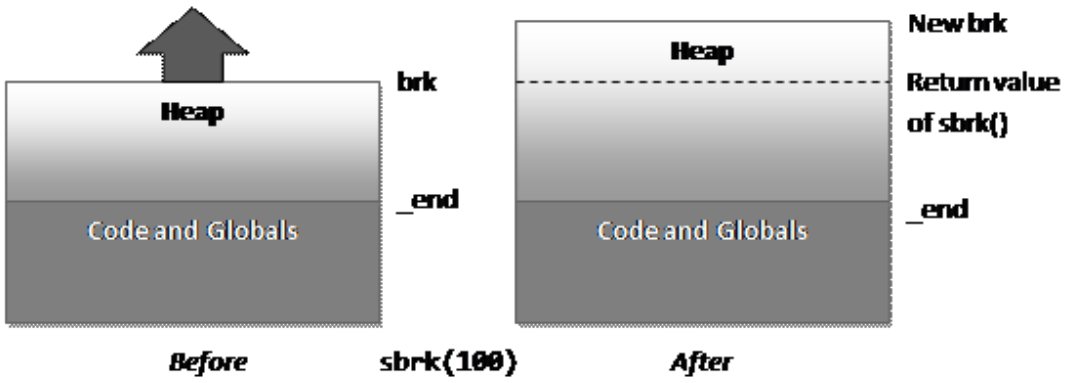
Project 3: A Custom malloc()
Due: Wednesday, November 15, 2017, at 11:59pm

Description

In our discussions of dynamic memory management we discussed the operation of the standard C library call, malloc(). Memory management systems designate a region of a process's address space from the symbol _end (where the code and data segments end) to brk as the heap. A call to malloc() attempts to find an empty block within the heap, and if it does not, expands the heap by adjusting brk to allocate more space for the heap.

As part of dynamic memory management, we also discussed various algorithms for the management of the empty spaces that may be created after a malloc()-managed heap has had some of it's allocations freed. In this assignment, you are asked to create your own version of malloc, one that uses the best-fit algorithm.

Details



We are programmatically able to grow or shrink the size of the heap by setting new values of brk. The function sbrk() handles scaling the brk value by its parameter:

```
void *sbrk(intptr_t increment);

DESCRIPTION

brk sets the end of the data segment to the value specified by  end_data_segment,
when that value is reasonable, the system does have  enough memory and the process
does not exceed its max data size (see setrlimit(2)).
```

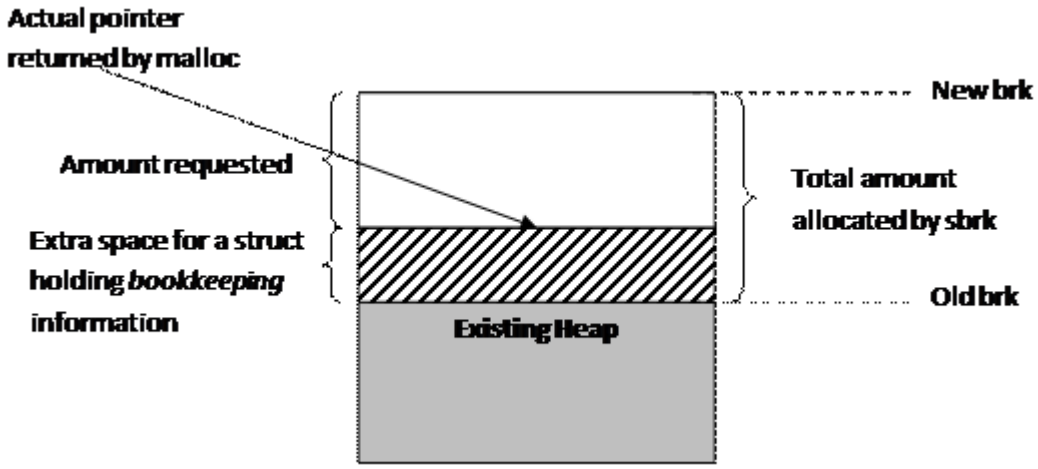
sbrk increments the program's data space by increment bytes. sbrk isn't a system call, it is just a C library wrapper. Calling sbrk with an increment of 0 can be used to find the current location of the program break.

RETURN VALUE

On success, brk returns zero, and sbrk returns a pointer to the start of the new area. On error, -1 is returned, and errno is set to ENOMEM.

A simple place to start then is to create a malloc which, with each request, simply increments brk by the amount requested and returns the old value of brk as the pointer. However, when you want to write a free() function, the parameter to free() is just a pointer to the start of the region, so you have no way to determine how much space to deallocate. In order to know what space is free or used, and how big each region is, we must use one of the techniques from class: Bitmaps or Linked lists.

From our discussion in class, linked lists seem like the better choice, but now we need some place to store this dynamic list of free and occupied memory regions inside of the heap. If we just allocated some fixed-size region, that space may not be adequate for how many nodes in the list we'd need to create. A better idea is illustrated in the figure below:



We can add some additional space to each update of brk in order to accommodate a structure that is a node in our linked list, and this structure can contain useful things like:

- The size of this chunk of memory
- Whether it is free or empty
- A pointer to the next node
- A pointer to the previous node

We then return back a pointer that is in the middle of the chunk we allocated, and thus the program calling malloc() will never notice the additional structure. However, when we get a pointer back to free, we can simply look at the memory before it for the structure that we wrote there with the information we need.

Requirements

You are to create three functions for this project.

1. A malloc() replacement called `void *my_malloc(int size)` that allocates memory using the best fit algorithm. Again, if no empty space is big enough, allocate more via sbrk().

2. A free() called `void my_free(void *ptr)` that deallocates a pointer that was originally allocated by the malloc you wrote above.

3. A dump_heap() function. You are going to copy and paste the same dump_heap() function in the Memory Management Lab (in `~wahn/public/cs449/heap/heap.c`). Make sure you copy this function before getting started on my_malloc or my_free. It will allow you to monitor your heap while debugging your program. This function will also be used for grading by the TA to check the integrity of your heap. *Hence, you will not get any points for anything without implementing dump_heap().*

Your malloc() function should split a free block into two, the free block now marked as an allocated block on the left, and the remaining unused space formed into a new free block on the right. In this way, the unused space can be used for future mallocs. Note that part of the unused space must be used to hold the new node, so the unused space must be **larger** than the size of a node for it to be split off.

Your free() function should coalesce adjacent free blocks as we described in class. If the block that touches brk is free, you should use sbrk() with a negative offset to reduce the size of the heap.

As you are developing, you will want to create a driver program that tests your calls to your mallocs and frees. For grading, we will use the drivers `~wahn/public/cs449/mallocdrv.c` and `~wahn/public/cs449/mallocdrv2.c` in order to test that your code works. Mallocdrv.c and mallocdrv2.c are designed to use the standard C library malloc as-is. Make sure you modify the MALLOC, FREE, and DUMP_HEAP() macros defined at the top to have it work with your code. Also, you will need to include your mymalloc.h header file with function declarations to use those functions inside mallocdrv.c. The output from using your own malloc should be identical to those given in `~wahn/public/cs449/mallocdrv.out` and `~wahn/public/cs449/mallocdrv2.out` (other than the randomization). The output is also identical to that using the C library malloc, minus the dump_heap() output.

Environment

For this project we will again be working on `thoth.cs.pitt.edu`

Hints/Notes

- When you manually change brk with sbrk, you may not call malloc or mmap, as they may have unintended consequences. All allocations will have to be done with your new custom malloc().
- In C, the sentinel value for the end of a linked list is having the next pointer set to NULL.
- sbrk(0) will tell you the current value of brk which can help in debugging
- gdb is your friend, no matter what you think after project 2

What to turn in

- A header file named mymalloc.h with the prototypes of your three functions.
- A C file named mymalloc.c with the implementations of your three functions.
- The test program you used during your initial testing.
- Any documentation you provide to help us grade your project. If your custom malloc() fails to pass test cases provided in mallocdrv.c and mallocdrv2.c, please document all the parts that work in the grading rubric to get partial credit. Also, your test program should demonstrate the parts that work to obtain the credit. The document should be named README.txt.

To create a tar.gz file, if your code is in a folder named project3, execute the following commands:

```
tar cvf USERNAME-project3.tar project3
gzip USERNAME-project3.tar
```

Where USERNAME is your username. Then copy your file to:

```
~wahn/submit/449/RECITATION_CLASS_NUMBER
```