Introduction to Computer Architecture

Assignment 2

Due November 27, 2023

*****CHAPTER 1 - FUNDAMENTAL*****

01. [25 = 5 + 10 + 5 + 5]

a. Please describe the two kinds of parallelism in applications.

b. Please describe the four major ways to exploit the preceding two kinds of application parallelism.

c. Please describe the principle of dynamic voltage-frequency scaling (DVFS).

d. Please describe the principle of overclocking.

02. [10 = 5 x 2]

Suppose we have made the following measurements:

- Frequency of FP operations = 25%
- Average CPI of FP operations = 4.0
- Average CPI of other instructions = 1.33
- Frequency of FPSQR = 2%
- CPI of FPSQR = 20

Assume that the two design alternatives are to decrease the CPI of FPSQR to 2 or to decrease the average CPI of all FP operations to 2.5.

Compare these two design alternatives using the processor performance equation.

*****APPENDIX A - INSTRUCTION*****

*****APPENDIX C - PIPELINE*****

*****APPENDIX B & CHAPTER 2 - MEMORY HIERARCHY*****

03. [20 = 6 + 7 + 7]

The LRU replacement policy is based on the assumption that if address A1 is accessed less recently than address A2 in the past, then A2 will be accessed again before A1 in the future. Hence, A2 is given priority over A1. Discuss how this assumption fails to hold when the loop larger than the instruction cache is being continuously executed. For example, consider a fully associative 128-byte instruction cache with a 4-byte block (every block can exactly hold one instruction). The cache uses an LRU replacement policy.

a. What is the asymptotic instruction miss rate for a 64-byte loop with a large number of iterations?

b. Repeat part (a) for loop sizes 192 bytes and 320 bytes.

c. If the cache replacement policy is changed to most recently used (MRU) (replace the most recently accessed cache line), which of the three above cases (64-, 192-, or 320-byte loops) would benefit from this policy?

04. [20 = 6 + 7 + 7]

You are trying to appreciate how important the principle of locality is in justifying the use of a cache memory, so you experiment with a computer having an L1 data cache and a main memory (you exclusively focus on data accesses). The latencies (in CPU cycles) of the different kinds of accesses are as follows: cache hit, 1 cycle; cache miss, 105 cycles; main memory access with cache disabled, 100 cycles.

a. When you run a program with an overall miss rate of 5%, what will the average memory access time (in CPU cycles) be?
b. Next, you run a program specifically designed to produce completely random data addresses with no locality. Toward that end, you use an array of size 256 MB (all of it fits in the main memory). Accesses to random elements of this array are continuously made (using a uniform random number generator to generate the elements indices). If your data cache size is 64 KB, what will the average memory access time be?
c. You observed that a cache hit produces a gain of 99 cycles (1 cycle vs. 100), but it produces a loss of 5 cycles in the case of a miss (105 cycles vs. 100). In the general case, we can express these two quantities as G (gain) and L (loss). Using these two quantities (G and L), identify the highest miss rate after which the cache use would be disadvantageous.

05. [15 = 5 x 3]

Consider a 16-way set associative cache:
Data words are 64 bits long;
Words are addressed to the half-word;
The cache holds a 2 Mbytes of data;
Each block holds 16 data words;
Physical addresses are 64 bits long.

How many bits of tag, index, and offset are needed to support references to this cache?

06. [10] Commit & Enjoy

[requirements:
a. please submit an extra copy of Q06 via course.zju.edu.cn for ease of (anonymous) compilation, which would be of great help for readers with similar experiences; photocopy of a handwritten version is also welcome.
b. if feedback from me is expected, please also indicate whether a written reply or a discussion appointment is favored.]

For almost all previous editions of this course, an assignment question sought to solicit thoughts and suggestions from the participants. For example, do you gradually understand strategies or things from different perspectives and weigh their tradeoffs? What do you think is the real challenge for you to learn this course? Do you consider interactions in class helpful? What held you back when you were trying to ask or answer questions in class? What suggestions (for better learning this course) would you like to provide to other students? What help or assistance would you like from me or other students? All their thoughtful and constructive feedback has encouraged us toward a more rewarding computer architecture class.

This time, I would like you to introspect beyond this course. Taking a course should be rewarding in many possible ways. As we discussed in the first lecture session, even if you may barely practice computer architecture principles after the class ends, if whatever you learn through this class---whether it be computer architecture per se, a philosophy it implies, a study tip or inspirational quote we share, or a new friend you know---keeps driving you toward your greater self, this course fulfills its mission.

In particular, you are highly expected to develop a clear vision and be determined to strive for it. Most students in the computer architecture class are junior. The third year cannot be more decisive for your future. If you aim to work in an IT company after graduation, start practicing skills that help you ace the interview. If you plan to pursue a higher degree, join a research lab to cultivate research experience and application materials. If you have not decided, do both if your time and energy permit, see which one you really prefer. Try to make your decision based on your own goal and experience. Work with people who keep your interest and passion alive. It is really, really important to identify a right role model to emulate and learn from. It is also highly decisive to focus on what really is essential, especially given that some of constantly emerging paradigms might turn into hypes and fade away. Stick to golden rules that should be objective during the selection. It should not be simply about what one claims to be or what one claims others less so. “See the world not as it is, but as it should be.” Think of the proverb “shallow brooks babble loudest, still waters run deep” once in a while. (Or as sg put it: “shallow water hualahuala, deep water kckc.”) In return, be part of the initiative that motivates yourself and people around you.

Meanwhile, if you ever consider assistance from me as possibly helpful, whether course related or beyond, never hesitate to reach out. As I proudly claim on my webpage, I am always proud to be part of the journey for someone to excel. And I am pretty sure that I would also love to be part of yours as well.

???Therefore, with this question, I would like you to share your thoughts on your goal and plan. For example, what is your goal after graduation? What is your plan to achieve that goal and what challenges might be involved? How do you manage to be motivated and determined? What helpful advices or suggestions did you get from senior students and professors? What suggestions would you like to offer peers with

similar goals? Or, it is possible that you are still finding your goals. Don’t rush and take your time. Being at such a young age, you have infinite possibilities to live your dreams. “Commit to something and commit hard. Doesn’t matter if you switch later. It’s easier to prove yourself if you’ve had to do it once before.”