Alan Palayil Homework - 1 Due: 9/16/2022

Q1 Ex 1.2

a) Assembly lines in automobile manufacturing.
→ "Performance via Pipelining."

b) Suspension bridge cables.
→ "Performance via Parallelism."

c) Aircraft and marine navigation systems that incorporate wind information.
→ "Performance via Prediction."

d) Express elevators in buildings.
→ "Make the Common Case Fast."

e) Library reserve desk.
→ "Hierarchy of Memories."

f) Increasing the gate area on a CMOS transistor to decrease its switching time Design for Moore's Law.
→ "Design for Moore's Law."

g) Adding electromagnetic aircraft catapults (which are electrically-powered as opposed to current steam-powered models), allowed by the increased power generation offered by new reactor technology.
→ "Dependability via Redundancy."

Q2 Ex 1.6

Formulae used for this problem.

$$\text{CPU clock cycle} = \sum_{i=1}^{n} (\text{CPU}_i) \times C_i \quad \& \quad \text{CPU} = \frac{\text{CPU clock cycle}}{\text{clock rate}}$$

From the given:

10% class A, 20% class B, 50% class C, and 20% class D.

The program executes

$10^6 \times 10\% = 10^5$ instructions of class A.

$10^6 \times 20\% = 2\times 10^5$ instructions of class B.

$10^6 \times 50\% = 5\times 10^5$ instructions of class C.

$10^6 \times 20\% = 2\times 10^5$ instructions of class D.

For Processor $P_1$, the CPI is: (1, 2, 3, 3).

$$\text{CPU clock cycles} = (1\times 10^5) + (2\times 2\times 10^5) + (3\times 5\times 10^5) + (3\times 2\times 10^5)$$
$$= 2.6\times 10^6 \quad -(i)$$

For Processor $P_2$, the CPI is: (2, 2, 2, 2).

$$\text{CPU clock cycles} = (2\times 1\times 10^5) + (2\times 2\times 10^5) + (2\times 5\times 10^5) + (2\times 2\times 10^5)$$
$$= 2\times 10^6 \quad -(ii)$$

From (i) & (ii), the execution time of each rocessor is:

$$\text{CPU}_{\text{Time}1} = \frac{2.6\times 10^6}{2.5\text{ GHz}} = 1.04\text{ ms} \quad -(A)$$

$$\text{CPU}_{\text{Time}2} = \frac{2\times 10^6}{3\text{ GHz}} = 666.67\text{ms} \quad -(B)$$

From (A) & (B), Processor $P_2$ is faster than $P_1$ //

P

a) CPI for Processors are:

$$\text{CPI}_{P_1} = \frac{\text{CPU clock cycles}}{\text{no. of instructions}} = \frac{2.6\times \cancel{10^6}}{\cancel{10^6}}$$

$$\boxed{\text{CPI}_{P_1} = 2.6}$$

$$\text{CPI}_{P_2} = \frac{\text{CPU clock cycles}}{\text{no. of instructions}} = \frac{2\times \cancel{10^6}}{\cancel{10^6}}$$

$$\boxed{\text{CPI}_{P_2} = 2}$$

b) CPU clock cycles were calculated in (i) & (ii)

$$\boxed{\begin{aligned}\text{CPU clock cycles}_{P_1} &= 2.6\times 10^6\\ \text{CPU clock cycles}_{P_2} &= 2\times 10^6\end{aligned}}$$

Q3 Ex 1.9

Formulae used for this problem.

$$\text{Clock cycles} = CPI_{FP} \times (\text{no. of FP instructions}) + CPI_{INT} \times (\text{no. of INT instructions}) + CPI_{L/S} \times (\text{no. of L/S instructions}) + CPI_{branch} \times (\text{no. of branch instructions})$$

$$\text{CPU execution time} = \frac{\text{clock cycle}}{\text{clock rate}}$$

$$\text{Relative speed} = \frac{\text{Time taken by 1 processor}}{\text{Time taken by p processor}}$$

Ex 1.9.1

For execution time for $P_1$:

$$P_1 \text{ clock cycles} = (2.56\times10^9 \times 1) + (1.28\times10^9 \times 12) + (2.56\times10^8 \times 5)$$
$$= 2.56\times10^9 + 1.536\times10^{10} + 1.28\times10^9$$
$$= 1.92\times10^{10}$$

$$CPU_{P_1} \text{ execution time} = \frac{1.92\times10^{10}}{2\times10^9} = 9.6 \text{ sec}$$

$$\therefore \text{Relative speed} = \frac{9.6}{9.6} = 1$$

For execution time for $P_2$:

$$P_2 \text{ clock cycles} = \frac{(2.56\times10^9 \times 1)}{0.7\times2} + \frac{(1.28\times10^9 \times 12)}{0.7\times2} + (2.56\times10^8 \times 5)$$
$$= \frac{2.56\times10^9}{1.4} + \frac{1.536\times10^{10}}{1.4} + 1.28\times10^9$$
$$= 1.404\times10^{10}$$

$$CPU_{P_2} \text{ execution time} = \frac{1.404\times10^{10}}{2\times10^9} = 7.02 \text{ sec}$$

$$\therefore \text{Relative speed} = \frac{9.6}{7.02} = 1.37$$

For execution time for $P_4$:

$$P_4 \text{ clock cycles} = \frac{(2.56\times10^9 \times 1)}{0.7\times4} + \frac{(1.28\times10^9 \times 12)}{0.7\times4} + (2.56\times10^8 \times 5)$$

$P_4$ clock cycles $= \frac{2.56\times10^9}{2.8} + \frac{1.536\times10^{10}}{2.8} + 1.28\times10^9$

$= 7.72\times10^9$

$CPU_{P_4}$ execution time $= \frac{7.72\times10^9}{2\times10^9} = 3.86$ sec

$\therefore$ Relative speed $= \frac{9.6}{3.86} = 2.49$ //

For execution time for $P_8$ :

$P_8$ clock cycles $= \frac{(2.56\times10^9\times1)}{0.7\times8} + \frac{(1.28\times10^9\times12)}{0.7\times8} + (2.56\times10^8\times5)$

$= \frac{2.56\times10^9}{5.6} + \frac{1.536\times10^{10}}{5.6} + 1.28\times10^9$

$= 4.5\times10^9$

CPU execution time $= \frac{4.5\times10^9}{2\times10^9} = 2.25$ sec

$\therefore$ Relative speed $= \frac{9.6}{2.25} = 4.27$ //

Ex 1.9.2

If the Arithmetic instructions are doubled. ($CPI_{FP}=2$)

The execution time for $P_1$:

Clock cycle for $P_1 = 2560\times2 + 1280\times12 + 256\times5$

$= 21760$

$CPU_{P_1}$ execution time $= \frac{21760}{2\times10^9} = 10.88$ ms //

The execution time for $P_2$:

Clock cycle for $P_2 = \frac{2560\times2}{0.7\times2} + \frac{1280\times12}{0.7\times2} + 256\times5$

$= 3657.14 + 10971.43 + 1280$

$= 15908.57$

$CPU_{P_2}$ execution time $= \frac{15908.57}{2\times10^9} = 7.95$ ms //

The execution time for $P_4$ :

$$\text{Clock cycle for } P_4 = \frac{2560 \times 2}{0.7 \times 4} + \frac{1280 \times 12}{0.7 \times 4} + 256 \times 5$$

$$= 1828.57 + 5485.71 + 1280$$

$$= 8594.28$$

$$CPU_{P_4} \text{ execution time} = \frac{8594.28}{2 \times 10^9} = 4.3\,ms \;//$$

The execution time for $P_8$ :

$$\text{Clock cycle for } P_8 = \frac{2560 \times 2}{0.7 \times 8} + \frac{1280 \times 12}{0.7 \times 8} + 256 \times 5$$

$$= 914.23 + 2742.86 + 1280$$

$$= 4937.08$$

$$CPU_{P_8} \text{ execution time} = \frac{4937.08}{2 \times 10^9} = 2.47\,ms \;//$$

Ex 1.9.3

For 4 processors,

$$P_4 \text{ clock cycles} = \frac{2.56 \times 10^9}{2.8} + \frac{1.536 \times 10^{10}}{2.8} + 1.28 \times 10^9$$

$$= 7.72 \times 10^9$$

$$CPU_{P_4} \text{ execution time} = \frac{7.72 \times 10^9}{2 \times 10^9} = 3.86 \text{ sec} \quad -(i)$$

To reduce the CPI of a single processor to match the performance of $P_4$.

$$P_1 \text{ clock cycle} = (2.56 \times 10^9 \times 1) + (1.28 \times 10^9 \times \alpha) + (2.56 \times 10^8 \times 5)$$

$$= 3.84 \times 10^9 + 1.28 \times 10^9$$

$$CPU_{P_1} \text{ execution time} = \frac{3.84 \times \cancel{10^9} + 1.28 \times \cancel{10^9} \times \alpha}{2 \times \cancel{10^9}}$$

$$3.86 \times 2 = 3.84 + 1.28\alpha \qquad [\text{From } (i)]$$

$$1.28\alpha = 3.88$$

$$\alpha = 3.03$$

$$\% \text{ Reduced CPI of L/s instructions is: } \frac{\alpha \times 100}{\text{L/s instr. original}} = \frac{3.03}{12} \times 100 = \boxed{25.3\%}$$

Q 4 Ex 1.13.1

From the given data, total execution time = 0.8 × execution time FP + Remaining time

$= 0.8 \times 70 + (250 - 70)$

$= 236$

% of total time reduction $= \frac{250 - 236}{250} \times 100$

$= 5.6\%$ for FP instructions.

Ex 1.13.2

If the total time is reduced by 20% = 0.8 × total time

$= 0.8 \times 250 = 200.$

∴ For the reduction of INT instructions, substituting a variable 'x':

Total time = x × Execution time$_{INT}$ + Remaining time.

$200 = x \times (250 - 70 - 85 - 40) + 70 + 85 + 40$

$x = \frac{200 - 195}{55}$

% of reduction (x) $= \frac{5 \times 100}{55}$

$= 9.1\%$ for INT instructions.

Ex 1.13.3

For the reduction of branch instructions, substituting a variable 'y':

y × Execution time$_{branch}$ + Total execution time − Execution time$_{branch}$ = Total time.

$y \times 40 + 250 - 40 = 200$

$40y + 210 = 200$

$40y = -10$

$y \simeq -0.25$

The reduction cannot be negative value.

Thus, reduction in only branch instructions is not possible.

Q5 Ex 1.14

$$\text{Time } (T) = \frac{(50\times1 + 110\times1 + 80\times4 + 16\times2)\times10^6}{2\times10^9}$$

$$= \frac{512}{2\times10^3}$$

$$(T) = 0.256 \text{ sec.}$$

Ex 1.14.1

Since time ($T_1$) is two times faster than time ($T$).

$$T_1 = \frac{0.256}{2}$$

$$T_1 = 0.128 \text{ sec}$$

To find $CPI_{FP}$

$$T_1 = \frac{(50\times CPI_{FP} + 110\times1 + 80\times4 + 16\times2)\times10^6}{2\times10^9}$$

$$0.128 = \frac{(50\times CPI_{FP} + 110\times1 + 80\times4 + 16\times2)\times10^6}{2\times10^9}$$

$$256 = 50\times CPI_{FP} + 110 + 320 + 32$$

$$50\,CPI_{FP} = -206$$

$$CPI_{FP} \approx -4$$

Since $CPI_{FP}$ is negative, the improvement of FP instruction is not possible if program runs 2 times faster//

Ex 1.14.2

To find $CPI_{L/S}$ if $T_1 = 0.128$ sec.

$$T_1 = \frac{(50\times1 + 110\times1 + 80\times CPI_{L/S} + 16\times2)\times10^6}{2\times10^9}$$

$$0.128 = \frac{(50\times1 + 110\times1 + 80\times CPI_{L/S} + 16\times2)\times10^6}{2\times10^9}$$

$$256 = 50 + 110 + 80\,CPI_{L/S} + 32$$

$$80\,CPI_{L/S} = 64$$

$$\therefore CPI_{L/S} = \frac{64}{80} = 0.8 \text{ //}$$

Ex 1.14.3

From the given data, new CPIs are:

n $CPI_{FP} = 0.6$

n $CPI_{INT} = 0.6$

n $CPI_{L/S} = 2.8$

n $CPI_{branch} = 1.4$

$$T_{new} = \frac{(50 \times 0.6 + 110 \times 0.6 + 80 \times 2.8 + 16 \times 1.4) \times 10^{6}}{2 \times 10^{9}}$$

$$= \frac{(30 + 66 + 224 + 22.4) \times 10^{6}}{2 \times 10^{9}}$$

$$= 171.2 \times 10^{-3} \text{ sec}$$

$$\therefore \text{Improved execution time} = \frac{\text{Original Time}}{\text{New Time}}$$

$$= \frac{256 \times \cancel{10^{-3}}}{171.2 \times \cancel{10^{-3}}}$$

$\boxed{\text{The improved time is: } 1.495}$ //