

CS 214: Systems Programming, Fall 2020

Assignment 1: ++Malloc

0. Introduction

In this assignment, you will implement `malloc()` and `free()` library calls for dynamic memory allocation that detect common programming and usage errors.

`Malloc(size_t size)` is a system library call that (hopefully) returns a pointer to a block of memory of at least the requested size. This memory comes from a main memory resource managed by the operating system. The `free(void *)` function informs the operating system that you are done with a given block of dynamically-allocated memory, and that it can reclaim it for other uses.

You will use a large array to simulate main memory (`static char myblock[4096]`). Your `malloc()` function will return pointers to this large array and your `free()` function will let your code know that a previously-allocated region can be reclaimed and used for other purposes. Programmers can easily make some very debilitating errors when using dynamic memory. Your versions of `malloc()` and `free()` will detect these errors and will react nicely by not allowing a user to do Bad Things. Your `malloc()` function should use a “first free” algorithm to select blocks of memory to allocate.

1. Detectable Errors

Your `malloc()` and `free()` implementation should be able to catch at least the following errors:

A: Free()ing addresses that are not pointers:

```
int x;  
free( (int*)x );
```

B: Free()ing pointers that were not allocated by `malloc()`:

```
p = (char *)malloc( 200 );  
free( p + 10 );  
- or -
```

```
int * x;  
free( x );
```

C: Redundant free()ing of the same pointer:

```
p = (char*)malloc(100);  
free( p );  
free( p );  
... is an error, but:  
p = (char *)malloc( 100 );  
free( p );  
p = (char *)malloc( 100 );  
free( p );
```

... is perfectly valid, even if `malloc()` returned the same pointer both times.

D: Saturation of dynamic memory:

```
p = (char*)malloc(5000);
```

- or -

```
p = (char*)malloc(4096);
```

```
q = (char*)malloc(1);
```

... your code must gracefully handle being asked for more memory than it can allocate.

2. Responding to Detected Errors

Your modified malloc() and free() should report the precise calls that caused dynamic memory problems during program execution. Your code should use the preprocessor LINE and FILE printf directives to print informative messages:

```
#define malloc( x ) mymalloc( x, __FILE__, __LINE__ )
```

```
#define free( x ) myfree( x, __FILE__, __LINE__ )
```

3. Testing and Instrumentation

After you are sure your code compiles and operates, you should test and profile your code. Writing code that works on basic test cases is nice, but in order to have useful code that you can trust, you must test it thoroughly and understand how your design decisions affect its operation. To this end, you will generate a series of workloads to test your implementation. Write a test program, memgrind.c, that will exercise your memory allocator under a series of the following malloc()/free() workloads:

A: malloc() 1 byte and immediately free it - do this 120 times

B: malloc() 1 byte, store the pointer in an array - do this 120 times.

Once you've malloc()ed 120 byte chunks, then free() the 120 1 byte pointers one by one.

C: 240 times, randomly choose between a 1 byte malloc() or free()ing one of the malloc()ed pointers

- Keep track of each operation so that you eventually malloc() 120 bytes, in total

- Keep track of each operation so that you eventually free() all pointers

(don't allow a free() if you have no pointers to free())

D,E: Two more workloads of your choosing

- Describe both workloads in your testplan.txt

Your memgrind.c should run all the workloads, one after the other, 50 times. It should record the run time for each workload and store it. When all 50 iterations of all the workloads have been run, memgrind.c should calculate the mean time for each workload to execute and output them in sequence. You might find the gettimeofday(struct timeval * tv, struct timezone * tz) function in the time.h library useful.

4. Submission

You should submit a Asst1.tar.gz containing:

A: readme.pdf documenting your metadata design

B: testcases.txt that describes your two workloads and why you included them

C: mymalloc.h with your malloc headers and definitions

D: mymalloc.c with your malloc function implementations

E: memgrind.c with your memory test and profiling code as described above

F: Makefile that builds and cleans memgrind with your mymalloc library

5. Grading

A: Correctness - how well your code operates

B: Testing thoroughness - quality and rationale behind your test cases

C: Design - how well-written and robust your code is, including modularity and comments