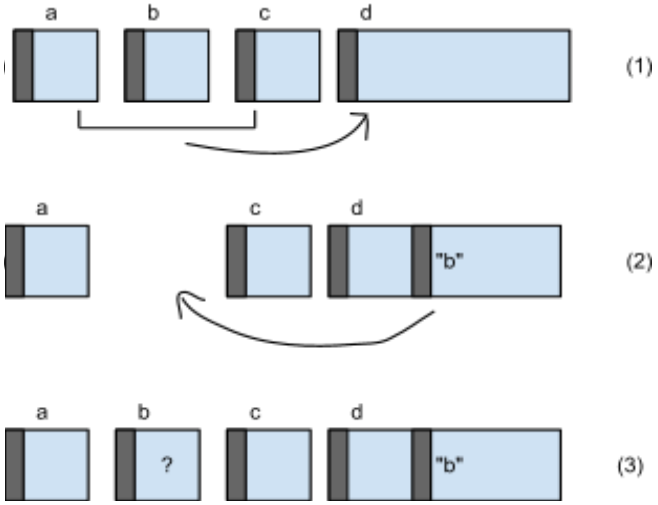
Lecture 8 Notes

Problem Set 1 and Announcements

- Discussion of progress on pset1--cumulative distribution graph
- pset is harder than anticipated--so 3 bonus late days (now 6 total for the semester)
- *wild applause*
- emails will be sent out w/info on git repos/submitting tonight
- How compare.pl works
- no need to denote final commit--but if you turn in late, let staff know.
- Test 26:
    - uses memcpy to copy allocated regions and metadata (1)
    - and uses memcpy to do the reverse copy (2)
    - and tries what should be an invalid free (3)
    - solution: check if pointers *to* b from adjacent links are valid



x86 Assembly code: how code is represented in memory

- focus on *reading* assembly code (nobody needs to do a ton of programming in assembly, but it's good to be able to understand it.)
- x86 originally designed in the 1970s with 16-bit address spaces
- Alpha: extremely clean computer architecture--with 64 bit instructions
- size of instruction in x86: anywhere from 1 byte to 15 bytes
- example programs--Eddie has compiled them with gcc -o1 -s
- -o1 means slightly optimized, -s means to output assembly code

- Assembly contains data and metadata
    - data: instructions and constants
    - metadata: debugging info and other metadata; indicated by a line that starts with a period

Example f00

```
rep
ret
```

- f is a label (NOT CODE)

- rep and ret are instructions
- rep not necessary--see textbook
- ret means return from function
- f is a void function (can't see any return values) that takes no arguments

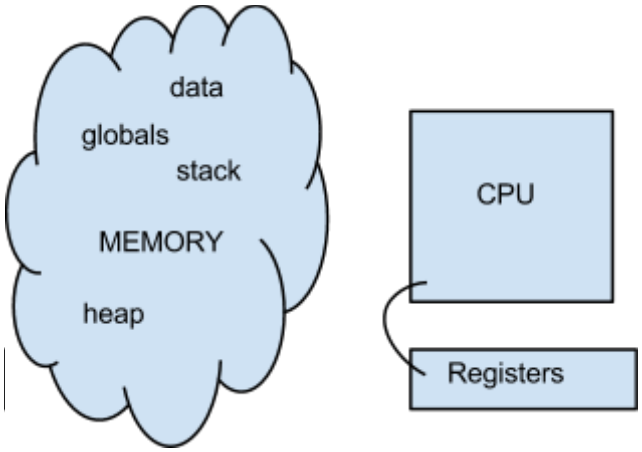
Example f01

```
movl    $0, %eax
ret
```

- this puts the value 0 in the eax register
- so 0 is returned, since eax register contains the return value

What is a register?

- the CPU can only directly interact with registers, not the rest of memory
- compiler maps variables onto registers
- x86 does arithmetic on registers, then moves results back into memory



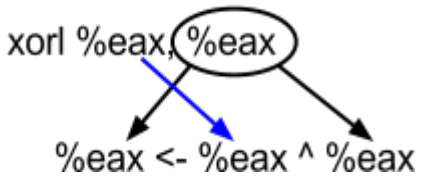
- x86 general registers:
- %eax, %ebx, %ecx, %edx, %esi, %edi, %ebp, %esp, %eip
- %eip stores the address of executing instruction
- CPU is like a Turing machine, with %eip storing the current state
- naming of registers: x is for extended...and e is for extra extended (to eventually be 32 bits)

Example f02

```
xorl    %eax, %eax
ret
```

General form of x86 instructions

- operator source, destination
- $ indicates a constant
- each instruction has an operator, a source, and a combined source/destination



- in C, the program just consists of return 0;
- but the xorl command is shorter than a movl to move 0 to %eax

BREAK

- note that any function that just returns zero can have return types of int, char, unsigned char, etc. (or if it returns NULL, char *, int *, etc.), but still corresponds to same assembly code.
- so the return type is lost--the processor doesn't know about types, just knows how to treat numbers in different ways.
- so we lose performance info when moving back from assembly to C

Example f03

```
movl    a, %eax
subl    b, %eax
ret
```

- subtracts `b` from `a`
- here, `a` and `b` are *globals*
- can't be heap addresses, since those are not known until runtime
- and can't be locals, since functions could be called in multiple locations on the stack

Variables:

- $ indicates constant (ex. $0)
- names (ex. `a`, `b`) are references to globals
- and % indicates registers (e.g. %eax)

Example f04

```
movl    a, %eax
addl    b, %eax
ret
```

- adds `b` to `a`
- (unsigned and signed ints don't make a difference with addition, so the assembly instructions are exactly the same)
- no such thing as declaring variables in assembly (except for globals)

Example f05

```
movl    x, %eax
movl    (%eax), %eax
ret
```

- indirect addressing
- in assembly, dereference an address by using ( ) → so (%eax) dereferences %eax

```
extern int x;
int f(void) {
      return *x;
}
```

Example f06

```
movl      x, %eax
movl      (%eax), %eax
ret
```

- the C source uses x as an array and returns x[0]...which is the same address as x
- So the assembly is the same, because the address is the same.

```
extern int x[];
int f(void) {
      return x[0];
}
```

Example f07

```
movzbl      x, %eax
ret
```

- in movzbl, `z` = zero, `b` = bytes
- `l` generally means 32 bits
- so movzbl means: move a byte with zero extension into 32-bit (“l”) register; last byte of register is that byte, all others are zero
- (zero extension means to put zeroes into the remaining unused bytes of the register)
- so the C source contains an unsigned char x, casted to an int and returned
- if we make it a signed char, the assembly has movsbl instead of movzbl:

```
movsbl      x, %eax
ret
```

- this means to move the byte and preserve sign by extending other bytes appropriately.

Example f10

```
movl        x , %eax
movzbl      (%eax), %eax
ret
```

- returns an unsigned char x, dereferenced.

```
extern unsigned char *x
int f() {
      return *x;
}
```

- if you use short instead of unsigned char, need movzwl
- where w=word (16-bit)
- also q = quad word (64-bit)

Example f11

```
movl        x , %eax
movzbl      1(%eax), %eax
ret
```

- 1(%eax) is the dereference of %eax + 1 → *(%eax + 1)
- so it corresponds to returning x[1]

```
extern unsigned char *x
int f() {
      return x[1];
}
```

Example f12

```
movl        4(%esp) , %eax
ret
```

- %esp is on the stack (s indicates stack)
- it's the identity function
- that's all folks

```
unsigned f(unsigned i) {
      return i;
}
```

Instruction general pattern: OP SRC DST SRC ← SRC OP DST (like += operators in C)	**What it does**
$[*stuff*]	*stuff* is a constant value
%[stuff]	stuff is an address
stuff	stuff is a reference to a global variable
(%stuff)	dereference (%stuff) to get *stuff
N(%stuff)	dereference (%stuff + N) = *(%stuff +N), where N = 1,2,3...
rep	not really necessary, spaceholder that makes makes function have >1 byte
ret	return from function
movl [A], [B]	moves [A] into [B]
xorl	XOR
subl [A], [B]	[B] - [A]
addl [A], [B]	[A]+[B]
movzbl [A], [B]	z=0, b= byte, l = 32bits move byte w/ zero extension into a 32bit register %eax |0|0|0|x|
movsbl [A], [B]	like movzbl, except s = sign extension, so will fill other bits with top byte of [A]
movzwl [A],[B]	w = 2 bytes/16 bits

Symbol/Register	What it does
%eax	register that holds return value of function
%ebx, ecx, edx, esi, edi, ebp, esp	general purpose registers commonly seen in code x - symbolizes extended register e - 32bit version of register s - stack
%eip	address of currently executing instruction (the current state of the “turing machine” x86 processor)