JOINT INSTITUTE
交大密西根学院

ECE3700J Introduction to Computer Organization

Homework 6

Assigned: October November 15, 2022

Due: 2:00pm on November 22, 2022

Submit a PDF file on Canvas

1. (10 points) The following code is written in C, where elements within the same row are stored contiguously. Assume each word is a 32-bit integer.

```
for (I=0; I<8; I++)
    for (J=0; J<8000; J++)
      A[I][J]=B[I][0]+A[J][I];
```

   (1) Which variable references exhibit temporal locality? (5 points)

   (2) Which variable references exhibit spatial locality? (5 points)

2. (40 points) Below is a list of 32-bit memory address references, given as word addresses: 0x03, 0xB4, 0x2B, 0x02, 0xBF, 0x58, 0xBE, 0x0E, 0xB5, 0x2C, 0xBA, 0xFD

   (1) For each of these references, identify the tag and the cache index given a direct-mapped cache with 8 one-word blocks. Also list if each reference is a hit or a miss, assuming the cache is initially empty. (10 points)

   (2) For each of these references, identify the tag and the cache index given a direct-mapped cache with two-word blocks and a total size of 4 blocks. Also list if each reference is a hit or a miss, assuming the cache is initially empty. (10 pints)

   (3) You are asked to optimize a cache design for the given references. There are three direct-mapped cache designs possible, all with a total of 8 words of data: C1 has 1-word blocks, C2 has 2-word blocks, and C3 has 4-word blocks. In terms of miss rate, which cache design is the best? If the miss stall time is 35 cycles, and C1 has an access time of 2 cycles, C2 takes 3 cycles, and C3 takes 5 cycles, which is the best cache design? (20 points)

3. (50 points) For a direct-mapped cache design with a 32-bit byte address, the following bits of the address are used to access the cache.

Tag	Index	Offset
31 – 10	9 – 5	4 – 0

(1) What is the cache block size (in words)? (5 points)

(2) How many blocks does the cache have? (5 points)

(3) What is the ratio between total bits required for such a cache implementation over the data storage bits? (5 points)

Beginning from power on, the following byte addresses for cache references are recorded.

Address											
0x00	0x04	0x10	0x84	0xE8	0xA0	0x400	0x1E	0x8C	0xC1C	0xB4	0x884

(4) (20 points) For each reference, list

a) its tag, index, and offset

b) whether it is a hit or a miss, and

c) How many blocks were replaced (if any)?

(5) What is the hit ratio? (5 points)

(6) Show the final state of the cache, with each valid line represented as <index, tag, data>. (10 points)

1. (1) B[I][0], I, J

(2) A[I][J]

		tag:	cache index:	
2.(1)	0x03 = 00000011	00000	011	miss
	0xB4 = 10110100	10110	100	miss
	0x2B = 00101011	00101	011	miss
	0x02 = 00000010	00000	010	miss
	0xBF = 10111111	10111	111	miss
	0x58 = 01011000	01011	000	miss
	0xBE = 10111110	10111	110	miss
	0x0E = 00001110	00001	110	miss
	0xB5 = 10110101	10110	101	miss
	0x2C = 00101100	00101	100	miss
	0xBA = 10111010	10111	010	miss
	0xFD = 11111101	11111	101	miss

(2)

	tag:	cache index:		C3:	
0x03 = 00000011	00000	01	miss	0	m
0xB4 = 1011 0100	1011 0	10	miss	1	m
0x2B = 0010 1011	0010 1	01	miss	0	m
0x02 = 0000 0010	00000	01	miss	0	m
0xBF = 1011 1111	10111	11	miss	1	m
0x58 = 0101 1000	01011	00	miss	0	m
0xBE = 1011 1110	10111	11	hit	1	h
0x0E = 0000 1110	00001	11	miss	1	m
0xB5 = 1011 0101	10110	10	hit	1	m
0x2C = 0010 1100	00101	10	miss	1	m
0xBA = 1011 1010	10111	01	miss	0	m
0xFD = 1111 1101	11111	10	miss	1	m

(3) miss rate: C1: 100% C2: 83.33% C3: 91.67% C2 best

$t_{C1} = 12 \times 2 + 12 \times 35 = 444$

$t_{C2} = 12 \times 3 + 10 \times 35 = 386$ t_2 best

$t_{C3} = 12 \times 5 + 11 \times 35 = 445$

3. (1) 8 words

(2) 32 blocks

(3) data storage bits: $32 \times 8 \times 32 = 8192$

total bits required: $32 \times (1 + 22) = 736$

$r = \frac{736}{8192} = 8.98\%$

(4)

	tag:	index:	offset:	h/m	num repl
0x00 = 00000000	22'b0	00000	00000	miss	0
0x04 = 00000100	22'b0	00000	00100	hit	0
0x10 = 00010000	22'b0	00000	10000	hit	0
0x84 = 1000 0100	22'b0	00100	00100	miss	0
0xE8 = 1110 1000	22'b0	00111	01000	miss	0
0xA0 = 1010 0000	22'b0	00101	00000	miss	0
0x400 = 0100 0000 0000	21'b0...01	00000	00000	miss	1
0x1E = 0001 1110	22'b0	00000	11110	miss	1
0x8C = 1000 1100	22'b0	00100	01100	hit	0
0xC1C = 1100 0001 1100	20'b0...011	00000	11100	miss	1
0xB4 = 1011 0100	22'b0	00101	10100	hit	0
0x884 = 1000 1000 0100	20'b0...010	00100	00100	miss	1

(5) hit ratio = 33.33%

(6)

index	V	Tag	Data 0	1	2	3	4	5	6	7
00000	1	20'b0...011	0xC00	0xC04	0xC08	0xC0C	0xC10	0xC14	0xC18	0xC1C
00001	0									
00010	0									
00011	0									
00100	1	20'b0...010	0x880	0x884	0x888	0x88C	0x890	0x894	0x898	0x89C
00101	1	22'b0	0xA00	0xA04	0xA08	0xA0C	0xB00	0xB04	0xB08	0xB0C
00110	0									
00111	1	22'b0	0xE00	0xE04	0xE08	0xE0C	0xF00	0xF04	0xF08	0xF0C
01000	0									
01001	0									

01010	0
01011	0
01100	0
01101	0
01110	0
01111	0
10000	0
10001	0
10010	0
10011	0
10100	0
10101	0
10110	0
10111	0
11000	0
11001	0
11010	0
11011	0
11100	0
11101	0
11110	0
11111	0