the CPU time has been reduced by a lower percentage.

1.11.8

> By how much has the CPU time been reduced?

$$\frac{700}{750} = 0.933$$

CPU time reduction: 6.7%.

1.11.9

> 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 aff ecting to the CPI and with a clock rate of 4 GHz, determine the number of instructions.

$$Instruction\ count = \frac{CPUtime \times Clock\ Rate}{CPI} = \frac{960 \times 10^{-9} \times 0.9 \times 4 \times 10^9}{1.61} = 2.15 \times 10^3$$

1.11.10

> 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.

$$Clock\ Rate_{new} = \frac{Instruction\ Count \times CPI}{0.9 \times CPUtime} = \frac{Clock\ Rate}{0.9} = 3.33GHz$$

1.11.11

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

$$Clock\ Rate_{new} = \frac{Instruction\ Count \times 0.85 \times CPI}{0.8 \times CPUtime} = \frac{0.85 \times Clock\ Rate}{0.8} = 3.19GHz$$