

Final Exam

CSC 252

8 May 2018

Computer Science Department
University of Rochester

Instructor: Yuhao Zhu

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Name: _____

Problem 0 (2 points): _____

Problem 1 (43 points): _____

Problem 2 (15 points): _____

Problem 3 (30 points): _____

Problem 4 (30 points): _____

Problem 5 (15 points): _____

Total (135 points): _____

Remember “I don’t know” is given 15% partial credit, but you must erase/cross everything else.

Please be sure your name is on each sheet of the exam.

Your answers to all questions must be contained in the given boxes. Use spare space to show all supporting work to earn partial credit.

You have 2 hours and 45 minutes to work (19:15 -- 22:00).

Please sign the following. I have not given nor received any unauthorized help on this exam.

Signature: _____

GOOD LUCK!!!
(And Have a Great Semester Break)

Problem 0: Warm-up (2 points)

Facebook is hiring hardware engineers. What do you think they are building?

Any answer is accepted.

Problem 1 (43 points)

Part a (5 points): A microarchitecture is predicting whether a branch is taken or not taken using a 1-bit predictor. The last five branches were: taken, taken, taken, taken, not taken. What does the branch predictor predict (choose): Taken or Not Taken?

Not Taken

Part b (5 points): In a typical Linux/Unix terminal, when you hit Ctrl + Z, which state are you putting the foreground process to (choose): Running, Stopped, Terminated?

Stopped

Part c (5 points): Cache blocking is a software-level performance optimization technique that improves what aspect of a program (choose): Locality, Parallelism, Concurrency, Security?

Locality

Part d (5 points): An application that is 90% parallelizable is executed on a single processor in 1.5 hours. If the application is allowed to run with an unlimited number of processors, what is the lower bound on its execution time?

9 mins. With an unlimited number of processors, the parallelizable part of a program would finish in no time, and the execution time is equivalent to the sequential part, which is $90 \text{ mins} * 0.1 = 9 \text{ mins}$.

Part e (5 points): On a page fault, the operating system often loads a page from the disk into memory. How does the operating system know whether it is necessary to write the previously occupied page in the memory back to the disk? Answer in fifteen words or fewer.

Check the dirty bit in the corresponding page table entry.

Part f (5 points): What is the cycle time of a 1 GHz processor?

1 ns

Part g (5 points): What is the fundamental reason that process context switch has a much higher overhead than thread context switch in Linux? Answer in twenty words or fewer.

Threads share virtual address space while processes have separate virtual address spaces.

Part h (5 points): Suppose we have two 4-bit 2's complement numbers:

1111

1110

Does the sum of the two numbers result in an overflow?

No.

Part i (3 points): Recall that the crux of tracing-based GC algorithms such as Mark-and-sweep and Mark-sweep-compact is to start from “root” variables and then identify all the reachable variables. In the following code snippet, suppose the program just finishes executing L7, which variables are regarded as “root”? Name only those that point to variables on the heap.

```
L1:   int *p3;

L2:   int* foo(int n) {
L3:     int i, *p1;
L4:     p1 = (int *) malloc(n * sizeof(int));
L5:     for (i=0; i<n; i++)
L6:       p1[i] = i;
L7:     p3 = p1[2];
L8:     return p1;
L9:   }

L10:  void bar() {
L11:    int *p2 = foo(5);
L12:  }
```

p1 and p3.

Problem 2 (15 points)

We assume that IEEE decided to add a new 8-bit representation with its main characteristics consistent with the 32/64-bit representations. Consider the following four 8-bit numbers:

A: 11100101

B: 00111001

C: 00001100

D: 00011101

The decimal values represented by the above numbers are as follows, *in no particular order*:

$$3\frac{1}{8}, -21, \frac{29}{32}, \frac{3}{8}$$

Part a (3 points): Represent decimal value $\frac{3}{8}$ in binary normalized form

Part b (3 points): Which 8-bit floating point number represents -21 (choose from A, B, C, D)?

Part c (3 points): Which 8-bit floating point number represents $\frac{29}{32}$ (choose from A, B, C, D)?

Part d (6 points): Given the above information, figure out the following:

(2 points) Number of bits needed for exponent:

(2 points) Number of bits needed for fraction:

(2 points) Bias:

Problem 3 (30 points)

A byte-addressable, write-back cache of *fixed total size* and *fixed cache line (a.k.a., block) size* is implemented as both a direct mapped cache and also as an N-way set-associative cache. In both cases, we will assume the cache is initially empty.

First, consider the cache organized as a direct mapped cache. The following sequence of 11 accesses generates the hits/misses shown. Some miss/hit entries are intentionally left blank.

Address	Read/Write	Direct Mapped (Hit/Miss)
0100001010	R	
1100100111	R	Miss
1110101000	R	Miss
0011000101	R	
0110111100	R	
1010110101	R	Miss
1100100000	R	Miss
0100001111	R	Hit
0101111111	W	Miss
0110110100	R	
0110100101	R	Miss

Note high order bits are the same but still miss.

Hit because of this miss

Part a (4 points): How many cache lines does each set have in a direct mapped cache?

Part b (2 points): What is the cache line (a.k.a., block) size?

Part c (2 points): What are the number of index bits for the direct mapped cache?

1 RZ FRQMLGHUWKHFDKHRUJDQJ HGDVD1 ZD VHWDRFLDMYHFDKHZ LWK WKHVDP HVMWQJ HDQG
 VDP HFDKHCQHVMJ HDVEH RUH 7KHVMWQJ HRI 3RYLKHGDG IRUWKLV1 ZD VHWDRFLDMYHFDKHLV
 ELW \$ WXP HMDWQWLVSDUFXDUFDKHZ RYLUKHDGLQHDFK FDKHCQHLCQXGHVWJ ELWDQG
 DGGWRQDCELWIRUERRNNHSLQJ HJ WKHYDQELWP RGLLHGELW/ 58 ELW VKDAGRQRWDIIFW
 WKLVSUREOP : HKDYHH SDQGHGWKHVWQVWR KRZ WKHKLWP LVHVIUWKHVDP HVHTXHQFRI
 DFFWHVZKHQWKHFDKHLVRUJDQJ HGDVDQ1 ZD VHWDRFLDMYHFDKHZ

\$ GGUHW	5 HDG : ULM	' LUHFWD DSSHG + LW0 LW	1 ZD DVRFDMYH 0 LW + LW
	5	0 LW	0 LW
	5	0 LW	0 LW
	5	0 LW	0 LW
	5	0 LW	0 LW
	5	0 LW	0 LW
	5	0 LW	0 LW
	5	0 LW	0 LW
	5	0 LW	+ LW
	5	+ LW	+ LW
	:	0 LW	0 LW
	5	0 LW	+ LW
	5	0 LW	0 LW

3 DUMG SRLQW : KDWV1 "

3 DUWH SRLQW : KDWVWKHXP EHURI LQGH ELWIRUWKH1 : D VHWDRFLDMYHFDKHZ

3 DUW SRLQW , VMLVDZ ULM DQDFMFDKHZ

1 R

3 DUWJ SRLQW SRLQVSHUEQDN 3QDVHFRP SOWWKHVFRQGWQVQDERYHE\ ILQDQJ LQ
 '+LWRU'0 LW IRUFDKRI WHEQNHQMHV 3, 'RQW QRZ' LVDFHSMGRQDSHUEQDNEDLV

3 UREOP SRLQW

: HZLVK VR HQKDOFHVKH[,6\$ E\ DGGLOJ DQHZ LQWVKFMRQ 7KHQHZ LQWVKFMRQ LV FDOG 67,
36VRUH, QGLUFW DQGLWIRUP DWLV

67, 5D 5E 2I I VHW

7KHRSFRGHRI 67, LV DQGLWELQDU HQFRGLQJ LV % WMRQJ

2 SFRGH ELW	5 D ELW	5 E ELW	2 IIVHW ELW
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67, RSHLDW/DVIRQZ V : HFRP SXMDYLUXDDGGUHW FDOG \$ E\ DGGLOJ VKHVLJQ H\ WQGHG
2I I VHW VR VKHFRQMQVRI UHJLVWU5E 7KHP HP RU QFDMRQ VSHLIHGE\ \$ FROMLQVVKHYLUXDO
DGGUHW% : HZLVK VR VRUHVKHFRQMQVRI UHJLVWU5D LQVR VKH DGGUHW VSHLIHGE\ %

7KHSURFHWRUKD/DVLP SQRQH QMHOYLUXDDP HP RU \ VWP 7KHUHLV DORD HQM 7/ % <RX
DUHJLYHQ VKHIRQZ LQJ LQIRUP DMRQ

- " 9LUXDO\$ GGUHW6SDFH . %
- " 3K\ VFDOO HP RU 6LJH . %
- " 37(6LJH % W
- " 7KHIRUP DWRI D37(LVVKRZ QEHQZ 7KH0 6%LVVKHYDQGLWDDG VKHQZ HUVHYLUDEELW
DUHIRUMKHSK\ VFDOSDJHQXP EHU 331 1 RMVKDVKHH\ DFVQXP EHURI ELWIRU331 LVIRU
\ RX VR GHMLP LQH 7KHUHWELW DUHDQZ D\ VSDGGHGZ LMK

9 DQG ELW		3K\ VFDOO DJH1 XP EHU
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- " HD[[
- " HE[[(
- " 3URJUDP &RXQMU HLS [

7KH7/ % WMEHRUHQ LQWVKFMRQ/UHQMGVR VMLV/SUREOP DUH\ HFXMG

9 DQG	9LUXDOO DJH1 XP EHU 931	37(
		9 DQG	3K\ VFDOO DJH1 XP EHU 331
	[&		[\$
	[[

3 DUMD SRLQW , QVKLVSDUJFXDU7/ % VKH9 DQG ELWQ VKH ILLWFRXP Q DQG VKH9 DQG ELWQ
 VKHVKLLGFRXP Q DUHVKHMDP HLG ERV 7/ % HQMLHV , QJHQHLDOLVLSRWEQVKDVKHMHVZ R YDQG
 ELWKDYHGLIHUHQWYDQXV'

<HV

3 DUME SRLQW : KDWVLELQDU HQFRGLQ IRU67, HD[HE[" \$ WXP HMDW HD[LV
 HQFRGHGDV DQG HE[LVHQFRGHGDV

3 DUMF SRLQW 7R SURFHWVKH67, LQWVKFMRQ RQHP XWWRVKURXJK VKH) HMK ' HFRGH HMF
 LQWVKFMRQ FQI : KDWLVVKHP Q LP XP QXP EHURI SK\ VFDODGGUHHV/VKDWFDQ EHDFFHWGLQ
 SURFHWLQJ DQ67, LQWVKFMRQ'

+ LQW

, QWVKFMRQ I HMK LV VKHQHFMWU ILLWVMS LQ SURFHWLQJ DQ LQWVKFMRQ
 , QVKHRQH QMHOYLXDCP HP RU V VMP VKHSDJHWQEQMHOYHLQ VKH SK\ VFDOP HP RU

3 DUNG SRLQW 1 RZ VKHSURFHWRUH[HFXMM67, HD[HE[, VWXUQHGRXVMDWLYH
 SK\ VFDOP HP RU DFFHWVZHUHQHGHG 7KHVQEQHEQZ VKRZ VKH9LUXDQ\$ GGUHW 9\$
 3K\ VFDQ\$ GGUHW 3\$ ' DQD DQGZ KHKHURUQRVKHJHZ DVD7/ %KLWRUHDFK RI VKHMILYH
 SK\ VFDOP HP RU DFFHWV/LQVKHRLGHUWKH RFFXUHG 6RP HRI VKEQDNVDUHLQWQMRQDQ QHW
 IRU RX VR ILQ

9 LUXDQ\$ GGUHW	3 K\ VFDQ\$ GGUHW	' DQD	7/ % + LW
[[[\$	<HV
1 \$	[[1 R
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&RP SOMVKHVEQDQGGILQVKHIRQZ LQ VKUHER[HV <RX FDQDWXP HMDWQRSDJHIDQOV
 RFFXUHG

+ LQW

: KDVGRH/VKHILLWV / %KLVF HDQ'

5 HFDOKRZ VR XVH37%5 DQG931 VR DFFHW/VKHSDJHVWEDH

8 VHKHILLWV DQG DWDFFHWH/VR ILXUHRXV/VKHSDJHVJ HILLWV(YHU VKLQ HOHZ LORORZ

SRLQW : KDV/VKHSDJHVJ H'

% VW

SRLQW : KDV/VKHVWV DQXP EHURI SK VFDOSDJH'

SRLQW : KDV/VKHGDV DQV KHSDJHVWEDH HUHJLVWU 37%5 "

[

SRLQW SRLQVSHUEODQN 3ODHFRP SOMVKHVWEDH DERYH 3, ' RQV QRZ ' LV DFFHSMG
RQDSHUEODQNEMLV

3 UREOP SRLQW

\$ SURJUD P HUZ UVMWKHIRCZ LQJ VZ R & FRGHVJIP HQW 6KHZ DQWVR UKQ WHP FRQFXUHQW
RQDP XOMFRHSURFHWRU FDCG6& XMJQ VZ R GLIHUHQWKUHDGV HFK RI Z KLFK Z LQKQ RQD
GLIHUHQWFRUH

7KUHDG7
D ;> @
E D <> @
ZKLOH I ODU
<> @

7KUHDG7
<> @
I ODU
> @
D

; < DQGI ODU KDYHEHQDQDFDMLQ P DQ P HP RU Z KLOH DQGE DUHFRQMLQHG LQWKH
SURFHWRUUHLVMU \$ UHGRUZ UVMVR DQ RI WKH HYDUDEOHV JHQHDMV DMLQJHP HP RU UHTXHW
7KHLQWDOYDOXH V RI DOP HP RU OFDMRQV DQG YDUDEOHV DUH \$ WXP HFDK OQRI WKH & FRGH
VJIP HQWRI HFK WKUHDG WDOQDMMVR DMLQJHP DFKLQHLQWVKFMRQ

3 DUMD SRLQW %RUKWKUHDGV KDYHDYDUDEOH D \$ UHVKH UHHLUQJ VR WKHVDP HYDUDEOH

1 R

3 DUME SRLQW : KDNDUHKHSRMEOH ILQDOYDOXH V RI <> @DVMJERK WKUHDGVI LQVK
H HFXMRQ' & RQMGHUDOMHSRMEOH WKUHDG LQMLUDYQJV

3 DUMF SRLQW : KDNDUHKHSRMEOH ILQDOYDOXH V RI E DVMJERK WKUHDGVI LQVK H HFXMRQ'
& RQMGHUDOMHSRMEOH WKUHDG LQMLUDYQJV

DDG