CMSC311, Fall 2009
Exam 1 - Study Guide

October 7, 2009

Overview These problems are representative of the types of exam problems you'll see next week. The number of problems here, and the difficult level of the problems are what you can expect in Exam 1.

I did not include any problems from the book on this study guide. However, you are high encouraged to study the homework problems in the book for the relevant sections.

We'll go over these problems in class next Monday.

This first problem will test your understanding of stack frames. It is based on the following recursive C function:

```
int silly(int n, int *p)
{
    int val, val2;

    if (n > 0)
        val2 = silly(n << 1, &val);
    else
        val = val2 = 0;

    *p = val + val2 + n;

    return val + val2;
}
```

This yields the following machine code:

```
silly:
        pushl %ebp
        movl %esp,%ebp
        subl $20,%esp
        pushl %ebx
        movl 8(%ebp),%ebx
        testl %ebx,%ebx
        jle .L3
        addl $-8,%esp
        leal -4(%ebp),%eax
        pushl %eax
        leal (%ebx,%ebx),%eax
        pushl %eax
        call silly
        jmp .L4
        .p2align 4,,7
.L3:
        xorl %eax,%eax
        movl %eax,-4(%ebp)
.L4:
        movl -4(%ebp),%edx
        addl %eax,%edx
        movl 12(%ebp),%eax
        addl %edx,%ebx
        movl %ebx,(%eax)
        movl -24(%ebp),%ebx
        movl %edx,%eax
        movl %ebp,%esp
        popl %ebp
        ret
```

Problem 1. (25 points):

A. Is the variable `val` stored on the stack? If so, at what byte offset (relative to `%ebp`) is it stored, and why is it necessary to store it on the stack?

B. Is the variable `val2` stored on the stack? If so, at what byte offset (relative to `%ebp`) is it stored, and why is it necessary to store it on the stack?

C. What (if anything) is stored at `-24(%ebp)`? If something is stored there, why is it necessary to store it?

D. What (if anything) is stored at `-8(%ebp)`? If something is stored there, why is it necessary to store it?

Problem 2. (15 points):

Condider the following assembly code for a C `for` loop:

```
loop:
        pushl %ebp
        movl %esp,%ebp
        movl 8(%ebp),%ecx
        movl 12(%ebp),%edx
        xorl %eax,%eax
        cmpl %edx,%ecx
        jle .L4
.L6:
        decl %ecx
        incl %edx
        incl %eax
        cmpl %edx,%ecx
        jg .L6
.L4:
        incl %eax
        movl %ebp,%esp
        popl %ebp
        ret
```

Based on the assembly code above, fill in the blanks below in its corresponding C source code. (Note: you may only use the symbolic variables `x`, `y`, and `result` in your expressions below — *do not use register names.*)

```
int loop(int x, int y)
{
   int result;

   for (_____________; ____________; result++ ) {

      __________;

      __________;
   }

   __________;

   return result;
}
```

Problem 3. (10 points):

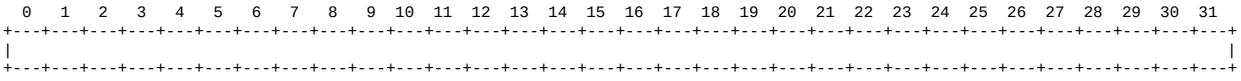
Consider the following datatype definitions on an IA32 (x86) machine running Linux.

```
typedef struct {
  char  c;
  int i;
  char *b;
  short s;
  double d;
} struct1;
```

```
typedef union {
  char  c;
  double *p;
  int i;
  double d;
  short *s;
} union1;
```

A. Using the template below (allowing a maximum of 32 bytes), indicate the allocation of data for a structure of type `struct1`. Mark off and label the areas for each individual element (there are 5 of them). Cross hatch the parts that are allocated, but not used (to satisfy alignment).

Assume the alignment rules discussed in class: data types of size x must be aligned on x-byte boundaries. **Clearly indicate the right hand boundary of the data structure with a vertical line**.



B. How many bytes are allocated for an object of type `struct1`?

C. What alignment is required for an object of type `struct1`? (If an object must be aligned on an x-byte boundary, then your answer should be x.)

D. If we define the fields of `struct1` in a different order, we can reduce the number of bytes wasted by each variable of type `struct1`. What is the number of **unused, allocated** bytes in the best case?

E. How many bytes are allocated for an object of type `union1`?

F. What alignment is required for an object of type `union1`? (If an object must be aligned on an x-byte boundary, then your answer should be x.)

Consider the following C program `prog.c`

```
main( int argc, char *argv[] )
{
  char **p = argv;
  int *i = ((int *)&argv)-1;

  while( (*i)-- )
    printf( "%s%s", *(p++), *i ? " ":"" );
  putchar( '\n' );
}
```

which is compiled on an Intel/32 based Linux machine using `cc -S prog.c` to yield the following `prog.s`:

```
        .file   "prog.c"
        .version        "01.01"
gcc2_compiled.:
.section        .rodata
.LC0:
        .string " "
.LC1:
        .string ""
.LC2:
        .string "%s%s"
.text
        .align 4
.globl main
        .type    main,@function
main:
        pushl %ebp
        movl %esp,%ebp
        subl $24,%esp
        movl 12(%ebp),%eax
        movl %eax,-4(%ebp)
        leal 12(%ebp),%eax
        leal -4(%eax),%edx
        movl %edx,-8(%ebp)
        .p2align 4,,7
.L3:
        movl -8(%ebp),%eax
        decl (%eax)
        cmpl $-1,(%eax)
        jne .L5
        jmp .L4
        .p2align 4,,7
```

```
.L5:
        addl $-4,%esp
        movl -8(%ebp),%eax
        cmpl $0,(%eax)
        je .L6
        movl $.LC0,%eax
        jmp .L7
        .p2align 4,,7
.L6:
        movl $.LC1,%eax
.L7:
        pushl %eax
        movl -4(%ebp),%eax
        movl (%eax),%edx
        pushl %edx
        addl $4,-4(%ebp)
        pushl $.LC2
        call printf
        addl $16,%esp
        jmp .L3
        .p2align 4,,7
.L4:
        addl $-12,%esp
        pushl $10
        call putchar
        addl $16,%esp
.L2:
        movl %ebp,%esp
        popl %ebp
        ret
.Lfe1:
        .size    main,.Lfe1-main
        .ident  "GCC: (GNU) 2.95.3 20010315 (release)"
```

Problem 4. (15 points):

For each of the four (4) variables, `argc, argv, p, i` used in `prog.c`, label the first place it is used in `prog.s` by writing the variable name (*e.g.*, `i` next to this first use on the listing above.

Problem 5. (10 points):

Consider the following short “C” procedure:

```
strcpy( char *d, char *s )
{
         while( *d++ = *s++ )
                ;
}
```

Write an equivalent procedure which uses a `do while` loop instead of the `while` loop used here.

Problem 6. (10 points):

Consider the following C functions and assembly code:

```
int fun4(int *ap, int *bp)
{
    int a = *ap;
    int b = *bp;
    return a+b;
}

int fun5(int *ap, int *bp)
{
    int b = *bp;
    *bp += *ap;
    return b;
}

int fun6(int *ap, int *bp)
{
    int a = *ap;
    *bp += *ap;
    return a;
}
```

```
pushl %ebp
movl %esp,%ebp
movl 8(%ebp),%edx
movl 12(%ebp),%eax
movl %ebp,%esp
movl (%edx),%edx
addl %edx,(%eax)
movl %edx,%eax
popl %ebp
ret
```

Which of the functions compiled into the assembly code shown?

Problem 7. (15 points):

In the following questions assume the variables `a` and `b` are signed integers and that the machine uses two's complement representation. Also assume that `MAX_INT` is the maximum integer, `MIN_INT` is the minimum integer, and `W` is one less than the word length (e.g., `W` = 31 for 32-bit integers).

Match each of the descriptions on the left with a line of code on the right (write in the letter). You will be given 2 points for each correct match.

1. One's complement of `a`

_____

2. `a`.

_____

3. `a & b`.

_____

4. `a * 7`.

_____

5. `a / 4` .

_____

6. `(a < 0) ? 1 : -1` .

_____

a. `~(~a | (b ^ (MIN_INT + MAX_INT)))`

b. `((a ^ b) & ~b) | (~(a ^ b) & b)`

c. `1 + (a << 3) + ~a`

d. `(a << 4) + (a << 2) + (a << 1)`

e. `((a < 0) ? (a + 3) : a) >> 2`

f. `a ^ (MIN_INT + MAX_INT)`

g. `~((a | (~a + 1)) >> W) & 1`

h. `~((a >> W) << 1)`

i. `a >> 2`