

# Computer Systems and Networks

Prof. Forsyth

## Homework 4 - C Review

Due: September 26<sup>th</sup> 2023

# 1 Introduction

In this homework, you will be implementing an arraylist and debugging code for a "Random Message Generator".

Before you begin, we **heavily** recommend using an Ubuntu virtual machine to test your code locally. You are responsible for making sure your code works on Ubuntu, as C may work slightly differently on different OSes. A guide for installing the virtual machine is on Canvas.

The files we provided include:

- `main.c`: main functions that generate the random message
- `main.h`: header file of the main function
- `arraylist.c`: functions that are used to manipulate the Arraylist
- `arraylist.h`: header file of Arraylist data structure
- `arraylist_test.h`: header file for the tests for the arraylist data structure.
- `arraylist_test.c`: functions for testing the the arraylist data structure
- `Makefile`: A script that can be used for compiling the code (optional).

You will be modifying `Arraylist.c`, `main.c`, and `main.h` for this homework.

## 2 Part 1: Implement to take in parameters from command lines

First lets knock out taking in arguments from the command line. There will be two command line arguments for this program. This code should be written in the main method in the `main.c` file. Look for inline comments will describe where you should implement your code. The arguments are are:

- `t` triggers the program to run the unit tests on the arraylist rather than generating a random message.
- `l` sets the length of the message that the program will generate.

We highly recommend using the `getopt()` function. The method head looks like this:

```
getopt(int argc, char *const argv[], const char *optstring)
```

where `argc` is the argument count, `argv` is argument array, and `optstring` is the specified list of characters, each representing a single character option. If the character in `optstring` is followed by `:`, the corresponding option will take in an argument, and that argument will be pointed by `optarg`.

This function will return the next option character (if one is found) from `argv` that matches a character in `optstring`. If no character in `argv` is in `optstring` or there is a missing argument, it will return `'?'`. If we set the first character of `optstring` to be `:` and we encounter a missing argument situation, it will return `:` instead. Otherwise, it will return `-1` which indicates that all option characters have been parsed.

Once implemented we recommend testing your code to make sure it takes in arguments properly. How you do that exactly is left to your discretion. However, we recommend using `printf` statements to show the contents of the `test` and `length` variables to ensure they are the correct values. These `printf` statements should **not** be in your final solution.

### 2.1 Compiling and Running

In the future, we will provide you with a Makefile for compiling your programs. However, for this assignment, we want you to be aware of how C programs are actually compiled. To compile a program you'll use the gcc compiler. To use the gcc compiler use the following format:

- `gcc PATH/TO/C/FILE PATH/TO/C/FILE ... -o PROGRAM_NAME`

Replace the capitalized words with the appropriate values. The program name can be anything you would like, since we will compile your programs on our own during grading. However, we will call the program `Word_Generator` if you would like to use that name. You will need to compile all the `.c` files that will be used in your program. In this case you will need to compile all the `.c` files provided.

If that seems like a lot to type whenever you want to compile you can use the **Makefile** provided. Essentially, add your `gcc` command to the line under "final:" and now typing `make` should compile your code. Please note that the line after "final:" needs to be indented. The Makefile is not turned in and is optional. Makefiles in the future will be provided and will have more functionality.

To run the program you will simply need to type the path to your program. One thing to not is that you will have to put `./` if you are in the same directory as your program. For example if you use the name `Word_Generator`:

- From same directory: `./Word_Generator -l 10`
- From different directory: `./PATH/.../Word_Generator -t`

### 3 Part 2: Implement the Arraylist methods

Next, implement the functions for the Arraylist data structure in `Arraylist.c`:

- **create\_arraylist**: Taking the capacity of the arraylist as an input, create an Arraylist using the backing array with type `** char`. Remember should use `malloc()` to allocate space for the storage of the Arraylist. The function should return a pointer to the Arraylist you created.
- **add\_at\_index**: Add a word to Arraylist at a specific index. If the length of the Arraylist is going to exceed the capacity, resize the Arraylist to twice its original capacity. You can call `resize()`, which is also a function you will implement, to do this.
- **append**: Add a word to the end of the Arraylist. Remember to resize as required in `add_at_index`.
- **remove\_from\_index**: Remove a word from the Arraylist at a certain index and return the word removed. Make sure to maintain the Arraylist contiguous.
- **resize**: Resize the backing array to hold twice its original capacity. It should now support `arraylist->capacity* 2` elements.

Please refer to the comments in `arraylist.h` for further guide lines. Also note that `arraylist.c` is almost blank. In short, you need to implement the functions defined in `arraylist.h`. Think of `arraylist.h` as the interface that your code is expected to comply to. If your code passes the `arraylist_tests` sanity tests and your word generator gives the expected output, then in your code should be good. We reserve the right to review the code to ensure that your implementation is not hard coded or incorrect (i.e. implemented a link list instead of an array list).

### 4 Part 3: Debug the main file

For the last part of the project, you will need to debug the provided code in `main.c` and `main.h`. This code is used to create a "random word generator" that, in short, draws a number of random words from an array called "Dictionary". There are **3** problematic lines of code that are causing problems located somewhere throughout the provided code. If you get stuck look for the comments for hints! This section is to prepare you for debugging C code on your projects that are much larger and more complex than this code.

Please note, this code almost works! By eliminating the mistakes causing segmentation faults, the code should run properly. All **3** errors in the code should cause segmentation faults and no other errors. If you are unclear if your fix changes the intended functionality of the code, please refer to the comments.

The intended output from the program is:

- -l 5: Message: go yellow Half jackets piano
- -l 10: Message: go yellow jackets piano science Half this is correct congratulations
- -l 15: Message: go yellow jackets piano science this is Half correct congratulations unruly red viola potato carrot

The output shown above should be the **only** output onto stdout (or stderr) that your program makes when the `l` argument is used. When the `t` argument is used **only** the outputs of the `arraylist_tests` should be shown on stdout (or stderr). We will not run your program with both the `t` and `l` arguments used simultaneously.

If this part seems tedious, often small bugs that are easily overlooked lead to headaches on the projects. Hopefully, this practice allows you to locate them easier in the future.

## 4.1 GDB Screenshots

For this section, you must use GDB to set a breakpoint and display two variable values in the terminal. Refer to the lab slides and other course content to run GDB and learn how to create variables in C:

Here is an example of what your screenshot should look like:

```
(gdb) break main.c:61
Breakpoint 1 at 0x11f3: file main.c, line 61.
(gdb) run -t -l 7
Starting program: /cs2200/cs2200-hw4/src/Word.Generator -t -l 7
[Thread debugging using libthread_db enabled]
Using host libthread_db library "/lib/x86_64-linux-gnu/libthread_db.so.1".

Breakpoint 1, main (argc=4, argv=0x7fffffffe6f8) at main.c:61
61         return 0;
(gdb) print length
[REDACTED]
(gdb) print tests
[REDACTED]
(gdb)
```

## 4.2 GDB Debugging Tips

If your program is crashing or misbehaving, you can use GDB to locate the bug. GDB is a command line interface that will allow you to set breakpoints, step through your code, see variable values, and identify segfaults. There are tons of online guides, click here (<http://condor.depaul.edu/glancast/373class/docs/gdb.html>) for one.

Within GDB, you can run your program with the `run` command:

```
$ (gdb) r -i <# of words>
```

You may find it useful to set a breakpoint inside the main loop of the simulator to debug specific simulator commands in your implementation. You can do this either by finding the line number inside `main.c` and breaking there:

```
$ (gdb) break main.c:53 ! set breakpoint at call to system_init
$ (gdb) r -i <# of words>
```

```
! (wait for breakpoint)
$ (gdb) s ! step into the function call
```

or by using the actual function name being called from the main loop:

```
$ (gdb) break sim_cmd ! set breakpoint at call to sim_c
$ (gdb) r -i <# of words>
! (wait for breakpoint)
$ (gdb) s ! step into the function call
```

Sometimes, you may want to examine a large area of memory. To do this in GDB, you can use the `x` command (short for examine). For example, to examine the first 24 bytes of the frame table, we could do the following:

```
$ (gdb) x/24xb frame_table
0x1004000aa: 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0x1004000b2: 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0x1004000ba: 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
```

The format of this command is `x/nfu [memory location]`, where  $n$  is the number of items to print,  $f$  is a formatting identifier, and  $u$  is the specifier for the units you would like to print.  $b$  specifies 1 byte,  $h$  specifies 2 bytes,  $w$  specifies 4 bytes, and  $g$  specifies 8 bytes.

If you use the corruption checker, you can set a breakpoint on `panic()` and use a backtrace to discover the context in which the panic occurred:

```
$ (gdb) break panic
$ (gdb) r -i <# of words>
! (wait for GDB to stop at the breakpoint)
$ (gdb) backtrace
$ (gdb) frame N ! where N is the frame number you want to examine
```

## 5 Submission

Files you will submit on **Gradescope**:

- GDB Screenshots
- `Arraylist.c`
- `main.c`
- `main.h`