University of California, Berkeley – College of Engineering

Department of Electrical Engineering and Computer Sciences

Spring 2010 Instructor: Dr. Dan Garcia 2010-03-09

☹ CS61C Midterm ☺

After the exam, indicate on the line above where you fall in the emotion spectrum between "sad" & "smiley"...

Last Name	Answer Key
First Name	
Student ID Number	
Login	cs61c-
Login First Letter (please circle)	a b c d e f g h i j k l m
Login Second Letter (please circle)	a b c d e f g h i j k l m n o p q r s t u v w x y z
*The name of your **LAB** TA (please circle)*	Bing Eric Long Michael Scott
Name of the person to your Left	
Name of the person to your Right	
*All the work is my own. I had no prior knowledge of the exam contents nor will I share the contents with others in CS61C who have not taken it yet. **(please sign)***	

a) Instructions (Read Me!)

- Don't Panic!
- This booklet contains 7 numbered pages including the cover page. Put all answers on these pages; don't hand in any stray pieces of paper.
- Please turn off all pagers, cell phones & beepers. Remove all hats & headphones. Place your backpacks, laptops and jackets at the front. Sit in every other seat. Nothing may be placed in the "no fly zone" spare seat/desk between students.
- Question 0 (1 point) involves filling in the front of this page and putting your login on every sheet of paper.
- You have 180 minutes to complete this exam. The exam is open book, no computers, PDAs, calculators.
- There may be partial credit for incomplete answers; write as much of the solution as you can. We will deduct points if your solution is far more complicated than necessary. When we provide a blank, please fit your answer within the space provided. You have 3 hours...relax.

Question	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
Minutes	1	45	15	30	30	30	(+30 to review) = 180
Points	**1**	**20**	**10**	**18**	**11**	**15**	**75**
Score							

Question 1: Brian Harvey would be proud… (20 pts, 45 min)

Working with a partner, you want to implement a scheme *sentence* ADT (a linked list of words), and you're going to start with the constructor se(*word*, *sentence*). Your partner writes the interface, and shows you how they want to call `se`, and your job will be to write the subroutine. You agree on the standard `struct` definition on the right.

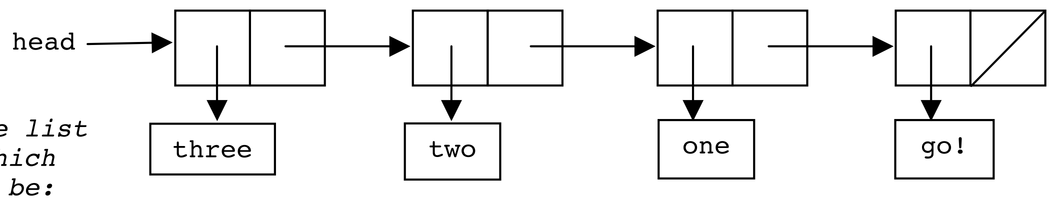
```
// Assume compiler packs tight

typedef struct sentence_node {
     char *word;
     struct sentence_node *next;
} sentence_t;
```

Here's how your friend wants to call `se`:

```
#include <string.h>
#include <stdio.h>
int i;
int main() {
    char word[8];
    sentence_t *head = (sentence_t *) malloc (sizeof(sentence_t)); // assume succeeds…
    head->word ="go!";
    head->next = NULL;
    for (i=1;i<=3;i++) {
        printf("Word? ");  scanf("%s",word); se(word,head);
    }
    // ← Right here, if you ran this program, and typed the following:
}
    // Word? one
    // Word? two
    // Word? three

    // …it'd create the list
    // to the right, which
    // in scheme would be:
    // (three two one go!)
```



a) Complete `se` so it will work with your friend's `main` code, even if he later supports longer words. Think about error checking you might need, and call `exit_with_msg` below, if needed. *Your solution should not need any looping/recursion, just statements that connect things up correctly.*

```
void se(char *word, sentence_t *head) {

    sentence_t *new = (sentence_t *) malloc (sizeof(sentence_t));

    if(!new) exit_with_msg("se: Couldn't allocate space for a new list node");

    new->word = head->word;

    new->next = head->next;

    head->next = new;    head->word = (char *) malloc (sizeof(char)*strlen(word)+1);
if(!head->word) exit_with_msg("se: Couldn't allocate space for the string");
strcpy(head->word,word);

}

void exit_with_msg(char *msg) { printf("Error! %s\n",msg); exit(1); }
```

b) At "← `Right here`", how much space (Bytes) is used by `i`, `word`, & `head` (and their data) together?

Stack	Heap	Static	Code
12 (8 word,4 head)	4*8(cons)+14(str)=46	4 (i) [or 8…go!\0]	4 (go!\0) [or 0]

Question 1: Brian Harvey would be proud… (continued) (20 pts, 45 min)

That interface is counterintuitive, you say. You decide the interface should be *changed* so that the boxed call to `se` looks like this: $\boxed{\texttt{head = se(word, head)}}$ and you now ask *them* to write `se`, but to save space, only keep ONE copy of any word. That is, they should check if the `word` is already in your sentence, and if it is, to *share* it. They write the following but you suspect `share_or_new` has bugs.

```
   sentence_t *se(char *word, sentence_t *head) {
       sentence_t *new = (sentence_t *) malloc (sizeof(sentence_t)); // assume succeeds…
       new->word = share_or_new(word, head);
       new->next = head;
       return new;
   }

   char *share_or_new(char *word, sentence_t *head) {
1      if (word = head->word)                 // Found it, share!
2          return head->word;
3      if(head == NULL) {                     // Didn't find it, create one
4          char new[10];
5          strcpy(new,word);
6          return new;
7      }
8      return share_or_new(word, head->next);   // Keep looking…
   }
```

c) Simulate running the program with the same user input as before.
If the code returns without error, show in scheme format, like `(three two one go!)`, what `head` is at "← ***Right here***".
If the code crashes, indicate the value of `i` when the error occurs. **(go! go! go! go!)** ____________

d) Just for fun, change the "=" in line `1` to "==" (make that change permanent in the code above).
Instead of our previous user input, we type the word `go!` three times. If there is **no** crash by the time we get to "← ***Right here***", *draw the box-and-pointer diagram* for `head` (just like on the previous page).
If there **is** a crash, *list the functions in the stack frame before the error.*
E.g., if `main` called `sub`, which called `subsub`, which crashed, you'd write: `main→sub→subsub→ERROR`.

main → se → share_or_new → share_or_new → ERROR

e) Finally, fix all the bugs so `se` works in general (not just for this particular `main`). Your fixes can be of the form: "change line `i` to (fill in the blank)", or "insert (fill in the blank) before/after line `i`", or "move lines `i` through `j` above line `k`. You may not need all the blanks.

Change line 1 to if(!strcmp(word,head->word))

Change line 4 to be char *new = (char *) malloc (strlen(word)*sizeof(char)+1);

Add if(!new) exit_with_msg("share_or_new: Couldn't malloc space for string"); below 4

Move lines 3 through 7 (8 with the addition of the line above) above line 1

Question 2: L1 and L2 below are Booth needed for the algorithm… (10 pts, 15 min)

Below is a MIPS function. Read it carefully and use it to answer the following questions.

```
myst:   move $v0, $0
L1:     andi $t0, $a0, 1
        beq  $t0, $0, L2
        addu $v0, $v0, $a1
L2:     sll  $a1, $a1, 1
        srl  $a0, $a0, 1
        bne  $a0, $0, L1
        jr $ra
```

a) In one sentence, briefly summarize what `myst` does, precisely (assume the inputs are unsigned). **Don't** describe the algorithm, abstract at a high level what the algorithm is doing. (e.g., "it returns the # of bits in common of its three arguments" or "sets `$a1` to `-$a0`")

It returns the lowest 32 bits of $a0*$a1 in $v0 = ($a0*$a1) mod 2^{32} = ($a0*$a1)&0xFFFFFFFF .

For question (b) only, assume `$a1` is a two's complement negative number.

b) Would `myst` still work? Briefly explain why or why not.

Yes. Adding two's complement numbers is no different than adding unsigned numbers,The answer'd be a 2s complement #. We're using addu, so there are no overflow worries.

For question (c) and (d), let's change the `srl` to `sra`.

c) For what values of its inputs would `myst` still do what you said it does in (a)?

When the MSB of $a0 is 0 (i.e., $a0 & 0x8000000 == 0)

d) When it *doesn't* return the same answer, what does `myst` return / do?

loops indefinitely ($a0 never gets to 0)

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Question 3: Tasting Menu… (18 pts, 30 min)

Thanks to a breakthrough, we can store 3 values per digit instead of the usual 2. Rather than encoding 0, 1, and 2, we choose to encode -1, 0, and 1 (We call these binary-with-negative base 2 digits *binets*). To make notation cleaner, we'll use 1̶ to represent -1, and we'll precede binets with `0bn`. Binet numbers allow us to express negative numbers with an "unsigned" encoding, which is great. However, now some numbers have multiple representations, like 1_{10} = `0bn0001` = `0bn0011̶` (i.e., $1*2^1 + -1*2^0 = 1$)

a) How many unique numbers can be represented using N unsigned binets? ______ $2^{N+1} - 1$ ________

b) Recall that we negated 2's complement binary numbers by inverting each bit and then adding a constant offset (1). It turns out we can negate unsigned binets with a similar technique! Fill in the truth table for what the binet "inversion" function should do *per bit*, and the constant offset that should be added at the end to make it work perfectly.

Original bit	New bit
1̶	1
0	0
1	1̶

Constant Offset
0

List all the representation(s) for zero for a binet nibble (4 binets). 0t0000 ______________________

Assume the heap has 7 contiguous free bytes left (below), and *best fit*, given two equally good candidates, will pick the leftmost one.

d) Fill in the gaps in the C snippet on the right such that the location of `e` is *different* depending on whether `malloc` uses first-fit, next-fit, or best-fit. Indicate in the diagram below where the remaining data is (by a single letter) and where the fits would place `e` (by writing `FIRST`, `NEXT` and `BEST` in the appropriate slot.

```
char *a, *b, *c, *d, *e;
a = (char*) malloc(__2__);
b = (char*) malloc(__1__);
c = (char*) malloc(__1__);
d = (char*) malloc(__1__);
free(__a__);
free(__c__);
e = (char*) malloc(1);
```

FIRST		b	BEST	d	NEXT	

e) We're using C99 and need to store `n` integers, but can't decide how to reserve space for them. What is the **best argument** for using each one? Also, if `$s0` contains the value of `n`, what *minimal* MAL MIPS would the C translate to, that reserves space and puts `&A[0]` (i.e., where `A` points) in `$s1`? All volatile registers have been saved & we'll soon need `$s0` and `$s1`. (Note: `malloc` is just a function)

	`int A[n];`	`int *A = (int *)malloc(sizeof(int)*n);`
Why?	Really fast (3 fast MIPS instructions)	Reliability (we can catch if malloc fails) OR can give storage to caller

MAL MIPS	`sll $t0 $s0 2`
	`subu $sp $sp $t0`
	`move $s1 $sp`
		`sll $a0 $s0 2`
		`jal malloc`
		`move $s1 $v0`

f) How many *total different instructions* could we list on the green sheet if, instead of an explicit `shamt` field, we stored the shift amt in the unused `rs`, register and expanded the `funct` field to use the `shamt` bits also? Be exact. $63+2^{11}(=2,048)=2,111$ ______________

Question 4: Did somebody say "Free Lunch"?! (11 pts, 30 min)

Consider two competing 8-bit floating point formats. Each contains the same fields (sign, exponent, significand) and follows the same general rules as the 32-bit IEEE standard (denorms, biased exponent, non-numeric values, etc.), but allocates its bits differently. To save you time, *you only need to complete and circle the (LEFT or RIGHT) blank whose value is closest to zero*, that's the only one we'll grade! (If they're the same value, write the answer in both, & circle both). E.g,. The number represented by `0x00` was 0 for both, so we circled both. But for "exponent bias", just from the # of `EE…E` bits in each, we know |LEFT's bias| < |RIGHT's bias|, so there's no need to calculate or write the answer on the RIGHT.

"LEFT" format: | S | EE | MMMMM |

scratch space (show all work here)

EE=00 → denorm, 0.MMMMM * $2^{-(BIAS-1)}$ =
0.MMMMMEE=01 → 1.MMMMM * $2^{1-BIAS=0}$ =
1.MMMMMEE=10 → 1.MMMMM * $2^{2-BIAS=1}$ =
1M.MMMMEE=11 → Inf, NaNs

Number represented by **0x00**: 0

Exponent Bias: 1

Numbers (0 ≤ n < 1): (32)#

32# Numbers (1 ≤ n < 2):

c) Difference between two smallest positive values: 2^{-5}

d) Difference between two biggest non-∞ values: (2^{-4})

e) Positive Integer closest to 0 it <u>cannot</u> represent: (4)

"RIGHT" format: | S | EEEEEE | M |

scratch space (show all work here)

E…E=000000→denorm, 0.M * $2^{-(BIAS-1)}$ = 0.M * 2^{-30}E…E=000001→ 1.F * $2^{1-BIAS=-30}$ = 1.M * 2^{-30}#=1 → 1.0*2^0 → M=0,E…E-31=0 → E…E=31SE…EM = 00111110_2 = 62_{10}E…E=111110→ 1.M * $2^{62-BIAS=31}$ = 1.M * 2^{31}E…E=111111→ Inf, NaNs

Number represented by **0x00**: 0

Exponent Bias: 31 (not graded, so no need to write)

Numbers (0 ≤ n < 1): 62#

Numbers (1 ≤ n < 2): (2)#

Difference between two smallest positive values: (2^{-31})

Difference between two biggest non-∞ values: 2^{30}

Positive Integer closest to 0 it <u>cannot</u> represent: 5

f) Which implementation is better for *approximating* π, (LEFT) or RIGHT ? (circle one)

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Question 5: Euclid's Revenge… (15 pts, 30 min)

The *Euclidean Algorithm* is used to find the greatest common divisor (GCD) of two numbers *a* and *b*. E.g., GCD(8,6)=2. The algorithm works because (a ≥ b): GCD(a,0)=a, GCD(*a*, *b*) = GCD(*b*, *a* mod *b*).

a) Implement the Euclidean Algorithm below recursively (but as efficiently as you can) in MAL MIPS. Follow the hints given by the comments; you may not need all the lines. To assist you, assume that `mod` is correctly implemented as a MIPS subroutine that returns `$a0 mod $a1` in `$v0`.
The first letter of the first MIPS instruction is `b`.

```
GCD:  bne   $a1, $0, rec          # Handle base case first; we assume a ≥ b
      addu  $v0, $a0, $0  ## return a
      j done
rec:  addiu $sp, $sp, -8  ## prologue     # Recursive case
      sw    $ra, 4($sp)                   # ← this should be circled (part d)
      ______________________
      sw    $a1, 0($sp)   ## save b   OR  sw $s0, 0($sp) ## save $s0 so we can use
                                      OR  move  $s0, $a1 ## keep b in $s0
      jal   mod
      move  $a1, $v0      ## b = a mod b
      lw $a0, 0($sp)      ## restore a  OR  move  $a0, $s0
      ______________________
      jal GCD
                          ## epilogue
                                      OR lw    $s0, 0($sp)
      lw    $ra, 4($sp)
      addiu $sp, $sp, 8
done: jr $ra
```

For questions (b) & (c), assume the address of `GCD` is `0x1000008`

Translate the first MIPS instruction to hex: **0x14A00002,0x14050002**

Translate the `jal GCD` to hex: **0x0C400002**

d) You notice your code sometimes crashes when you call GCD with large numbers. Circle the instruction that causes the crash, and in *two words*, explain why does it crash. **stack overflow**

In *two words*, what can you do to combat this instability? **rewrite iteratively**