

Winter '18 CIS 314 Assignment 8 – 100/100 points – Due Friday, 3/16, 11:59 PM

Please submit individual source files for coding exercises (see naming conventions below) and a single solution document for non-coding exercises (.txt or .pdf only), when appropriate. Your code and answers need to be documented to the point that the graders can understand your thought process. Full credit will not be awarded if sufficient work is not shown.

1. [20] Assume that you're given the task of optimizing graphics software that operates in the CMYK (Cyan, Magenta, Yellow, Black) color space. Specifically, you need to determine the efficiency of the following algorithm on a machine with a 2048-byte direct-mapped data cache with 32-byte blocks. You are given the following definitions:

```
struct point_color {
    int c;
    int m;
    int y;
    int k;
};

struct point_color square[16][16];
```

Assume the following:

- `sizeof(int) == 4`.
- `square` begins at memory address 0.
- The cache is initially empty.
- The only memory accesses are to the entries of the array `square`. Variables `i` and `j` are stored in registers.

Determine the cache performance of the following code:

```
for (i = 0; i < 16; i++) {
    for (j = 0; j < 16; j++) {
        square[i][j].c = 1;
        square[i][j].m = 0;
        square[i][j].y = 0;
        square[i][j].k = 0;
    }
}
```

A. What is the total number of memory writes? It may help to think in terms of `movl` instructions.

B. What is the total number of memory writes that miss in the cache?

C. What is the miss rate?

Include your answers in your solutions document.

2. [80] Write a C program to simulate a simple 64B direct-mapped cache with 4B blocks (i.e., 16 cache sets). This program builds upon many of the topics covered in this course and will require a comprehensive knowledge of caching theory (see chapter 6.4). Your program should:

- (5) Define a struct to represent a cache block. Your struct should define a bit that represents whether or not the block is valid (use an unsigned char), a 26-bit tag (use an unsigned int), and a 4-byte value (use an unsigned char[4]).
- Implement these functions using only bitwise ops (no division or modulo arithmetic):
  - (5) *unsigned int getOffset(unsigned int address)* – returns the byte offset of the address within its cache block.
  - (5) *unsigned int getSet(unsigned int address)* – returns the cache set for the address.
  - (5) *unsigned int getTag(unsigned int address)* – returns the cache tag for the address.
- Implement a *main* function that:
  - (5) Allocates enough memory to hold 16 cache blocks (1 per set). Initialize your cache such that all blocks are invalid.
  - Repeatedly prompts the user to either:
    - (20) Write a value – prompt the user for a 32-bit hex address and a 32-bit hex value (as unsigned ints). Writes the 4-byte value at the appropriate location in the cache for the given address, evicting an existing block if necessary. You may assume that the user enters an address that is a multiple of 4 so that the beginning of the value aligns with the beginning of a cache block. This is to simulate moving an entire block from memory into the cache. Print the set index, tag, and value of the new block being written. If a valid block is evicted, also print the set index, tag, and value of the evicted block.
    - (20) Read a byte – prompt the user for a 32-bit hex address (as an unsigned int). Prints the set index and tag corresponding to the address. Also print “hit” and the hex value of the byte at that address if the cache contains a valid value corresponding to the address. Otherwise, print “miss” and indicate the reason for the miss (i.e., invalid block or tag mismatch).
    - (10) Print values – prints the set index, tag, and value for all valid blocks in the cache.
    - (5) Quit – quits the simulation.

- Your program should not crash if given invalid input (e.g., commands other than write/read/print/quit, values that can't be parsed as unsigned ints, negative addresses, etc).
- Hint: use `printf("%x")` to output hex values directly.
- Hint: use your solution from assignment 1, problem 1 as a guide for printing the cache values as individual bytes.

Name your source file 8-2.c.

Here is output from a sample run of the application (your output does not need to match exactly):

```
Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: w
Enter 32-bit unsigned hex address: 0x0
Enter 32-bit unsigned hex value: 0xaabb
wrote set: 0 - tag: 0 - valid: 1 - value: bb aa 00 00
Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: w
Enter 32-bit unsigned hex address: 0x8
Enter 32-bit unsigned hex value: 0xbbcc
wrote set: 2 - tag: 0 - valid: 1 - value: cc bb 00 00
Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: p
set: 0 - tag: 0 - valid: 1 - value: bb aa 00 00
set: 2 - tag: 0 - valid: 1 - value: cc bb 00 00
Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: w
Enter 32-bit unsigned hex address: 0x40
Enter 32-bit unsigned hex value: 0xccdd
evicting block - set: 0 - tag: 0 - valid: 1 - value: bb aa 00 00
wrote set: 0 - tag: 1 - valid: 1 - value: dd cc 00 00
Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: p
set: 0 - tag: 1 - valid: 1 - value: dd cc 00 00
set: 2 - tag: 0 - valid: 1 - value: cc bb 00 00
Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: r
```

```
Enter 32-bit unsigned hex address: 0x0

looking for set: 0 - tag: 0

found set: 0 - tag: 1 - offset: 0 - valid: 1 - value: dd

tags don't match - miss!

Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: r

Enter 32-bit unsigned hex address: 0x4

looking for set: 1 - tag: 0

no valid set found - miss!

Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: r

Enter 32-bit unsigned hex address: 0x8

looking for set: 2 - tag: 0

found set: 2 - tag: 0 - offset: 0 - valid: 1 - value: cc

hit!

Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: r

Enter 32-bit unsigned hex address: 0x40

looking for set: 0 - tag: 1

found set: 0 - tag: 1 - offset: 0 - valid: 1 - value: dd

hit!

Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: r

Enter 32-bit unsigned hex address: 0x41

looking for set: 0 - tag: 1

found set: 0 - tag: 1 - offset: 1 - valid: 1 - value: cc

hit!

Enter 'r' for read, 'w' for write, 'p' to print, 'q' to quit: q
```

Zip the source files and solution document (if applicable), name the .zip file <Your Full Name>Assignment8.zip (e.g., EricWillsAssignment8.zip), and upload the .zip file to Canvas (see Assignments section for submission link).