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CSE 240A – Computer Architecture, Homework 1

Question 1

1. Compute CPI

$$\boldsymbol{CPI = 0.5 * 1 + 0.2 * 2 + 0.1 * 2 + 0.2 * 3 = 1.7}$$

2. Find most performance improvement:
   a. ALU: 60%, 1 cycle
      Load: 16%, 4 cycles
      Store: 8%, 2 cycles
      Branch: 16%, 3 cycles

$$\boldsymbol{CPI = 0.6 * 1 + 0.16 * 4 + 0.08 * 2 + 0.16 * 3 = 1.88}$$

   b. ALU: 40%, 1 cycle
      Load: 20%, 2 cycles
      Store: 10%, 2 cycles
      Branch: 30%, 3 cycles

$$\boldsymbol{CPI = 0.4 * 1 + 0.2 * 2 + 0.1 * 2 + 0.3 * 3 = 1.9}$$

   c. ALU: 30%, 1 cycle
      Load: 28%, 2 cycles
      Store: 14%, 2 cycles
      Branch: 28%, 2 cycles

$$\boldsymbol{CPI = 0.3 * 1 + 0.28 * 2 + 0.14 * 2 + 0.28 * 2 = 1.7}$$

3. Compute MIPS
   a. $\boldsymbol{MIPS = \frac{500 * 10^6}{1.88 * 10^6} = 265.957}$
   b. $\boldsymbol{MIPS = \frac{500 * 10^6}{1.9 * 10^6} = 263.157}$
   c. $\boldsymbol{MIPS = \frac{500 * 10^6}{1.7 * 10^6} = 294.118}$

4. Few ALU instructions are now paired with load
   ALU: 41.18%, 1 cycle
   ALU+Load: 17.65%, 1 cycle
   Load: 5.88%, 2 cycles
   Store: 11.75%, 2 cycles

Branch: 20%, 5 cycles

$$\boldsymbol{CPI = \frac{35 * 1 + 15 * 1 + 5 * 2 + 10 * 2 + 20 * 5}{85} = 2.118}$$

5. How long does it take to execute program?

$$\boldsymbol{Time = \frac{500 * 1 + 80 * 2 + 200 * 2 + 100 * 3}{500} = 2.72\ seconds}$$

6. How to optimize the processor?
   We need to optimize the instruction that has the most effect on our system. ALU instruction take only 1 clock cycle and cannot be reduced further. We are left with either of Load, Store or Branch. From these, Load and Branch have equal frequency, greater than Store. Reducing Store from 3 cycles to 1 will achieve better performance than reducing load from 2 cycles to 1.
   Improving the cycles for the branch instructions is possible by upgrading the branch predictor.

Question 2

1. Achieve 1.15X speedup

$$Speedup = \frac{CPI_{old}}{CPI_{new}} = 1.15$$
$$CPI_{new} = 1.478$$

   ALU operation cannot be optimized further as it takes only 1 clock cycle.
   Optimizing load to complete in 1 cycle would give us a CPI of 1.5 which is not sufficient.
   Optimizing store to complete in 1 cycle achieves CPI of 1.6, which again is not sufficient.
   If we were to optimize branch to complete in 1 cycle, we get a CPI of 1.3, which is equal to a speed up of 1.31X.

2. $\boldsymbol{Speed\ Up = \frac{1}{(1-P)+\frac{P}{N}} = \frac{1}{(1-0.5883)+\frac{0.5883}{1000}} = 2.425}$

3. $\boldsymbol{Speed\ Up = \frac{1}{(1-P)+\frac{P}{N}} = \frac{1}{(1-0.2)+\frac{0.2}{\infty}} = 1.25}$

4. What are benchmarks?
   Benchmark is the process of running programs or a set of programs (or other operations) to access the relative performance between different machines. Modern processors are very complex, and it is impossible to speculate and compare their performance from the specifications alone. Benchmarks help us understand how different machines stack up against each other in term of performance, latency, power consumption, etc.