COMP7300 Fall 2021 HW02

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1. **A common measure of performance for a processor is the rate at which instructions are executed which is often expressed in MIPS. Express MIPS rate in terms of clock rate and CPI.**

   (a) Some definitions:
   - clock frequency: f , thus, cycle time: $1/f$
   - CPI: Average cycles per instruction for a program
   - CPI_i: the number of cycles required for instruction type i
   - I_i: the number of executed instructions of type i for a given program
   - I_c: the instructions count

   (b) Then we can calculate CPI as below:

   $$CPI = \frac{\sum_{i=1}^{n}(CPI_i \times I_i)}{I_c}$$

   (c) Calculate execution time for a given program:

   $$T = I_c \times CPI \times \frac{1}{f}$$

   (d) MIPS (Millions of instructions per second):

   $$MIPS\ rate = \frac{I_c}{T \times 10^6} = \frac{f}{CPI \times 10^6}$$

2. **A benchmark program is run on a 6 GHz processor. The object code consists of the following instruction mix and clock cycle counts. Determine the effective CPI, MIPS rate and execution time for this program.**

Instruction Type	Instruction Count	Clock Count
Integer Arithmetic	40,000	1
Data Transfer	35,000	2
Floating Point	18,000	3
Control transfer	11,000	2

   Answer:

   - $CPI = \frac{40000\times1+35000\times2+18000\times3+11000\times2}{104000} = 1.79$

- 6 GHz = 6,000,000,000
- $MIPS = \frac{f}{CPI} = \frac{6000 \times 10^6}{1.79 \times 10^6} = 3352\ MIPS$
- $ExecutionTime = \frac{CPI \times InstructionCount}{f} = \frac{1.79 \times 104000}{6000 \times 10^6} = 31 \times 10^{-6} sec$

3. **In the Intel architecture, the addresses are staggered into two separate units (e.g. all even addressed words in one unit and odd ones in another). What might be the purpose of this technique?**

   Answer:

   - The main purpose of the technique is to improve the computer's performance. When the execution speed of CPU is much faster than the main memory accessing, by separating memory into two modules – odd and even – processor could access even and odd addresses in parallel, therefore, the speed has not increased though, the throughput has increased.
   - It also can save the memory by allotting almost exactly the required space, e.g., integer one word only while float might take 2 words.

4. **What is Amdahl's Law? Explain the Speedup equation.**

   Amdahl's law, first proposed by Gene Amdahl in 1967, is a formula which is often used in parallel computing to predict the theoretical speedup when using multiple processors compared to the single processor.

$$SpeedUp = \frac{1}{(1-f) + \frac{f}{N}}$$

   - f - a fraction that involves code that is infinitely parallelizable.
   - N - number of processors
   - When f is small, the use of parallel processors has little effect;
   - As N approaches infinity, speedup is bound by 1/(1-f), so that there are diminishing returns for using more processors.

5. **What are SPEC Benchmarks? Discuss any three components of the SPEC CPU benchmark suite. Discuss the use of AM, GM and HM for performance evaluation. Which means should you use for which metrics?**

   - A benchmark suite is a collection of programs, defined computer in a particular application or system programming area. The best known such collection of benchmark is defined and maintained by the Standard Performance Evaluation Corporation (SPEC), an industry consortium. This organization defines several benchmark suites aimed at evaluating computer systems. SPEC performance measurements are widely used for comparison and research purposes.
   - Three Components:
     – 400.perlbench, integer benchmark, using C language, is PERL programming language interpreter, applied to a set of three programs.
     – 403.gcc, integer benchmark, Using C language, is basded on gcc Version 3.2, generates code for Opteron.
     – 435.gromacs, floating-point benchmark, using C and Fortran language, that

simulates Newtonian equations of motion for hundreds of millions of particles.

- **– AM:** It is good for execution time. Arithmetic Mean, is used for a time-based variable, such as program execution time, has the important property that it is directly proportional to the total time.
  – GM: It is good for normalized value. Geometric Mean gives the same weight for all values, thus, it can be measuring the relative performance of machine.
  – HM: It is good for rates. Harmonic Mean is used for the mean value of the execution time.
- **–Base metric:** if different unit, Use GM. If same unit, use AM
  –Peak metric: Use AM
  –Speed metric: Use AM
  –Rate metric: Use HM

6. **List and briefly define some of the techniques used in contemporary processors to increase performance.**

   - Pipelining: Pipelining enables a processor to work simultaneously on multiple instructions by performing a different phase for each of the multiple instructions at the same time
   - Branch Prediction: The processor looks ahead in the instruction code fetched from memory and predicts which branch or instructions, are likely to be processed next
   - Superscalar execution: This is the ability to issue more than one instruction in every processor clock cycle.
   - Data flow analysis: the processor analyzes which instructions are dependent on each other' result, or data, to create an optimized schedule of instructions.
   - Speculative execution: Using branch prediction and data flow analysis, some processors speculatively execute instructions ahead of their actual appearance in the program execution, holding the results in temporary locations.

7. **Suppose a program P makes extensive use of floating-point operations, so that 35% of the time gets consumed in floats. You designed a new hardware that doubles the speed of float executions. What is the effective speedup achieved?**

   Answer:

   SpeedUp = $\frac{1}{(1-f)+\frac{f}{N}}$ = $\frac{1}{(1-0.35)+\frac{0.35}{2}}$ = 1.21