

CS 214: Systems Programming, Spring 2017

Assignment 1: Memory Allocation++

0. Introduction

In this assignment, you will implement `malloc()` and `free()` library calls for dynamic memory allocation that detect common programming and usage errors. For this project, use a "first free" algorithm to select free blocks to allocate.

`Malloc(size_t size)` is a system call that 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[5000]`). 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.

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( &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(5001);
```

- or -

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

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

... your code must gracefully handle being asked for memory than it can allocate without exploding.

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: 1000 separate malloc()s of 1 byte, then free() the 1000 1 byte pointers one by one

B: first malloc() 1 byte and immediately free it - do this 1000 times

C: Randomly choose between a 1 byte malloc() or free()ing a 1 byte pointer - do this 1000 times

- Keep track of each operation so that you eventually malloc() 1000 bytes, in total

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

D: Randomly choose between a randomly-sized malloc() or free()ing a pointer – do this many times (see below)

- Keep track of each malloc so that all mallocs do not exceed your total memory capacity

- Keep track of each operation so that you eventually malloc() 1000 times

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

- Choose a random allocation size between 1 and 64 bytes

E,F: Two more workloads of your choosing

- Describe both workloads in your testplan.txt

Run all of the workloads above (including yours) 100 times, while timing each workload. You might find the gettimeofday(struct timeval * tv, struct timezone * tz) function in the time.h library useful. Your memgrind.c should calculate the mean time for execution of each workload over the 100 executions and output it.

You should run memgrind yourself and include its results in your readme.pdf. Be sure to discuss your findings, especially any interesting or unexpected results.

4. Submission

You should submit a Asst1.tar.gz containing:

- A: readme.pdf documenting your design and workload data and findings
- 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
- D: Analysis - your analysis and documentation of results in your readme.pdf

6. Groups

You must have a group of two for this project. You do not need to keep your same group from Asst0.