CSE 333 – SECTION 2

Memory Management, Valgrind

How are exercises going?

- In CSE333 exercise, watch out for these points:
- Comments
  - Program Comments – Author, copyright, problem description at the top
  - Function Comments – Near the prototype/declaration in header files
- `clint` or `cpplint` errors
  - Help you write standardized, clean codes.
  - However, we don’t really care about some of its complaints. E.g. Sizeof() clint/cpplint errors can be ignored.
- Valgrind errors

Memory Management

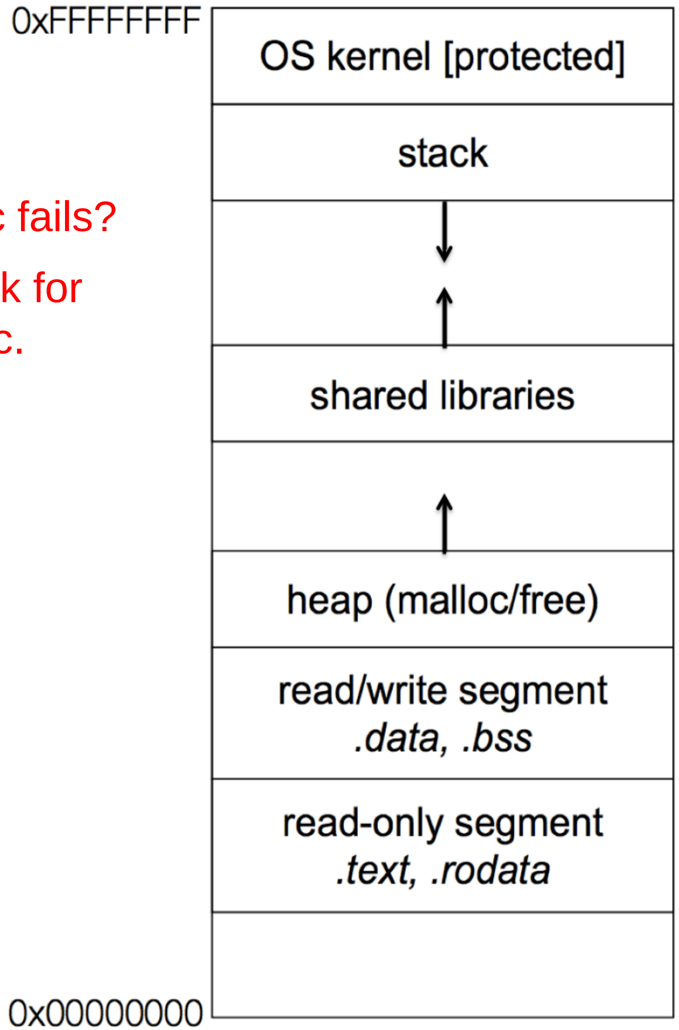
- Heap
  - Large pool of unused memory
  - malloc() allocates chunks of this memory

    Side note: What if malloc fails?

    In this class always check for the return value of malloc.
  - free() deallocates memory and reclaims space

- Stack and stack frame
  - Stores temporary/local variables
  - Each function has its own stack frame

- Lifetime on heap vs. Lifetime on stack



ex01

- Ex01-0
  - 1) Sub() is not declared in ex01-0.c.
  - 2) Declare sub() before main
  - 3) Compiler does not know if sub() exist, but the linker knows. So it produces the right output.
- Ex01-1
  - 1) Calling printf() without declaring would cause implicit declaration of printf(). C compiler assumes that function without prototype returns int and takes undefined-but-fixed number of arguments. This is incompatible with the built-in printf();
  - 2) printf() is located in the C standard library, and by default the linker links C standard library.
- Ex01-2
  - The address of literal “five” is passed to sub(), and is implicitly converted to a long int.
- Ex01-3
  - 1) A,B,C
  - 2) AA,BB,CC,main
  - 3) You can’t tell.

Symbol table

- .text(code)
- .data(contains initialized static variables, that is, global variables and static local variables)
- .rodata(*read-only data segment*)
- .bss(uninitialized data, both variables and constants)

Demo: buggy code

buggy.c demo + code fix

Some buggy code

https://courses.cs.washington.edu/courses/cse333/17wi/sections/2/buggy.c

```c
#include <stdio.h>
#include <stdlib.h>

// Returns an array containing [n, n+1, ... , m-1, m]. If n>m, then the
// array returned is []. If an error occurs, NULL is returned.

int *RangeArray(int n, int m) {
  int length = m-n+1;

  // Heap allocate the array needed to return
  int *array = (int*) malloc(sizeof(int)*length);

   // Initialize the elements
   for(int i=0;i<=length; i++)
     array[i] = i+n;

   return array;
 }

 // Accepts two integers as arguments
 int main(int argc, char *argv[]) {
   if(argc != 3) return EXIT_FAILURE;
   int n = atoi(argv[1]), m = atoi(argv[2]);  // Parse cmd-line args
   int *nums = RangeArray(n,m);

   // Print the resulting array
   for(int i=0; i<= (m-n+1); i++)
     printf("%d", nums[i]);
   puts("");

   return EXIT_SUCCESS;
 }
```

Valgrind output

```
==22891== Command: ./warmup 1 10
==22891==
==22891== Invalid write of size 4
==22891== at 0x400616: RangeArray (warmup.c:14)
==22891== by 0x400683: main (warmup.c:22)
==22891== Address 0x51d2068 is 0 bytes after a block of size 40 alloc'd
==22891== at 0x4C2A93D: malloc (in /usr/lib/valgrind/vgpreload_memcheck-amd64-linux.so)
==22891== by 0x4005EC: RangeArray (warmup.c:10)
==22891== by 0x400683: main (warmup.c:22)
==22891==
==22891== Invalid read of size 4
==22891== at 0x4006A5: main (warmup.c:26)
==22891== Address 0x51d2068 is 0 bytes after a block of size 40 alloc'd
==22891== at 0x4C2A93D: malloc (in /usr/lib/valgrind/vgpreload_memcheck-amd64-linux.so)
==22891== by 0x4005EC: RangeArray (warmup.c:10)
==22891== by 0x400683: main (warmup.c:22)
==22891==
1 2 3 4 5 6 7 8 9 10 11
==22891==
==22891== HEAP SUMMARY:
==22891== in use at exit: 40 bytes in 1 blocks
==22891== total heap usage: 1 allocs, 0 frees, 40 bytes allocated
==22891==
==22891== 40 bytes in 1 blocks are definitely lost in loss record 1 of 1
==22891== at 0x4C2A93D: malloc (in /usr/lib/valgrind/vgpreload_memcheck-amd64-linux.so)
==22891== by 0x4005EC: RangeArray (warmup.c:10)
==22891== by 0x400683: main (warmup.c:22)
==22891==
==22891== LEAK SUMMARY:
==22891== definitely lost: 40 bytes in 1 blocks
==22891== indirectly lost: 0 bytes in 0 blocks
==22891== possibly lost: 0 bytes in 0 blocks
==22891== still reachable: 0 bytes in 0 blocks
==22891== suppressed: 0 bytes in 0 blocks
==22891==
==22891== For counts of detected and suppressed errors, rerun with: -v
==22891== ERROR SUMMARY: 3 errors from 3 contexts (suppressed: 3 from 3)
```

Valgrind errors

- An `Invalid read` means that the memory location that the process was trying to read is outside of the memory addresses that are available to the process. size 8 means that the process was trying to read 8 bytes. On 64-bit platforms this could be a pointer, but also for example a long int.

Valgrind memory leak report

- "definitely lost" means your program is leaking memory -- fix those leaks!
- "indirectly lost" means your program is leaking memory in a pointer-based structure. (E.g. if the root node of a binary tree is "definitely lost", all the children will be "indirectly lost".) If you fix the "definitely lost" leaks, the "indirectly lost" leaks should go away.
- "possibly lost" means your program is leaking memory, unless you're doing unusual things with pointers that could cause them to point into the middle of an allocated block; see the user manual for some possible causes.
- "still reachable" means your program is probably ok -- it didn't free some memory it could have. This is quite common and often reasonable. Don't use --show-reachable=yes if you don't want to see these reports.
- "suppressed" means that a leak error has been suppressed. There are some suppressions in the default suppression files. You can ignore suppressed errors.

- What are some common complaints?

- Invalid writes
- Invalid reads
- Use of uninitialized memory

- For Explanation of error messages, refer to the Valgrind user manual
- http://valgrind.org/docs/manual/mc-manual.html

Note from section:
C99 standard: **free**(**NULL**) is guaranteed to be safe. Checking just adds unnecessary clutter to your code.

Memory Errors

- Use of uninitialized memory
- Reading/writing memory after it has been freed – Dangling pointers
- Reading/writing to the end of malloc'd blocks
- Reading/writing to inappropriate areas on the stack
- Memory leaks where pointers to malloc'd blocks are lost
- Mismatched use of malloc/new/new[] vs free/delete/delete[]

`Valgrind is your friend!!`