15-213 Recitation: C Review

TA’s

2 Oct 2017

Agenda

- Logistics
- Attack Lab Conclusion
- C Assessment
- C Programming Style
- C Exercise
- Cache Lab Overview
- Appendix:
  - Valgrind
  - Clang / LLVM
  - Cache Structure

Logistics

- Attack Lab is due **tomorrow at midnight**!
  - Come to office hours for help
  - `rtarget` phase 3 is only worth 5 points
    - 0.2% of your grade ≈ 0% of your grade
- Cache Lab will be released shortly thereafter!

Attack Lab Conclusion

- Don’t use functions vulnerable to buffer overflow (like `gets`)
  - Use functions that allow you to specify buffer lengths:
    - `fgets` instead of `gets`
    - `strncpy` instead of `strcpy`
    - `strncat` instead of `strcat`
    - `snprintf` instead of `sprint`
  - Use `sscanf` and `fscanf` with input lengths (`%213s`)

- Stack protection makes buffer overflow very hard…
  - But very hard ≠ impossible!

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 = 6
```

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 = 6
int B = sum(2, 1) * 3;        // B = 6
```

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…
  - Refer the C Bootcamp slides
- Was the test so easy you were bored? If not…
  - Refer the C Bootcamp slides
- When in doubt…
  - Refer the C Bootcamp slides
- 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);
```

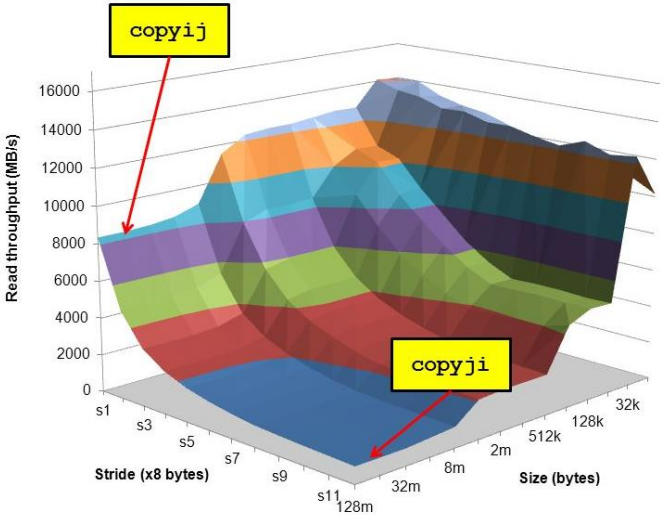
- Square root in C:

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

Cache Lab Overview

- Programs exhibiting locality run *a lot* faster!
  - Temporal Locality – same item referenced again
  - Spatial Locality – nearby items referenced again

- Cache Lab's Goal:
  - Understand how L1, L2, … etc. caches work
  - Optimize memory dependent code to minimize cache misses and evictions
    - Noticeable increase in speed



If you get stuck…

- Reread the writeup
- Look at CS:APP Chapter 6
- Review lecture notes (http://cs.cmu.edu/~213)
- Come to Office Hours (Sunday to Thursday, 5-9pm WH-5207)
- Post private question on Piazza
- `man malloc`, `man valgrind`, `man gdb`

Cache Lab Tips!

- Review cache and memory lectures
  - Ask if you don’t understand something
- Start early, this can be a challenging lab!
- Don’t get discouraged!
  - If you try something that doesn't work, take a well deserved break, and then try again
- Finally, **Good luck on Cache Lab!**

Appendix

- Valgrind
- Clang / LLVM
- Cache Structure

Appendix: Valgrind

- Tool used for debugging memory use
  - Finds many potential memory leaks and double frees
  - Shows heap usage over time
  - Detects invalid memory reads and writes
  - To learn more… man valgrind

- Finding memory leaks
  - `$ valgrind –leak-resolution=high –leak-check=full –show-reachable=yes –track-fds=yes ./myProgram arg1 arg2`

Appendix: Clang / LLVM

- Clang is a (gcc equivalent) C compiler
  - Support for code analyses and transformation
  - Compiler will check you variable usage and declarations
  - Compiler will create code recording all memory accesses to a file
  - Useful for Cache Lab Part B (Matrix Transpose)

Appendix: Cache Structure