Agenda

- Attack Lab
- C Exercises
- C Conventions
- C Debugging
- Version Control
- Compilation
- Demonstration

Attack Lab...

is due Thursday. Start now if you haven’t yet.

Some warnings about C

- It’s possible to write bad code. Don’t.
- Watch out for implicit casting.
- Watch out for undefined behavior.
- Watch out for memory leaks.
- Macros and pointer arithmetic can be tricky.
- K&R is the official reference on how things behave.

C-0

```
int foo(unsigned int u) {
    return (u > -1) ? 1 : 0;
}
```

C-0

```
int foo(unsigned int u) {
    return (u > -1) ? 1 : 0;
}
```

-1 is cast to an unsigned int in the comparison, so the comparison that is happening is actually `u > int_max`. This always returns 0.

C-1

```
int main() {
   int* a = malloc(100*sizeof(int));
   for (int i=0; i<100; i++) {
      a[i] = i / a[i];
   }
   free(a);
   return 0;
}
```

C-1

```
int main() {
   int* a = malloc(100*sizeof(int));
   for (int i=0; i<100; i++) {
      a[i] = i / a[i];
   }
   free(a);
   return 0;
}
```

No value in `a` was initialized. The behavior of `main` is undefined.

C-2

```
int main() {
   char w[strlen("C programming")];
   strcpy(w,"C programming");
   printf("%s\n", w);
   return 0;
}
```

C-2

```
int main() {
   char w[strlen("C programming")];
   strcpy(w,"C programming");
   printf("%s\n", w);
   return 0;
}
```

`strlen` returns the length of the string not including the null character, so we end up writing a null byte outside the bounds of `w`.

C-3

```
struct ht_node {
    int key;
    int data;
};
typedef struct ht_node* node;

node makeNnode(int k, int e) {
    node curr = malloc(sizeof(node));
    curr->key = k;
    curr->data = e;
    return curr;
}
```

C-3

```
struct ht_node {
    int key;
    int data;
};
typedef struct ht_node* node;

node makeNnode(int k, int e) {
    node curr = malloc(sizeof(node));
    curr->key = k;
    curr->data = e;
    return curr;
}
```

`node` is a `typedef` to a `struct ht_node` pointer, not the actual struct. So `malloc` could return 4 or 8 depending on system word size.

C-4

```
char *strcdup(int n, char c) {
   char dup[n+1];
   int i;
   for (i = 0; i < n; i++)
      dup[i] = c;
   dup[i] = '\0';
   char *A = dup;
   return A;
}
```

C-4

```
char *strcdup(int n, char c) {
   char dup[n+1];
   int i;
   for (i = 0; i < n; i++)
      dup[i] = c;
   dup[i] = '\0';
   char *A = dup;
   return A;
}
```

`strcdup` returns a stack-allocated pointer. The contents of `A` will be unpredictable once the function returns.

C-5

```
#define IS_GREATER(a, b) a > b
inline int isGreater(int a, int b) {
   return a > b ? 1 : 0;
}
int m1 = IS_GREATER(1, 0) + 1;
int m2 = isGreater(1, 0) + 1;
```

C-5

```
#define IS_GREATER(a, b) a > b
inline int isGreater(int a, int b) {
   return a > b ? 1 : 0;
}
int m1 = IS_GREATER(1, 0) + 1;
int m2 = isGreater(1, 0) + 1;
```

`IS_GREATER` is a macro that is not wrapped in parentheses. `m1` will actually evaluate to `0`, since `1 > 0+1 = 0`.

C-6

```
#define NEXT_BYTE(a) ((char*)(a + 1));

int a1 = 54; // &a1 = 0x100
long long a2 = 42; // &a2 = 0x200
void* b1 = NEXT_BYTE(&a1);
void* b2 = NEXT_BYTE(&a2);
```

C-6

```
#define NEXT_BYTE(a) ((char*)(a + 1));

int a1 = 54; // &a1 = 0x100
long long a2 = 42; // &a2 = 0x200
void* b1 = NEXT_BYTE(&a1);
void* b2 = NEXT_BYTE(&a2);
```

`b1` is a void pointer to the address `0x104`.
`b2` is a void pointer to the address `0x208`.

C Workshop

- If you had trouble with the previous exercises, **go!!!**
- Saturday, October 10 in the afternoon. Details TBA.
- Material:
  - Undefined behavior, casting
  - Structs, pointers
  - Memory management
  - Standard library functions
  - Random stuff: macros, typedefs, function pointers, header guards… and anything else you have questions on!

The C Standard Library

- `#include <stdlib.h>`
- Use it. It is your friend!
- Don’t write code that’s already been written!
  - Your work might have a bug or lack features
- All C Standard Library functions are documented.
  - Use the UNIX `man` command to look up usage

Robustness

- Code that crashes is bad.
  - Avoid making bad things!
  - Don’t write code with undefined behavior
  - Check for failed system calls and invalid input
- Some errors should be recoverable, others not
  - Proxy Lab is an excellent example of this
- Free memory that you allocate
  - Leaky code will crash (and code that crashes is bad!)
  - Memory leaks will cost you style points

Robustness: Continued

- CSAPP wrappers check return values of system calls
  - Terminate program when error is encountered
  - `Malloc, Free, Open, Close, Fork,` etc.
  - Super duper useful for Proxy & Shell Labs
- Alternatively, check for error codes yourself
  - Useful when you don't want program to terminate

```
FILE *pfile; // file pointer
if (!(pfile = fopen("myfile.txt", "r"))) {
    printf("Could not find file. Opening default!");
    pfile = fopen("default.txt", "r");
}
```

Quick C Tip: `getopt`

- Used for parsing command-line arguments
- **Don't write your own code for this**. Not worth it.
  - In fact, we actively discourage it
  - Autograder randomizes argument order
  - Try it: `man getopt`

Style Points

- We read and grade your code for style
  - Style guide: http://cs.cmu.edu/~213/codeStyle.html
  - Vim macro to highlight lines longer than 80 cols:
    - `2mat ErrorMsg '\%80v.'`
  - Emacs users… :

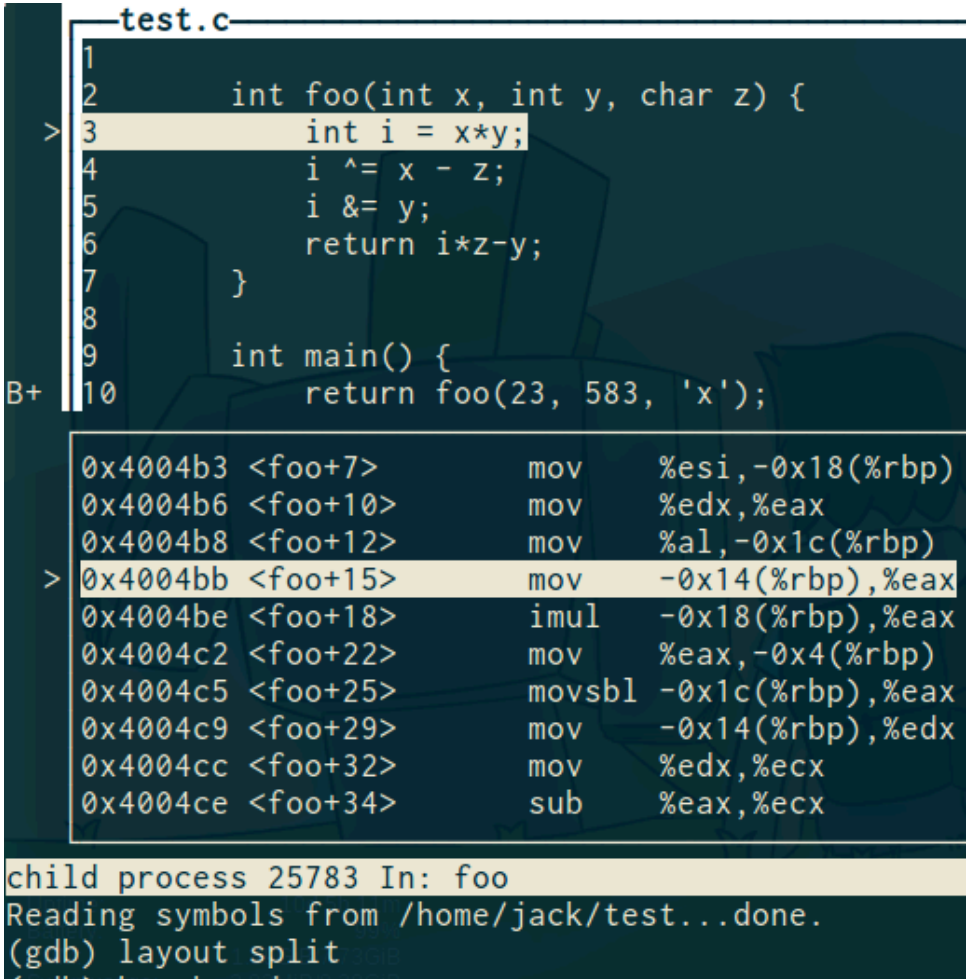
```
(setq whitespace-style '(trailing lines space-
 before-tab indentation space-after-tab)
 whitespace-line-column 80)
```

- View your annotated code on Autolab

gdb

- Step through C code side-by-side with Assembly
  - Print variables, not just registers and addresses!
  - Break at lines, not just addresses and functions!
- `gdbtui <binary>` is gdb with a less-breakable user interface.
  - Nice for looking at your code during execution
  - Type `layout split` to view Assembly alongside

gdbtui


test.c
1
2 int foo(int x, int y, char z) {
> 3 int i = x*y;
4 i ^= x - z;
5 i &= y;
6 return i*z-y;
7 }
8
9 int main() {
B+ 10 return foo(23, 583, 'x');
0x4004b3 <foo+7> mov %esi,-0x18(%rbp)
0x4004b6 <foo+10> mov %edx,%eax
0x4004b8 <foo+12> mov %al,-0x1c(%rbp)
> 0x4004bb <foo+15> mov -0x14(%rbp),%eax
0x4004be <foo+18> imul -0x18(%rbp),%eax
0x4004c2 <foo+22> mov %eax,-0x4(%rbp)
0x4004c5 <foo+25> movsbl -0x1c(%rbp),%eax
0x4004c9 <foo+29> mov -0x14(%rbp),%edx
0x4004cc <foo+32> mov %edx,%ecx
0x4004ce <foo+34> sub %eax,%ecx
child process 25783 In: foo
Reading symbols from /home/jack/test...done.
(gdb) layout split

`valgrind`

- Best tool for finding...
  - Memory leaks
  - Other memory errors (like double frees)
  - Memory corruption
- Use `gcc` with `-g` to give you line numbers of leaks
- Use `valgrind --leak-check=full` for thoroughness

Version Control: Your Friend

- You may find it useful to use version control if you are already familiar with it
- If not, that's okay, it's not required. Making regular submissions to Autolab can act as a checkpointing system too.

`gcc`

- GNU Compiler Collection
- Is a C compiler, among other things
- We will give you instructions for compilation in handouts
- `man gcc` if you're having trouble

`make`

- Lab handouts come with a `Makefile`
  - Don’t modify them
- You write your own for Proxy Lab
  - Examples for syntax found in previous labs
- `make` reads `Makefile` and compiles your project
- Easy way to automate tedious shell commands