15-213 Recitation: C Review

TA’s

11 Feb 2019

Agenda

- Logistics
- C Assessment
- C Programming Style
- C Exercise
- Stack Frame
- Attack Lab Introduction

Logistics

- Bomb Lab is due **Thursday at midnight**!
  - “But if you wait until the last minute, it only takes a minute!” – NOT!
  - Don’t waste your grace days on this assignment!
- Attack Lab will be released shortly thereafter!

C Assessment

- 3.5 Basic C Programming Questions

- Take some time to write down your answer for each question

C Assessment: Question 1

- Which lines have a problem and how can you fix it?

```
1   int main(int argc, char** argv) {
2         int *a = (int*) malloc(213 * sizeof(int));
3         for (int i=0; i<213; i++) {
4               if (a[i] == 0) a[i]=i;
5               else a[i]=-i;
6         }
7         return 0;
8   }
```

C Assessment: Question 1

- `malloc` can fail!

```
1   int main(int argc, char** argv) {
2         int *a = (int*) malloc(213 * sizeof(int));
          if (a == NULL) return 0;
3         for (int i=0; i<213; i++) {
4               if (a[i] == 0) a[i]=i;
5               else a[i]=-i;
6         }
7         return 0;
8   }
```

C Assessment: Question 1

- Allocated memory is not initialized!

```
1   int main(int argc, char** argv) {
2         int *a = (int*) calloc(213, sizeof(int));
          if (a == NULL) return 0;
3         for (int i=0; i<213; i++) {
4               if (a[i] == 0) a[i]=i;
5               else a[i]=-i;
6         }
7         return 0;
8   }
```

C Assessment: Question 1

- Declaring variables inside a for loop requires `-std=c99`

```
1   int main(int argc, char** argv) {
2         int *a = (int*) calloc(213, sizeof(int));
          if (a == NULL) return 0;
3         for (int i=0; i<213; i++) {
4               if (a[i] == 0) a[i]=i;
5               else a[i]=-i;
6         }
7         return 0;
8   }
```

C Assessment: Question 1

- All allocated memory must be freed!

```
1   int main(int argc, char** argv) {
2         int *a = (int*) calloc(213, sizeof(int));
          if (a == NULL) return 0;
3         for (int i=0; i<213; i++) {
4               if (a[i] == 0) a[i]=i;
5               else a[i]=-i;
6         }
          free(a);
7         return 0;
8   }
```

C Assessment: Question 2

- What are the values of A and B?

```
#define SUM(x, y) x + y

int sum(int x, int y) {
    return x + y;
}

int A = SUM(2, 1) * 3;
int B = sum(2, 1) * 3;
```

C Assessment: Question 2

- What is wrong with our macro `SUM`?

```
#define SUM(x, y) x + y

int sum(int x, int y) {
    return x + y;
}

int A = SUM(2, 1) * 3;        // A = 2 + 1 * 3 = 5!?
int B = sum(2, 1) * 3;        // B = 9
```

C Assessment: Question 2

- Use parenthesis around result!

```
#define SUM(x, y) (x + y)

int sum(int x, int y) {
    return x + y;
}

int A = SUM(2, 1) * 3;        // A = 9
int B = sum(2, 1) * 3;        // B = 9
```

C Assessment: Question 2 Part B

- What are the values of A and B?

```
#define MULT(x, y) (x * y)

int mult(int x, int y) {
    return x * y;
}

int A = MULT(2, 0 + 1) * 3;
int B = mult(2, 0 + 1) * 3;
```

C Assessment: Question 2 Part B

- What is wrong with our macro `MULT`?

```
#define MULT(x, y) (x * y)

int mult(int x, int y) {
    return x * y;
}

int A = MULT(2, 0 + 1) * 3;        // A = (2 * 0 + 1) * 3 = 3?!
int B = mult(2, 0 + 1) * 3;        // B = 6
```

C Assessment: Question 2 Part B

- Use parenthesis around macro arguments (and result)!

```
#define MULT(x, y) ((x) * (y))

int mult(int x, int y) {
    return x * y;
}

int A = MULT(2, 0 + 1) * 3;        // A = ((2) * (0 + 1)) * 3 = 6
int B = mult(2, 0 + 1) * 3;        // B = 6
```

C Assessment: Question 2

- Macros are good for compile-time decisions
  - Assert, requires, etc
  - dbg_print
- Macros are not functions and should not be used interchangeably

C Assessment: Question 3

- What lines make `safe_int_malloc` not so safe?

```
1   int *safe_int_malloc(int *pointer) {
2         pointer = malloc(sizeof(int));
3         if (pointer == NULL) exit(-1);
4         return &pointer;
5   }
```

C Assessment: Question 3

- `pointer` is a local copy of the pointer!

```
1   int *safe_int_malloc(int **pointer) {
2         *pointer = malloc(sizeof(int));
3         if (pointer == NULL) exit(-1);
4         return &pointer;
5   }
```

C Assessment: Question 3

- `&pointer` is a location on the stack in `safe_int_malloc`'s frame!

```
1   int **safe_int_malloc(int **pointer) {
2         *pointer = malloc(sizeof(int));
3         if (pointer == NULL) exit(-1);
4         return pointer;
5   }
```

C Assessment Conclusion

- Did you answer every question correctly? If not…
  - Attend the C Bootcamp on Feb 24
- Was the test so easy you were bored? If not…
  - Attend the C Bootcamp on Feb 24
- When in doubt…
  - Attend the C Bootcamp on Feb 24
- This will be *very* important for the rest of this class, so make sure you are comfortable with the material covered or come to the C Bootcamp!

C Programming Style

- Document your code with comments
- Check error and failure conditions
- Write modular code
- Use consistent formatting
- Avoid memory and file descriptor leaks

- Warning: *Dr. Evil* has returned to grade style on Cache Lab! ☺
  - Refer to full 213 Style Guide: http://cs.cmu.edu/~213/codeStyle.html

C Exercise

- Learn to use `getopt`
  - Extremely useful for Cache Lab
  - Processes command line arguments
- Let's write a Pythagorean Triples Solver!
  - Pair up!
  - Login to a shark machine
  - `$ wget http://cs.cmu.edu/~213/recitations/rec6.tar`
  - `$ tar xvf rec6.tar`
  - `$ cd rec6`
- But first, a simple `getopt` example…
  - `$ vim getopt-example.c`

C Exercise: `$ man 3 getopt`

- `int getopt(int argc, char * const argv[], const char *optstring);`
- `getopt` returns -1 when done parsing
- `optstring` is string with command line arguments
  - Characters followed by colon require arguments
    - Find argument text in `char *optarg`
  - `getopt` can't find argument or finds illegal argument sets `optarg` to "?"
  - Example: "`abc:d:`"
    - `a` and `b` are boolean arguments (not followed by text)
    - `c` and `d` are followed by text (found in `char *optarg`)

C Exercise: C Hints and Math Reminders

- $a^2 + b^2 = c^2$
  - $\Rightarrow a = \sqrt{c^2 - b^2}$
  - $\Rightarrow b = \sqrt{c^2 - a^2}$
  - $\Rightarrow c = \sqrt{a^2 + b^2}$
  - $\Rightarrow 3^2 + 4^2 = 5^2$

- String to float in C:

```
#include <stdlib.h>
float atof(const char *str);
```

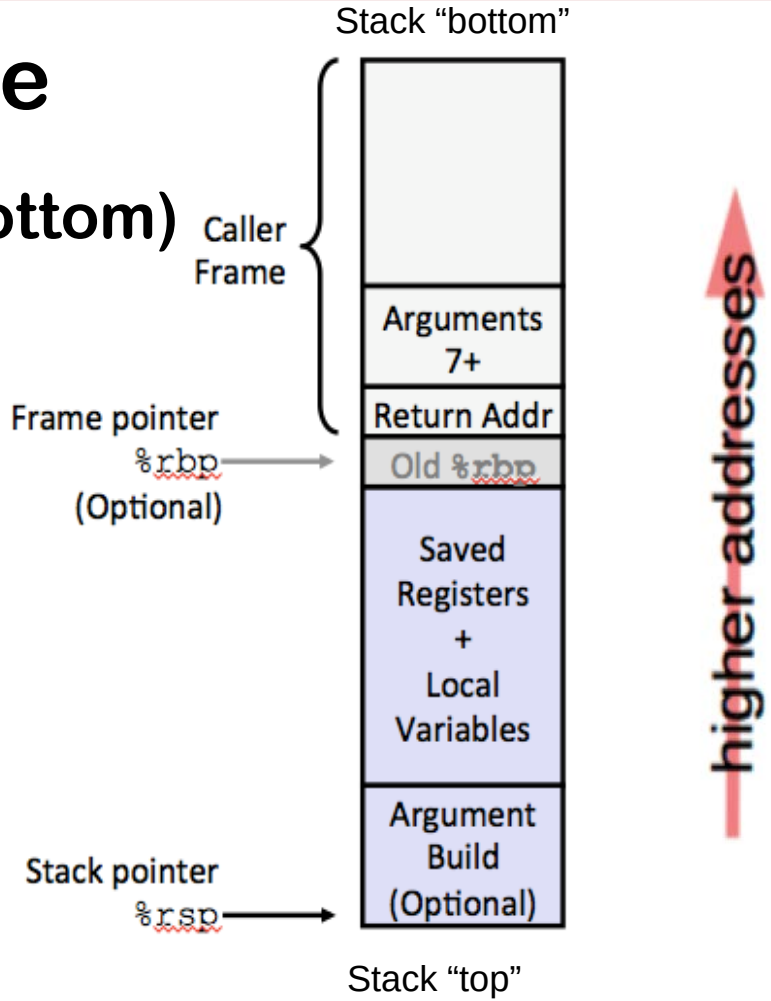
- Square root in C:

```
#include <math.h>
float sqrt(float x);
```

x86-64/Linux Stack Frame

- **Current Stack Frame ("Top" to Bottom)**
  - "Argument build:"
    - Parameters for function about to call
  - Local variables
    - If can't keep in registers
  - Saved register context
  - Old frame pointer (optional)

- **Caller Stack Frame**
  - Return address
    - Pushed by call instruction
  - Arguments for this call



Attack Lab

- We're letting you hijack programs by running buffer overflow attacks on them.
  - Is that not justification enough?
- To understand stack discipline and stack frames
- To defeat relatively secure programs with return oriented programming